Project Details

Project Name: BT 40d CAN Sol 575 6h

Location: 31842 Frontage Rd, Bozeman, MT 59715, USA

Unique ID: 5P-19.75-10TOP-XD-24-L-5Hx12W-3J10

Dealer: ______________________________

Date: Mon Jun 02 2025

Number of Modules: 60

Number of Poles: 5

Date Sold:

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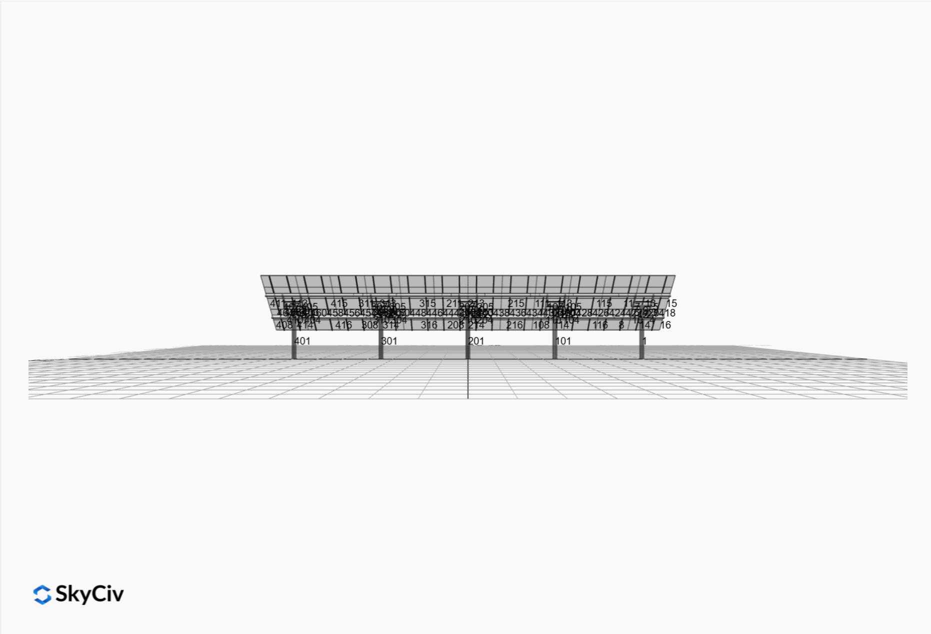


Array Dimensions N/S	18.79 ft
Array Dimensions E/W	90.70 ft
Winter Tilt Angle	40
Front Edge Clearance	6 ft

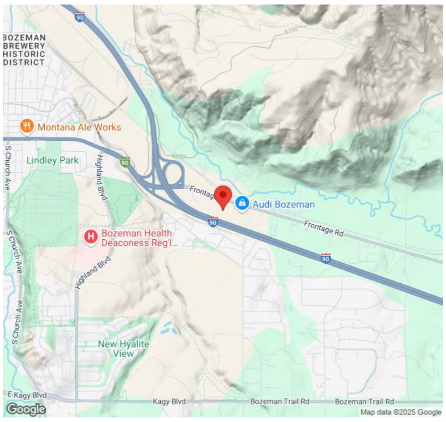
MT Solar Bill of Materials (5P-19.75-10TOP-XD-24-L-5Hx12W-3J10)

Part	Short Description	BOM Qty
MTS-PC-10	10IN Pole Cap Assembly	5
MTS-HF-XD	H-Frame Assembly-XD	5
MTS-XD-Wing-24	24IN 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	12

Rail Bill of Materials

Part	Qty
Rails (226in)	24
Rail Attachment	96
Module Mid Clamp	96
Module End Clamp	48
Ground Lug	12

Site Details:



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

Array Specification

Duty Classification:	XD
Module Width:	44.60 in
Module Length:	89.70in
Number of Rows:	5
Number of Columns:	12
Total Number of Modules:	60
Winter Tilt Angle:	40
Front Edge Clearance:	6
Total Array Height at Tilt:	18.08 ft
Total Frame Length:	90.50 ft
Module Info/Notes:	TOPBiHiKu6 CS6W-575TB-AG
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	90.70 ft
Rail Length:	225.50 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	12.04 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: 8.00 ft Pile 2: 8.50 ft Pile 3: 8.50 ft Pile 4: 8.50 ft Pile 5: 8.00 ft
Foundation Volume:	24.593 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

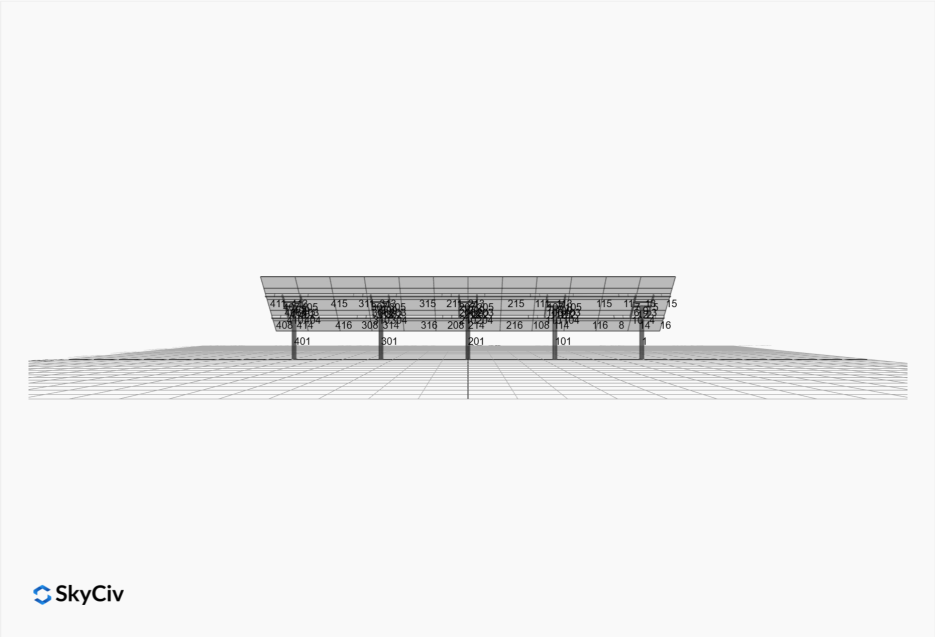
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

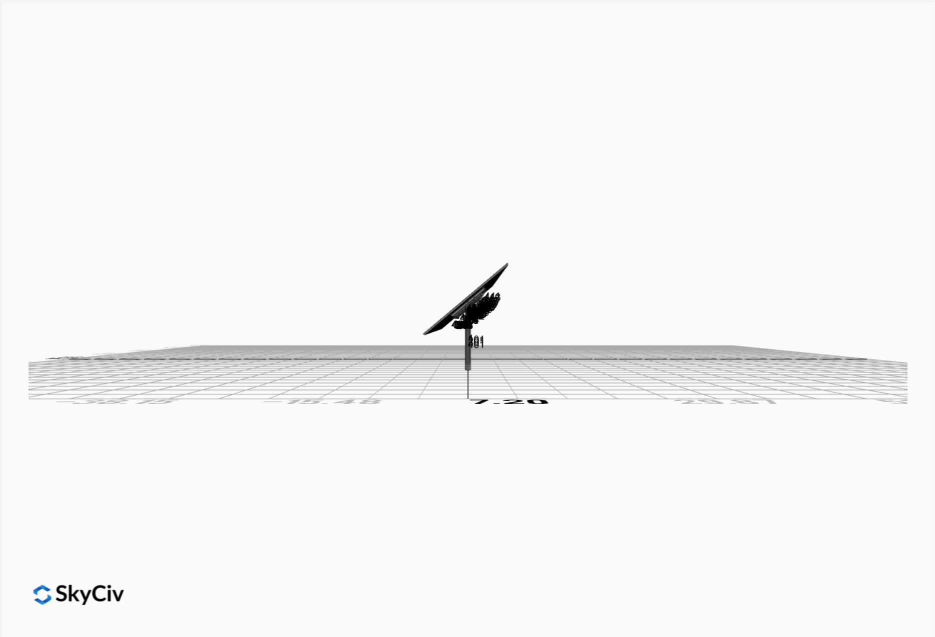
AutoDesigner Input

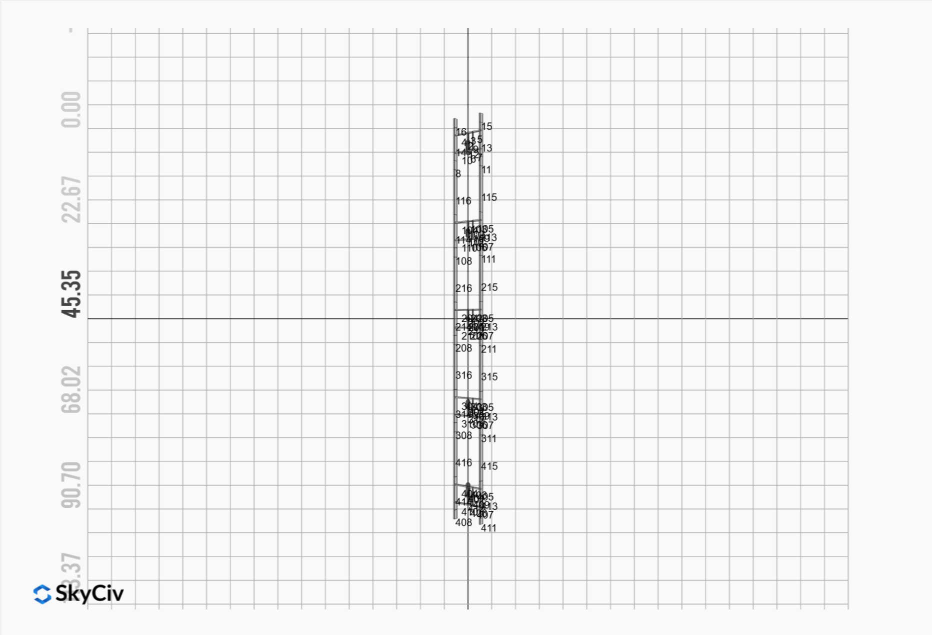
{"wind_speed_override":115,"snow_load_override":51,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"Thomas Burney","designer_email":"thomas.burney@onsiteenergyinc.com","designer_phone":"","project_id":"BT 40d CAN Sol 575 6h","site_address":"31842 Frontage Rd, Bozeman, MT 59715, USA","module_info":"TOPBiHiKu6 CS6W-575TB-AG","module_width":44.6,"module_length":89.7,"number_rows":"5","number_columns":12,"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":40,"ground_clearance":6,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","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)
- Foundation Design and Sizing is approximate only



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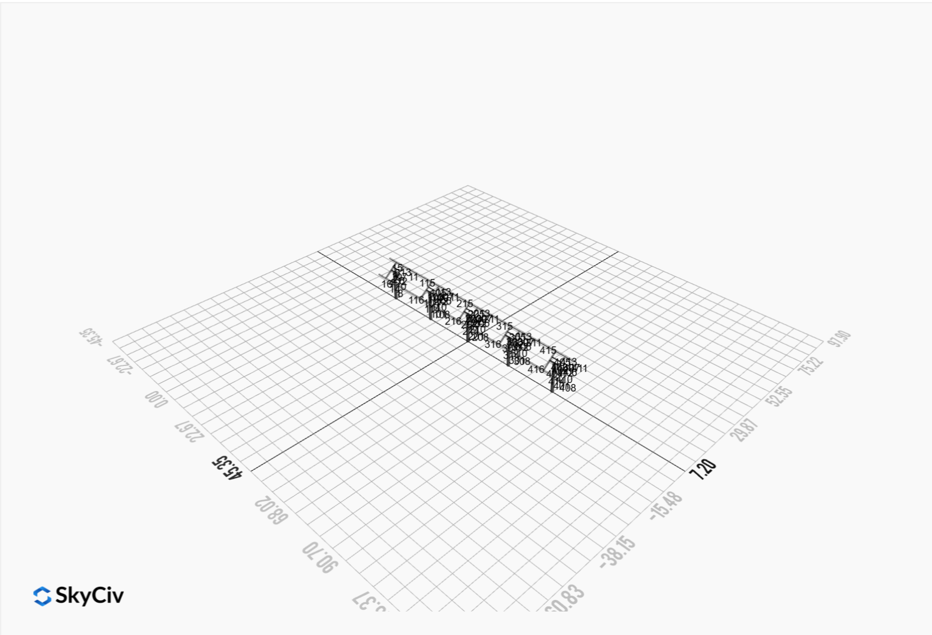
45.35
68.02
90.70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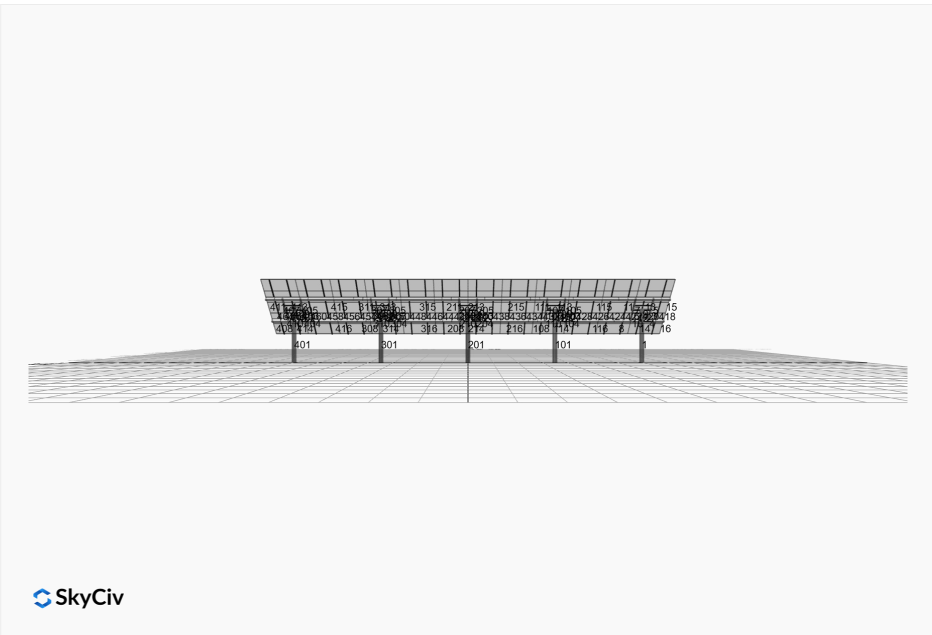
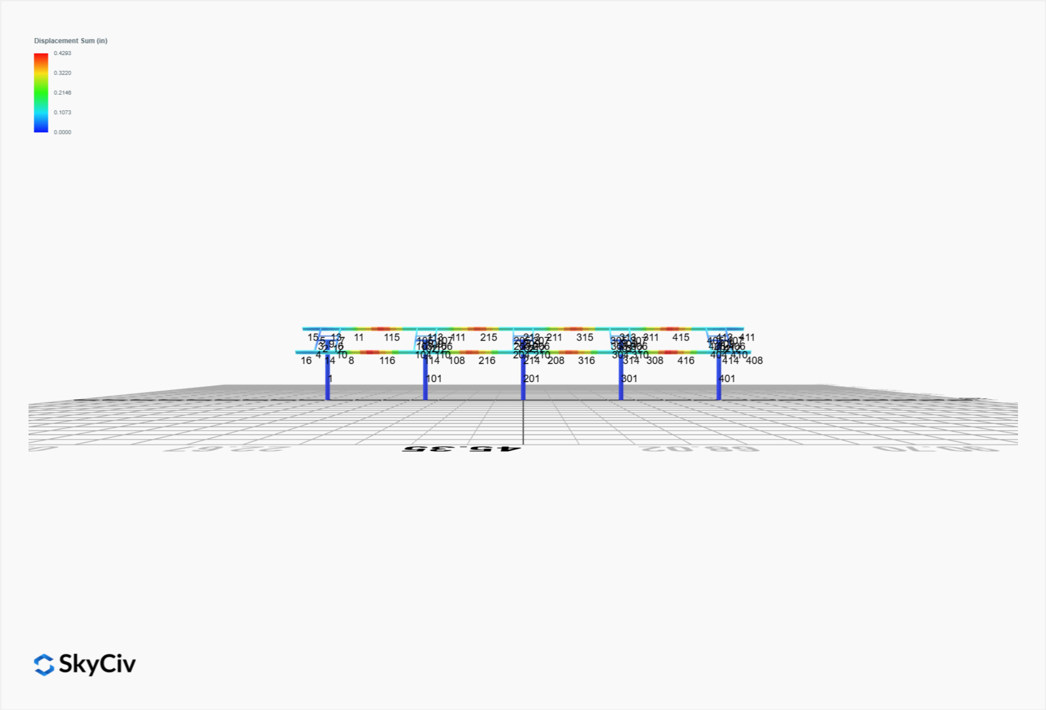
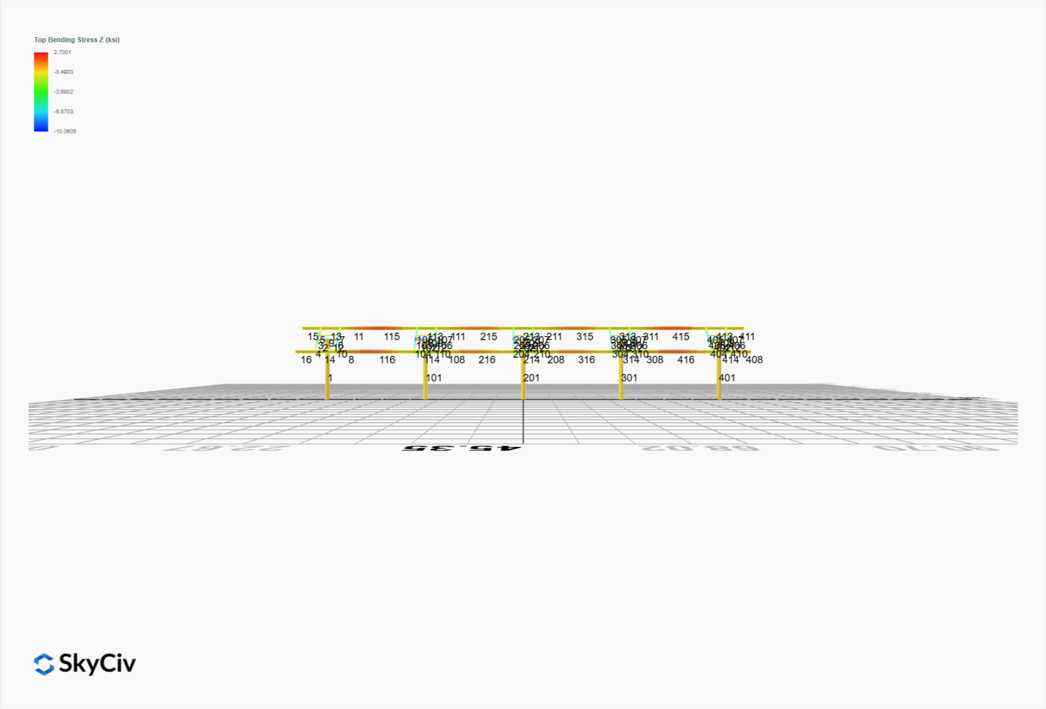
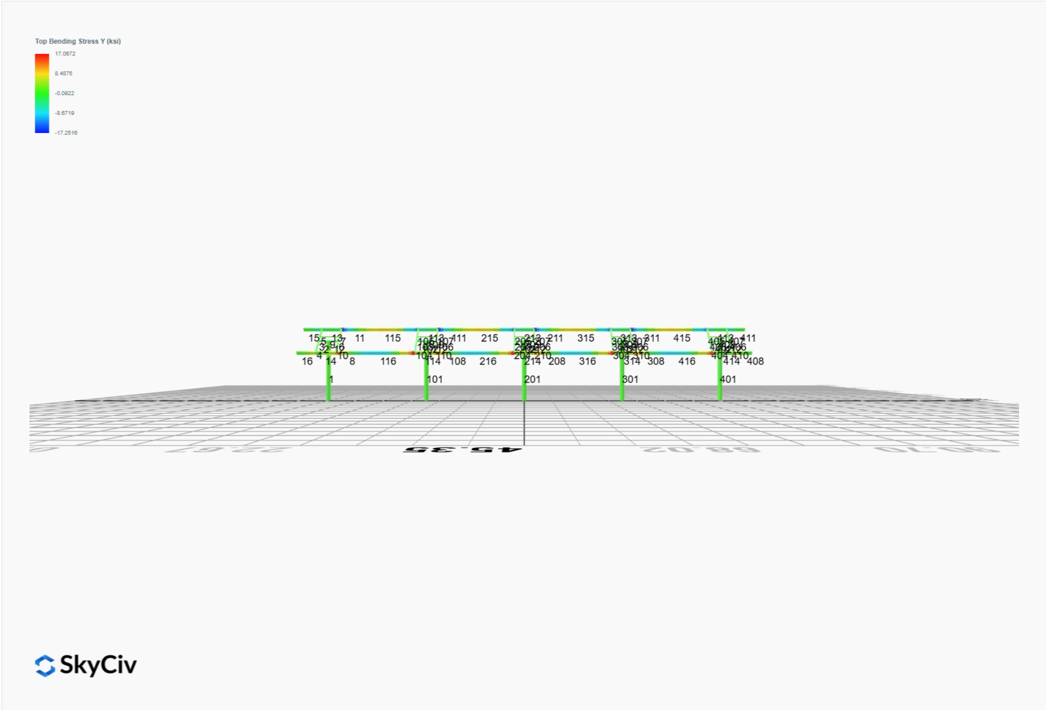
7.20
-15.48
-38.15
29.87
52.55
75.22


401
301
201
101
1

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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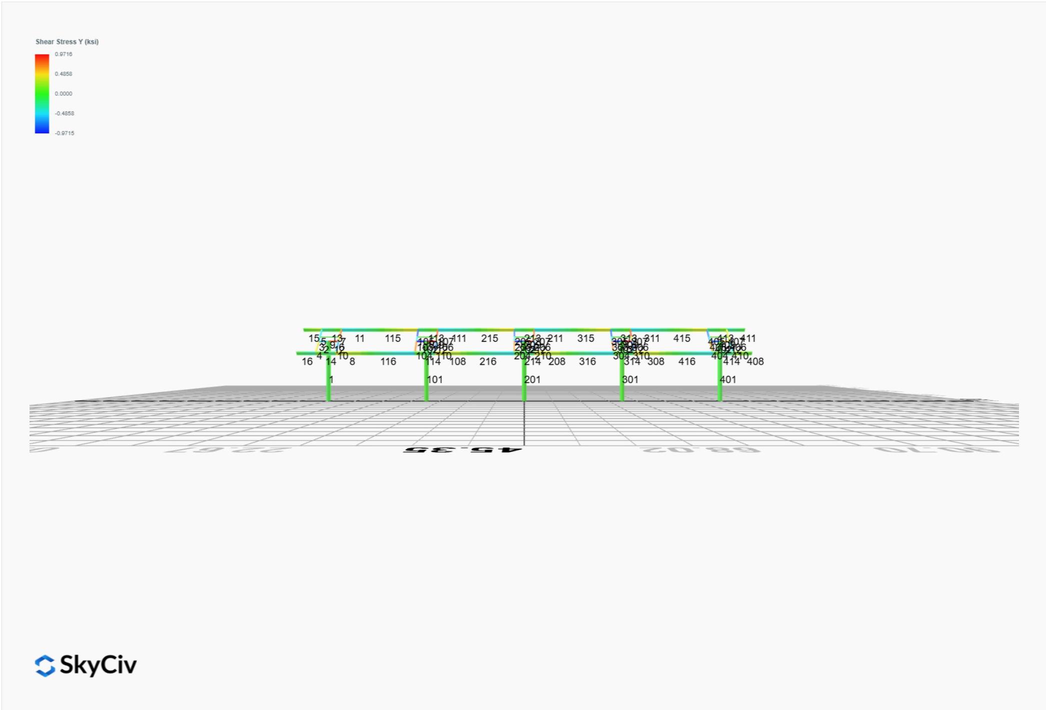
-0.0922
-8.6719
-17.2516


Shear Stress Y (ksi)
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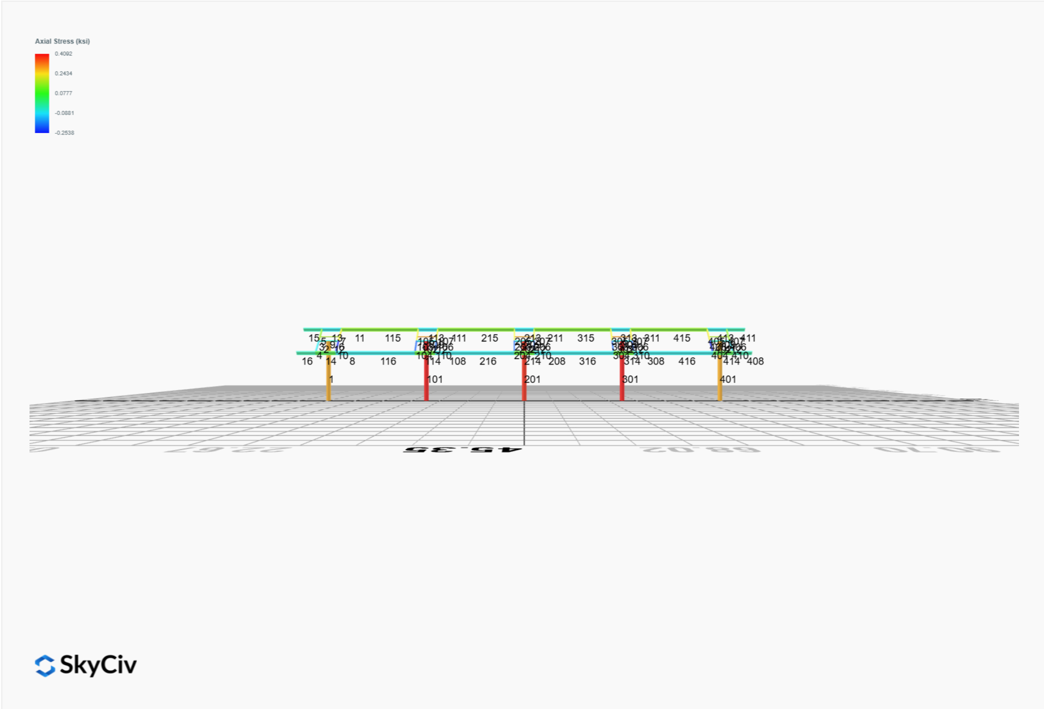
0.4858
0.0000
-0.4858
-0.9715



Axial Stress (ksi)
0.4092
0.2434
0.0777
-0.0881
-0.2538
SkyCiv

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	0.0307	2.3967	0.0730	0.2392	-0.0540	-0.3282
ULS: 2. D + L	0.0307	2.3967	0.0730	0.2392	-0.0540	-0.3282
ULS: 3. D + (S or Lr or R)	0.1000	6.0912	0.2385	0.7834	-0.1775	-1.1178
ULS: 3. D + (S or Lr or R)	0.0307	2.3967	0.0730	0.2392	-0.0540	-0.3282
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0827	5.1676	0.1972	0.6474	-0.1466	-0.9204
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0307	2.3967	0.0730	0.2392	-0.0540	-0.3282
ULS: 5b. D + 0.7E	0.0307	2.3967	0.0730	0.2392	-0.0540	-0.3282
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0827	5.1676	0.1972	0.6474	-0.1466	-0.9204
ULS: 8. 0.6D + 0.7E	0.0184	1.4380	0.0438	0.1435	-0.0324	-0.1969
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.2680	7.4568	0.3991	1.2174	-1.6416	53.3559
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.2680	7.4568	0.3991	1.2174	-1.6416	53.3559
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.4499	-1.6313	-0.1791	-0.5167	1.1747	-40.9349
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.9608	-1.0397	-0.1640	-0.4702	1.1135	-45.2013
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1413	8.9627	0.4417	1.3810	-1.3373	39.3427
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1413	8.9627	0.4417	1.3810	-1.3373	39.3427
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6471	2.1466	0.0081	0.0804	0.7749	-31.3754
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2803	2.5903	0.0194	0.1153	0.7290	-34.5752
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1933	6.1918	0.3176	0.9728	-1.2447	39.9349
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1933	6.1918	0.3176	0.9728	-1.2447	39.9349
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5951	-0.6243	-0.1161	-0.3277	0.8675	-30.7832
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2282	-0.1806	-0.1047	-0.2928	0.8216	-33.9830
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.2802	6.4982	0.3699	1.1217	-1.6200	53.4872
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.2802	6.4982	0.3699	1.1217	-1.6200	53.4872
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.4377	-2.5900	-0.2083	-0.6124	1.1963	-40.8036
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.9485	-1.9984	-0.1932	-0.5659	1.1351	-45.0700

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.1584
Shear X	-7.1644
Shear Z	0.7169
Moment X	2.1989
Moment Y (Twist)	2.7838
Moment Z	89.5279

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.9627
Shear X	-4.2802
Shear Z	0.4417
Moment X	1.3810
Moment Y (Twist)	1.6416
Moment Z	53.4872

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	-0.0297	2.9187	-0.0045	-0.0167	0.0236	0.3582
ULS: 2. D + L	-0.0297	2.9187	-0.0045	-0.0167	0.0236	0.3582
ULS: 3. D + (S or Lr or R)	-0.0968	7.7910	-0.0147	-0.0543	0.0769	1.1309
ULS: 3. D + (S or Lr or R)	-0.0297	2.9187	-0.0045	-0.0167	0.0236	0.3582
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0800	6.5729	-0.0122	-0.0449	0.0635	0.9378

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0297	2.9187	-0.0045	-0.0167	0.0236	0.3582
ULS: 5b. D + 0.7E	-0.0297	2.9187	-0.0045	-0.0167	0.0236	0.3582
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0800	6.5729	-0.0122	-0.0449	0.0635	0.9378
ULS: 8. 0.6D + 0.7E	-0.0178	1.7512	-0.0027	-0.0100	0.0142	0.2149
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.6440	9.6702	0.0088	0.0090	-0.1176	69.9653
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.6440	9.6702	0.0088	0.0090	-0.1176	69.9653
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.4531	-2.4697	-0.0111	-0.0257	0.1132	-52.1314
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.7444	-1.6312	-0.0231	-0.0622	0.1783	-56.8525
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.2907	11.6365	-0.0022	-0.0256	-0.0424	53.1431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.2907	11.6365	-0.0022	-0.0256	-0.0424	53.1431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2821	2.5316	-0.0171	-0.0516	0.1308	-38.4295
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7506	3.1605	-0.0261	-0.0790	0.1796	-41.9703
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.2404	7.9823	0.0054	0.0026	-0.0823	52.5635
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.2404	7.9823	0.0054	0.0026	-0.0823	52.5635
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3324	-1.1226	-0.0095	-0.0234	0.0908	-39.0090
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.8009	-0.4938	-0.0184	-0.0508	0.1397	-42.5499
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-5.6321	8.5027	0.0106	0.0157	-0.1271	69.8220
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-5.6321	8.5027	0.0106	0.0157	-0.1271	69.8220
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.4650	-3.6372	-0.0093	-0.0190	0.1038	-52.2747
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.7563	-2.7987	-0.0212	-0.0555	0.1689	-56.9958

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	17.1882
Shear X	-9.4230
Shear Z	-0.0428
Moment X	-0.1229
Moment Y (Twist)	0.3209
Moment Z	117.9764

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	11.6365
Shear X	-5.6440
Shear Z	-0.0261
Moment X	-0.0790
Moment Y (Twist)	0.1796
Moment Z	69.9653

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	-0.0020	2.8798	0.0000	-0.0000	0.0000	0.0771
ULS: 2. D + L	-0.0020	2.8798	0.0000	-0.0000	0.0000	0.0771
ULS: 3. D + (S or Lr or R)	-0.0064	7.6644	0.0000	-0.0001	0.0001	0.2140
ULS: 3. D + (S or Lr or R)	-0.0020	2.8798	0.0000	-0.0000	0.0000	0.0771
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0053	6.4682	0.0000	-0.0000	0.0001	0.1798
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0020	2.8798	0.0000	-0.0000	0.0000	0.0771
ULS: 5b. D + 0.7E	-0.0020	2.8798	0.0000	-0.0000	0.0000	0.0771
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0053	6.4682	0.0000	-0.0000	0.0001	0.1798
ULS: 8. 0.6D + 0.7E	-0.0012	1.7279	0.0000	-0.0000	0.0000	0.0463
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.5935	9.5478	0.0000	-0.0000	0.0000	69.9900
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.5935	9.5478	0.0000	-0.0000	0.0000	69.9900
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.4514	-2.4295	0.0000	-0.0000	0.0000	-52.4970
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.7894	-1.6456	0.0000	-0.0000	0.0000	-57.8022

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	-4.1990	11.4692	0.0000	-0.0000	0.0001	52.6145
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1990	11.4692	0.0000	-0.0000	0.0001	52.6145
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3347	2.4863	0.0000	-0.0000	0.0001	-39.2508
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.8382	3.0742	0.0000	-0.0000	0.0001	-43.2297
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.1956	7.8808	0.0000	-0.0000	0.0000	52.5118
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1956	7.8808	0.0000	-0.0000	0.0000	52.5118
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3380	-1.1022	0.0000	-0.0000	0.0000	-39.3535
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.8416	-0.5142	0.0000	-0.0000	0.0000	-43.3324
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-5.5928	8.3959	0.0000	-0.0000	0.0000	69.9592
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-5.5928	8.3959	0.0000	-0.0000	0.0000	69.9592
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.4521	-3.5814	0.0000	-0.0000	0.0000	-52.5278
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.7902	-2.7975	0.0000	-0.0000	0.0000	-57.8331

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	16.9642
Shear X	-9.3258
Shear Z	0.0000
Moment X	-0.0005
Moment Y (Twist)	0.0010
Moment Z	117.8926

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	11.4692
Shear X	-5.5935
Shear Z	0.0000
Moment X	-0.0001
Moment Y (Twist)	0.0001
Moment Z	69.9900

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	-0.0297	2.9187	0.0045	0.0167	-0.0236	0.3582
ULS: 2. D + L	-0.0297	2.9187	0.0045	0.0167	-0.0236	0.3582
ULS: 3. D + (S or Lr or R)	-0.0968	7.7910	0.0147	0.0542	-0.0766	1.1309
ULS: 3. D + (S or Lr or R)	-0.0297	2.9187	0.0045	0.0167	-0.0236	0.3582
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0800	6.5729	0.0122	0.0448	-0.0634	0.9377
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0297	2.9187	0.0045	0.0167	-0.0236	0.3582
ULS: 5b. D + 0.7E	-0.0297	2.9187	0.0045	0.0167	-0.0236	0.3582
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0800	6.5729	0.0122	0.0448	-0.0634	0.9377
ULS: 8. 0.6D + 0.7E	-0.0178	1.7512	0.0027	0.0100	-0.0141	0.2149
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.6440	9.6702	-0.0088	-0.0090	0.1177	69.9653
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.6440	9.6702	-0.0088	-0.0090	0.1177	69.9653
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.4531	-2.4697	0.0111	0.0257	-0.1132	-52.1314
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.7444	-1.6312	0.0231	0.0622	-0.1783	-56.8525
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.2907	11.6365	0.0022	0.0255	0.0426	53.1431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.2907	11.6365	0.0022	0.0255	0.0426	53.1431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2821	2.5316	0.0171	0.0516	-0.1306	-38.4295
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7506	3.1605	0.0261	0.0789	-0.1794	-41.9703
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.2404	7.9823	-0.0054	-0.0026	0.0824	52.5635
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.2404	7.9823	-0.0054	-0.0026	0.0824	52.5635
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3324	-1.1226	0.0095	0.0234	-0.0908	-39.0090
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.8009	-0.4938	0.0184	0.0508	-0.1396	-42.5499

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-5.6321	8.5027	-0.0106	-0.0157	0.1271	69.8220
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-5.6321	8.5027	-0.0106	-0.0157	0.1271	69.8220
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.4650	-3.6372	0.0093	0.0190	-0.1038	-52.2747
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.7563	-2.7987	0.0212	0.0555	-0.1689	-56.9958

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	17.1882
Shear X	-9.4231
Shear Z	0.0428
Moment X	0.1233
Moment Y (Twist)	0.3208
Moment Z	117.9765

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	11.6365
Shear X	-5.6440
Shear Z	0.0261
Moment X	0.0789
Moment Y (Twist)	0.1794
Moment Z	69.9653

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	0.0307	2.3967	-0.0730	-0.2393	0.0541	-0.3282
ULS: 2. D + L	0.0307	2.3967	-0.0730	-0.2393	0.0541	-0.3282
ULS: 3. D + (S or Lr or R)	0.1000	6.0912	-0.2386	-0.7838	0.1777	-1.1176
ULS: 3. D + (S or Lr or R)	0.0307	2.3967	-0.0730	-0.2393	0.0541	-0.3282
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0827	5.1676	-0.1972	-0.6477	0.1468	-0.9203
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0307	2.3967	-0.0730	-0.2393	0.0541	-0.3282
ULS: 5b. D + 0.7E	0.0307	2.3967	-0.0730	-0.2393	0.0541	-0.3282
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0827	5.1676	-0.1972	-0.6477	0.1468	-0.9203
ULS: 8. 0.6D + 0.7E	0.0184	1.4380	-0.0438	-0.1436	0.0324	-0.1969
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.2680	7.4568	-0.3991	-1.2174	1.6416	53.3559
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.2680	7.4568	-0.3991	-1.2174	1.6416	53.3559
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.4499	-1.6313	0.1791	0.5167	-1.1746	-40.9349
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.9608	-1.0397	0.1640	0.4702	-1.1135	-45.2012
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1413	8.9627	-0.4417	-1.3813	1.3374	39.3428
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1413	8.9627	-0.4417	-1.3813	1.3374	39.3428
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6471	2.1466	-0.0081	-0.0807	-0.7747	-31.3753
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2802	2.5903	-0.0194	-0.1156	-0.7289	-34.5751
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.1933	6.1918	-0.3176	-0.9729	1.2447	39.9349
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.1933	6.1918	-0.3176	-0.9729	1.2447	39.9349
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.5951	-0.6243	0.1161	0.3277	-0.8675	-30.7832
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.2282	-0.1806	0.1047	0.2928	-0.8216	-33.9830
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.2802	6.4982	-0.3699	-1.1217	1.6200	53.4872
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.2802	6.4982	-0.3699	-1.1217	1.6200	53.4872
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.4377	-2.5900	0.2083	0.6124	-1.1963	-40.8036
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.9485	-1.9984	0.1932	0.5659	-1.1351	-45.0700

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino 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	13.1584
Shear X	-7.1644
Shear Z	-0.7168
Moment X	-2.1995
Moment Y (Twist)	2.7847
Moment Z	89.5290

Result	Value (kip, kip-ft)
Axial	8.9627
Shear X	-4.2802
Shear Z	-0.4417
Moment X	-1.3813
Moment Y (Twist)	1.6416
Moment Z	53.4872

Project Details

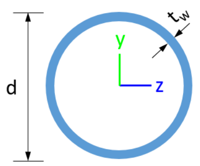
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

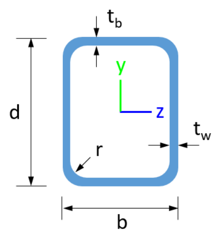
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

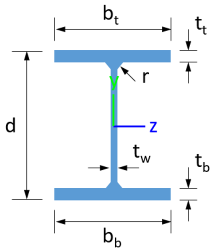
Section Dimensions



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)

3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
11	10in Pipe Sch 40	11.91	321.47	160.73	160.73	0.00	39.38	39.38
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	11	25.28	25.28	12.04	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.19,2.08,1.17,1.17,1.16,1.17,1.17,1.17,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.66,1.78,1.67,1.67,1.66,1.62,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.82,1.67,1.67,1.66,1.64	300	200	1
5	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,2.58,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.01,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.52,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67	300	200	1
8	20	1.33	1.33	2.05	1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.30,1.04,1.30,1.30,1.30,1.22,1.30,1.30,1.32,1.33,1.30,1.30,1.30,1.01,1.30,1.30,1.30,1.23	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.68,1.67,1.67,1.66,1.53,1.67,1.67,1.66,1.66	300	200	1
11	20	1.33	1.33	2.05	1.32,1.32,1.32,1.32,1.32,1.32,1.36,1.36,1.38,1.40,1.36,1.36,1.37,1.39,1.34,1.34,1.23,1.19,1.36,1.36,1.38,1.40,1.36,1.36,1.37,1.38	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.19,1.20,1.19,1.20,1.20,1.19,1.17,1.17,1.15,1.21,1.17,1.17,1.16,1.21,1.18,1.18,1.32,3.93,1.17,1.17,1.15,1.21,1.17,1.17,1.16,1.21	300	200	1
14	20	4.88	4.00	7.50	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.67,1.18,1.18,1.19,1.29,1.18,1.18,1.21,1.30,1.18,1.18,1.18,1.72,1.18,1.18,1.19,1.25	300	200	1
15	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	11	25.28	25.28	12.04	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.23,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.56,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.67,1.67,1.67,1.66,1.18,1.67,1.67,1.66,1.66	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.72,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.30,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,2.28,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
108	20	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.09,2.09,2.08,2.13,2.09,2.09,2.08,2.11,2.09,2.09,2.35,2.10,2.09,2.09,2.08,2.37,2.09,2.09,2.08,2.11	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.59,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.67,1.67,1.67,1.66,1.40,1.67,1.67,1.66,1.66	300	200	1
111	20	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,1.96,1.96,1.75,1.76,1.93,1.93,1.84,1.82,2.06,2.06,2.11,1.09,1.97,1.97,1.74,1.75,1.92,1.92,1.86,1.84	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.08,1.09,1.10,1.08,1.08,1.08,1.10,1.07,1.07,1.03,1.06,1.08,1.08,1.09,1.11,1.08,1.08,1.08,1.09	300	200	1
114	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.06,1.07,1.08,1.06,1.06,1.07,1.06,1.06,1.06,1.04,1.05,1.06,1.06,1.07,1.09,1.06,1.06,1.07,1.06	300	200	1
115	20	6.63	6.63	10.20	1.14,1.14,1.14,1.14,1.14,1.14,1.12,1.12,1.11,1.11,1.12,1.12,1.12,1.11,1.13,1.13,1.25,2.24,1.12,1.12,1.11,1.11,1.12,1.12,1.12,1.11	300	200	1
116	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.34,1.15,1.15,1.14,1.17,1.15,1.15,1.18,1.15,1.15,1.15,1.14,1.48,1.15,1.15,1.15,1.17	300	200	1
201	11	25.28	25.28	12.04	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,2.15,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.56,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.67,1.67,1.67,1.66,1.19,1.67,1.67,1.66,1.66	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.12,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,2.14,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.12,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
208	20	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.10,1.59,2.09,2.09,2.10,2.07,2.09,2.09,2.07,2.09,2.09,2.09,2.10,1.45,2.09,2.09,2.10,2.07	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.56,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.67,1.67,1.67,1.66,1.19,1.67,1.67,1.66,1.66	300	200	1
211	20	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.08,2.08,2.07,2.08,2.08,2.08,2.07,2.08,2.09,2.09,2.29,1.03,2.08,2.08,2.07,2.08,2.08,2.08,2.08,2.08	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.01,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04	300	200	1
214	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.01,1.04,1.04,1.04,1.03,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.01,1.04,1.04,1.04,1.03	300	200	1
215	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.16,1.16,1.15,1.16,1.16,1.16,1.20,1.44,1.16,1.16,1.15,1.15,1.16,1.16,1.15,1.16	300	200	1
216	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.11,1.16,1.16,1.16,1.15,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.10,1.16,1.16,1.16,1.15	300	200	1
301	11	25.28	25.28	12.04	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.30,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.59,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.67,1.67,1.67,1.66,1.40,1.67,1.67,1.66,1.66	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,2.28,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.23,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.72,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
308	20	1.33	1.33	2.05	2.00,2.00,2.00,2.01,2.00,2.00,1.89,1.89,1.81,2.29,1.88,1.88,1.84,2.08,1.93,1.93,2.11,1.98,1.89,1.89,1.81,2.20,1.88,1.88,1.85,2.08	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.56,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.67,1.67,1.67,1.66,1.18,1.67,1.67,1.66,1.66	300	200	1
311	20	1.33	1.33	2.05	1.85,1.85,1.85,1.84,1.85,1.85,1.58,1.58,1.46,1.46,1.56,1.56,1.52,1.50,1.66,1.66,2.25,1.14,1.59,1.59,1.46,1.46,1.56,1.56,1.53,1.51	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.08,1.09,1.10,1.08,1.08,1.08,1.10,1.07,1.07,1.03,1.06,1.08,1.08,1.09,1.11,1.08,1.08,1.08,1.09	300	200	1
314	20	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.06,1.07,1.08,1.06,1.06,1.07,1.06,1.06,1.06,1.04,1.05,1.06,1.06,1.07,1.09,1.06,1.06,1.07,1.06	300	200	1

315	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.12,1.12,1.13,1.13,1.13,1.13,1.14,1.14,1.24,1.46,1.14,1.14,1.12,1.12,1.13,1.13,1.13,1.13	300	200	1
316	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.18,1.16,1.16,1.16,1.17,1.16,1.16,1.19,1.16,1.16,1.16,1.15,1.19,1.16,1.16,1.16,1.17	300	200	1
401	11	25.28	25.28	12.04	-	300	200	1
402	6	1.30	1.30	2.00	-	300	200	1
403	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.01,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18	300	200	1
404	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.65,1.67,1.67,1.69,1.68,1.67,1.67,1.66,1.53,1.67,1.67,1.66,1.66	300	200	1
405	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.52,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67	300	200	1
406	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.19,2.08,1.17,1.17,1.16,1.17,1.17,1.17,1.17,1.17	300	200	1
407	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,2.57,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
408	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	3	2.60	2.60	4.00	-	300	200	1
410	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.66,1.78,1.67,1.67,1.66,1.62,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.82,1.67,1.67,1.66,1.64	300	200	1
411	20	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
412	6	1.30	1.30	2.00	-	300	200	1
413	20	4.88	4.00	7.50	1.19,1.20,1.19,1.20,1.20,1.19,1.17,1.17,1.15,1.21,1.17,1.17,1.16,1.21,1.18,1.18,1.32,3.94,1.17,1.17,1.14,1.21,1.17,1.17,1.16,1.21	300	200	1
414	20	4.88	4.00	7.50	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.67,1.18,1.18,1.19,1.29,1.18,1.18,1.21,1.29,1.18,1.18,1.18,1.72,1.18,1.18,1.19,1.25	300	200	1
415	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.09,1.08,1.08,1.09,2.37,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.09	300	200	1
416	20	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.08,1.08,1.08,1.11,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.09,1.08,1.08,1.08,1.18,1.08,1.08,1.08,1.08	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	535.87	325.47	147.68	147.68	160.76	160.76
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	35.00	6.46	56.26	44.91
14	159.30	97.43	35.93	6.46	56.26	44.91
15	159.30	113.66	46.90	6.46	56.26	44.91
16	159.30	113.66	46.90	6.46	56.26	44.91
101	535.87	325.47	147.68	147.68	160.76	160.76
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95

104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	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	31.58	6.46	56.26	44.91
114	159.30	97.43	31.81	6.46	56.26	44.91
115	159.30	75.13	21.34	6.46	56.26	44.91
116	159.30	75.13	22.01	6.46	56.26	44.91
201	535.87	325.47	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	30.78	6.46	56.26	44.91
214	159.30	97.43	30.84	6.46	56.26	44.91
215	159.30	75.13	22.17	6.46	56.26	44.91
216	159.30	75.13	21.27	6.46	56.26	44.91
301	535.87	325.47	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	31.58	6.46	56.26	44.91
314	159.30	97.43	31.80	6.46	56.26	44.91
315	159.30	75.13	21.64	6.46	56.26	44.91
316	159.30	75.13	22.21	6.46	56.26	44.91
401	535.87	325.47	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	151.65	149.10	20.17	14.14	54.12	28.95
408	159.30	113.66	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	113.66	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	34.99	6.46	56.26	44.91
414	159.30	97.43	35.94	6.46	56.26	44.91
415	159.30	75.13	20.87	6.46	56.26	44.91
416	159.30	75.13	20.78	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	0.040	0.606	0.043	0.044	0.004	0.641	#13	0.413	Not Required	Pass
2	0.003	0.265	0.193	0.066	0.041	0.459	#13	0.054	Not Required	Pass
3	0.007	0.558	0.028	0.054	0.002	0.563	#13	0.046	Not Required	Pass
4	0.006	0.521	0.083	0.052	0.021	0.589	#13	0.082	Not Required	Pass
5	0.006	0.346	0.064	0.055	0.017	0.349	#13	0.076	Not Required	Pass
6	0.011	0.806	0.109	0.082	0.029	0.870	#13	0.046	Not Required	Pass
7	0.012	0.500	0.190	0.080	0.047	0.523	#13	0.076	Not Required	Pass
8	0.004	0.137	0.205	0.044	0.023	0.221	#24	0.102	Not Required	Pass
9	0.008	0.073	0.091	0.004	0.005	0.160	#13	0.206	Not Required	Pass
10	0.013	0.732	0.181	0.073	0.040	0.745	#13	0.082	Not Required	Pass
11	0.006	0.137	0.212	0.049	0.023	0.221	#6	0.102	Not Required	Pass
12	0.001	0.501	0.296	0.101	0.055	0.798	#13	0.054	Not Required	Pass
13	0.009	0.134	0.531	0.064	0.029	0.580	#21	0.306	Not Required	Pass
14	0.006	0.117	0.522	0.057	0.029	0.550	#24	0.204	Not Required	Pass
15	0.000	0.020	0.051	0.017	0.007	0.068	#21	Not Required	Not Required	Pass
16	0.000	0.019	0.051	0.016	0.007	0.067	#21	Not Required	Not Required	Pass
101	0.053	0.799	0.003	0.059	0.000	0.825	#13	0.413	Not Required	Pass
102	0.004	0.507	0.326	0.110	0.061	0.834	#13	0.036	Not Required	Pass
103	0.011	0.878	0.070	0.087	0.010	0.918	#13	0.046	Not Required	Pass
104	0.011	0.852	0.193	0.085	0.042	0.924	#13	0.082	Not Required	Pass
105	0.011	0.545	0.201	0.087	0.052	0.572	#13	0.076	Not Required	Pass
106	0.011	0.895	0.069	0.089	0.010	0.928	#13	0.046	Not Required	Pass
107	0.011	0.556	0.192	0.089	0.050	0.582	#13	0.076	Not Required	Pass
108	0.005	0.057	0.197	0.048	0.023	0.234	#21	0.102	Not Required	Pass
109	0.018	0.068	0.061	0.001	0.000	0.132	#13	0.206	Not Required	Pass
110	0.011	0.849	0.184	0.085	0.040	0.910	#13	0.082	Not Required	Pass
111	0.006	0.077	0.205	0.051	0.023	0.232	#21	0.102	Not Required	Pass
112	0.004	0.513	0.333	0.110	0.064	0.847	#13	0.036	Not Required	Pass
113	0.009	0.235	0.545	0.069	0.030	0.713	#21	0.306	Not Required	Pass
114	0.010	0.264	0.540	0.067	0.030	0.726	#21	0.306	Not Required	Pass
115	0.012	0.454	0.286	0.054	0.023	0.655	#21	0.507	Not Required	Pass
116	0.006	0.408	0.284	0.054	0.023	0.623	#21	0.507	Not Required	Pass
201	0.052	0.798	0.000	0.058	0.000	0.824	#13	0.413	Not Required	Pass
202	0.003	0.505	0.327	0.109	0.062	0.832	#13	0.036	Not Required	Pass
203	0.011	0.890	0.069	0.088	0.010	0.927	#13	0.046	Not Required	Pass
204	0.011	0.826	0.183	0.082	0.040	0.889	#13	0.082	Not Required	Pass
205	0.011	0.553	0.191	0.088	0.049	0.576	#13	0.076	Not Required	Pass

206	0.011	0.890	0.069	0.088	0.010	0.927	#13	0.046	Not Required	Pass
207	0.011	0.553	0.191	0.088	0.049	0.576	#13	0.076	Not Required	Pass
208	0.005	0.057	0.196	0.049	0.023	0.232	#21	0.102	Not Required	Pass
209	0.017	0.065	0.061	0.001	0.000	0.130	#13	0.206	Not Required	Pass
210	0.011	0.826	0.183	0.082	0.040	0.889	#13	0.082	Not Required	Pass
211	0.006	0.067	0.202	0.053	0.023	0.241	#21	0.102	Not Required	Pass
212	0.003	0.505	0.327	0.109	0.062	0.832	#13	0.036	Not Required	Pass
213	0.009	0.276	0.518	0.067	0.029	0.728	#21	0.306	Not Required	Pass
214	0.010	0.270	0.510	0.063	0.029	0.708	#21	0.306	Not Required	Pass
215	0.012	0.327	0.286	0.053	0.023	0.551	#21	0.507	Not Required	Pass
216	0.007	0.285	0.283	0.049	0.023	0.521	#21	0.507	Not Required	Pass
301	0.053	0.799	0.003	0.059	0.000	0.825	#13	0.413	Not Required	Pass
302	0.004	0.513	0.333	0.110	0.064	0.847	#13	0.036	Not Required	Pass
303	0.011	0.895	0.069	0.089	0.010	0.928	#13	0.046	Not Required	Pass
304	0.011	0.849	0.185	0.085	0.040	0.910	#13	0.082	Not Required	Pass
305	0.011	0.556	0.192	0.089	0.050	0.582	#13	0.076	Not Required	Pass
306	0.011	0.878	0.070	0.087	0.010	0.918	#13	0.046	Not Required	Pass
307	0.011	0.545	0.201	0.087	0.052	0.572	#13	0.076	Not Required	Pass
308	0.004	0.088	0.219	0.054	0.023	0.241	#21	0.102	Not Required	Pass
309	0.018	0.068	0.061	0.001	0.000	0.132	#13	0.206	Not Required	Pass
310	0.011	0.852	0.193	0.085	0.042	0.924	#13	0.082	Not Required	Pass
311	0.006	0.112	0.224	0.054	0.023	0.234	#21	0.102	Not Required	Pass
312	0.004	0.507	0.326	0.110	0.061	0.834	#13	0.036	Not Required	Pass
313	0.009	0.235	0.546	0.069	0.030	0.713	#21	0.306	Not Required	Pass
314	0.010	0.264	0.539	0.067	0.030	0.726	#21	0.306	Not Required	Pass
315	0.012	0.332	0.287	0.051	0.023	0.554	#21	0.507	Not Required	Pass
316	0.007	0.286	0.283	0.048	0.023	0.521	#21	0.507	Not Required	Pass
401	0.040	0.606	0.043	0.044	0.004	0.641	#13	0.413	Not Required	Pass
402	0.001	0.501	0.296	0.101	0.055	0.798	#13	0.054	Not Required	Pass
403	0.011	0.806	0.109	0.082	0.029	0.870	#13	0.046	Not Required	Pass
404	0.013	0.732	0.181	0.073	0.040	0.745	#13	0.082	Not Required	Pass
405	0.012	0.500	0.190	0.080	0.047	0.523	#13	0.076	Not Required	Pass
406	0.007	0.558	0.028	0.054	0.002	0.563	#13	0.046	Not Required	Pass
407	0.006	0.346	0.064	0.055	0.017	0.349	#13	0.076	Not Required	Pass
408	0.000	0.019	0.051	0.016	0.007	0.067	#21	Not Required	Not Required	Pass
409	0.008	0.073	0.091	0.004	0.005	0.160	#13	0.206	Not Required	Pass
410	0.006	0.521	0.083	0.052	0.021	0.589	#13	0.082	Not Required	Pass
411	0.000	0.020	0.051	0.017	0.007	0.068	#21	Not Required	Not Required	Pass
412	0.003	0.265	0.193	0.066	0.041	0.459	#13	0.054	Not Required	Pass
413	0.009	0.134	0.531	0.064	0.029	0.580	#21	0.204	Not Required	Pass
414	0.006	0.117	0.522	0.057	0.029	0.550	#24	0.306	Not Required	Pass
415	0.012	0.465	0.287	0.049	0.023	0.666	#21	0.507	Not Required	Pass
416	0.006	0.432	0.282	0.044	0.023	0.636	#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/comression)
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

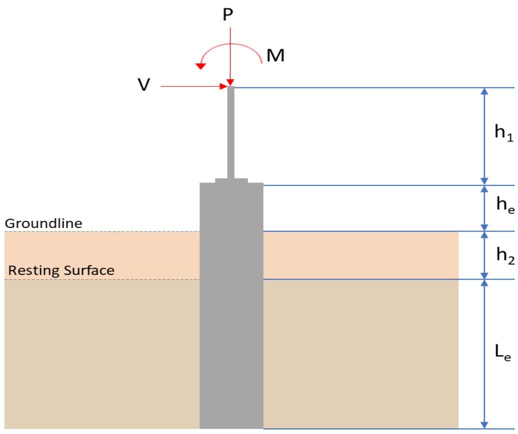
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 8\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - 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)	8.963	13.158
V_x (kip)	-4.280	-7.164
V_z (kip)	0.442	0.717
M_x (kipft)	1.381	2.199
M_z (kipft)	53.487	89.528

Material Properties

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

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

$$H_o = \frac{(-4.28\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.68153\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(53.487\ \text{kipft}) + ((-4.28\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.517\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.2692\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.442\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.070382\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.381\ \text{kipft}) + ((0.442\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.2199\ \text{kipft/ft}$$

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:
$L_{e,z} = 3.1358\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.2692\ \text{ft}), (3.1358\ \text{ft})]$$

$$L_{e,req} = 7.269\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.269\ \text{ft})}{(8\ \text{ft})}$$

$$Ratio = 0.90863$$

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

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

$$q = \frac{(8.963\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.56019\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.56019\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.28009$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.68153\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.517\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.517\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (8.517\ \mathrm{kipft/ft})) + (4 \times (-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5327\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.517\ \mathrm{kipft/ft})) + (3 \times (-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^2}{(8\ \mathrm{ft})^2 \times [(3 \times (8.517\ \mathrm{kipft/ft})) + (2 \times (-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.25099\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.517\ \mathrm{kipft/ft})) + ((-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 1.0858\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5327\ \mathrm{ft})}{2}$$

$$p_a = 0.41496\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25099\ \mathrm{kip/ft^2}\right)}{\left(0.41496\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.60485$$

Status: **PASS**
Ratio: **0.600**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0858\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90483$$

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

Considering z-direction:

$H_o = 0.070382\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.2199\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2199\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (0.070382\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (0.2199\ \mathrm{kipft/ft})) + (4 \times (0.070382\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.7537\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.2199\ \mathrm{kipft/ft})) + (3 \times (0.070382\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\ 2}}{(8\ \mathrm{ft})^2 \times [(3 \times (0.2199\ \mathrm{kipft/ft})) + (2 \times (0.070382\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.043301\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.2199\ \mathrm{kipft/ft})) + ((0.070382\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 0.094019\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.7537\ \mathrm{ft})}{2}$$

$$p_a = 0.43153\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.043301\ \mathrm{kip/ft^2}\right)}{\left(0.43153\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.10034$$

Status: **PASS**
Ratio: **0.100**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

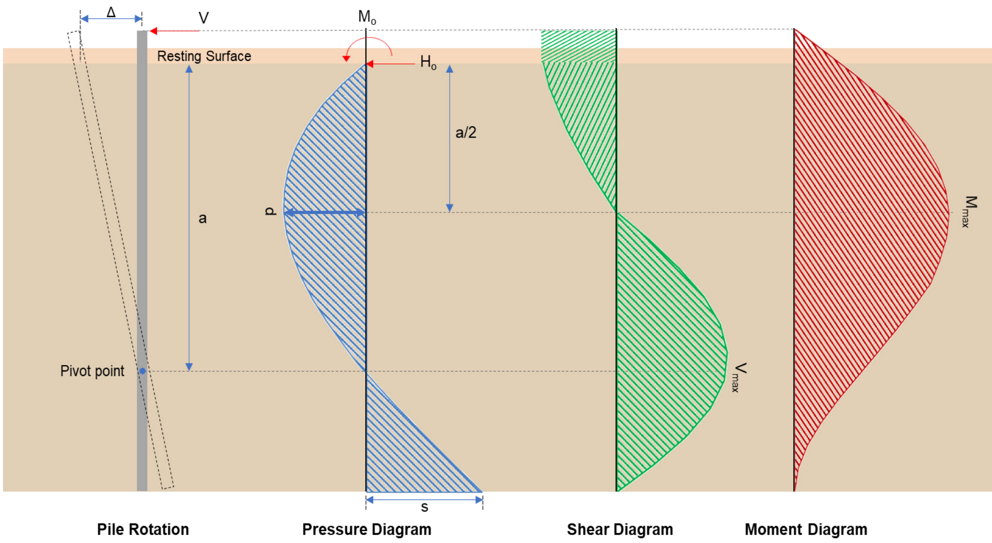
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.094019\ \mathrm{kip/ft^2})}{(1.2\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.078349$$

Status: **PASS**
Ratio: **0.080**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.164\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1408\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(89.528\ \mathrm{kipft}) + ((-7.164\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 14.256\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.256\ \mathrm{kipft/ft})}{(-1.1408\ \mathrm{kip/ft})}$$

$$E = 12.497\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.256\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-1.1408\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (14.256\ \text{kipft/ft})) + (4 \times (-1.1408\ \text{kip/ft}) \times (8\ \text{ft}))}$$

$$a = 5.5327\ \text{ft}$$

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

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

$$V_{max} = ((-1.1408\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.497\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.5327\ \text{ft})}{(8\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.497\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.5327\ \text{ft})}{(8\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.622\ \text{kip}$$

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

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

$$M_{max} = ((-1.1408\ \text{kip/ft}) \times (48\ \text{in}) \times (8\ \text{ft})) \times \left[\left(\frac{(12.497\ \text{ft})}{(8\ \text{ft})} + \frac{(5.5327\ \text{ft})}{2 \times (8\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.497\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.5327\ \text{ft})}{2 \times (8\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.497\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.5327\ \text{ft})}{2 \times (8\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 59.178\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.717\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.11417\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.199\ \text{kipft}) + ((0.717\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.35016\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.35016\ \text{kipft/ft})}{(0.11417\ \text{kip/ft})}$$

$$E = 3.0669\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.35016\ \text{kipft/ft}) \times (8\ \text{ft})) + \left(3 \times (0.11417\ \text{kip/ft}) \times (8\ \text{ft})^2\right)}{(6 \times (0.35016\ \text{kipft/ft})) + (4 \times (0.11417\ \text{kip/ft}) \times (8\ \text{ft}))}$$

$$a = 5.7566\ \text{ft}$$

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

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

$$V_{max} = ((0.11417\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.0669\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.7566\ \text{ft})}{(8\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.0669\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.7566\ \text{ft})}{(8\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.61533\ \text{kip}$$

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

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

$$M_{max} = ((0.11417\ \text{kip/ft}) \times (48\ \text{in}) \times (8\ \text{ft})) \times \left[\left(\frac{(3.0669\ \text{ft})}{(8\ \text{ft})} + \frac{(5.7566\ \text{ft})}{2 \times (8\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.0669\ \text{ft})}{(8\ \text{ft})} + 3\right) \times \left(\frac{(5.7566\ \text{ft})}{2 \times (8\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.0669\ \text{ft})}{(8\ \text{ft})} + 2\right) \times \left(\frac{(5.7566\ \text{ft})}{2 \times (8\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.1366\ \text{kipft}$$

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,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.158\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.159\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.159\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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

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

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

	$$Ratio = 0.96556$$	Status: **PASS** Ratio: **0.970**
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, \left(1.5\ d_{bar}\right)\right]$$ $$s_{rebar} = Max\left[1.5, \left(1.5 \times (0.625\ \mathrm{in})\right)\right]$$ $$s_{rebar} = 1.5\ \mathrm{in}$$ **Ties:**	
25.7.2.2 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), Min\left(D, b\right)\right]$$ $$s_{ties} = Min\left[\left(16 \times (0.625\ \mathrm{in})\right), \left(48 \times (0.375\ \mathrm{in})\right), Min\left((48\ \mathrm{in}), (48\ \mathrm{in})\right)\right]$$ $$s_{ties} = 10\ \mathrm{in}$$ **Summary:** Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \mathrm{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.158\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$ $$Ratio = 0.0049185$$	Status: **PASS** Ratio: **0.000**
22.5.2.2 22.5.5.1.3 22.5.5.1.1	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \mathrm{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \mathrm{in})$$ $$d = 38.4\ \mathrm{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \mathrm{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 13.158 \text{ kip} \rightarrow 13158 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13158 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.24 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.24 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.24 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - 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)

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\,\left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((120.24 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.24 \text{ kip}$$

Considering x-direction:

$V_{max} = 15.622 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(15.622 \text{ kip})}{(111.24 \text{ kip})}$$ $$Ratio = 0.14044$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $V_{max} = 0.61533 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.61533 \text{ kip})}{(111.24 \text{ kip})}$$ $$Ratio = 0.0055317$$	Status: **PASS** Ratio: **0.010**
14.5.2.1b	**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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 59.178 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(59.178 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.23709$$	Status: **PASS** Ratio: **0.240**
	Considering z-direction: $M_{max} = 2.1366 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(2.1366 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00856$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

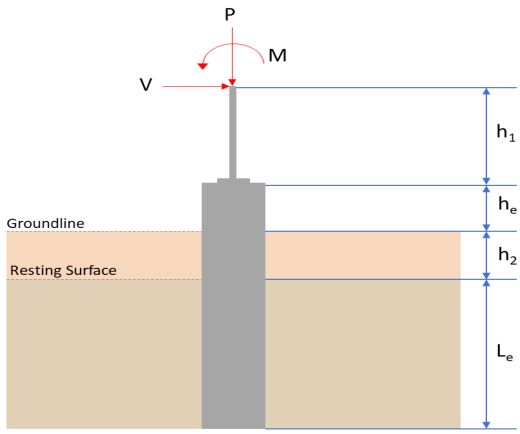
SkyCiv Foundation Design

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
$L = 8$ 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)	8.963	13.158
V_x (kip)	-4.280	-7.164
V_z (kip)	-0.442	-0.717
M_x (kipft)	-1.381	-2.199
M_z (kipft)	53.487	89.529

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,

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

$$H_o = \frac{(-4.28 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.68153 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(53.487\ \mathrm{kipft}) + ((-4.28\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.517\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.2692\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.442\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.070382\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.381\ \mathrm{kipft}) + ((-0.442\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.2199\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.0689\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.2692\ \mathrm{ft}), (2.0689\ \mathrm{ft})]$$

$$L_{e,req} = 7.269\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.269\ \mathrm{ft})}{(8\ \mathrm{ft})}$$

$$Ratio = 0.90863$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.963\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.56019\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.56019\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.28009$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.68153\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.517\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.517\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{(6 \times (8.517\ \mathrm{kipft/ft})) + (4 \times (-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))}$$

$$a = 5.5327\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.517\ \mathrm{kipft/ft})) + (3 \times (-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]^{\,2}}{(8\ \mathrm{ft})^2 \times [(3 \times (8.517\ \mathrm{kipft/ft})) + (2 \times (-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}$$

$$p = 0.25099\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.517\ \mathrm{kipft/ft})) + ((-0.68153\ \mathrm{kip/ft}) \times (8\ \mathrm{ft}))]}{(8\ \mathrm{ft})^2}$$

$$s = 1.0858\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5327\ \mathrm{ft})}{2}$$

$$p_a = 0.41496\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25099 \text{ kip/ft}^2\right)}{\left(0.41496 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.60485$$

Status: **PASS**
Ratio: **0.600**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8 \text{ ft})$$

$$p_s = 1.2 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0858 \text{ kip/ft}^2\right)}{\left(1.2 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.90483$$

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

Considering z-direction:

$H_o = -0.070382 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.2199 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2199 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-0.070382 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (0.2199 \text{ kipft/ft})) + (4 \times (-0.070382 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.7537 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.2199 \text{ kipft/ft})) + (3 \times (-0.070382 \text{ kip/ft}) \times (8 \text{ ft})]^{\,2}}{(8 \text{ ft})^2 \times [(3 \times (0.2199 \text{ kipft/ft})) + (2 \times (-0.070382 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = -0.016467 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.2199 \text{ kipft/ft})) + ((-0.070382 \text{ kip/ft}) \times (8 \text{ ft})]}{(8 \text{ ft})^2}$$

$$s = -0.011555 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.7537 \text{ ft})}{2}$$

$$p_a = 0.43153 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.016467 \text{ kip/ft}^2\right)}{\left(0.43153 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.03816$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8\ \mathrm{ft})$$

$$p_s = 1.2\ \mathrm{kip/ft^2}$$

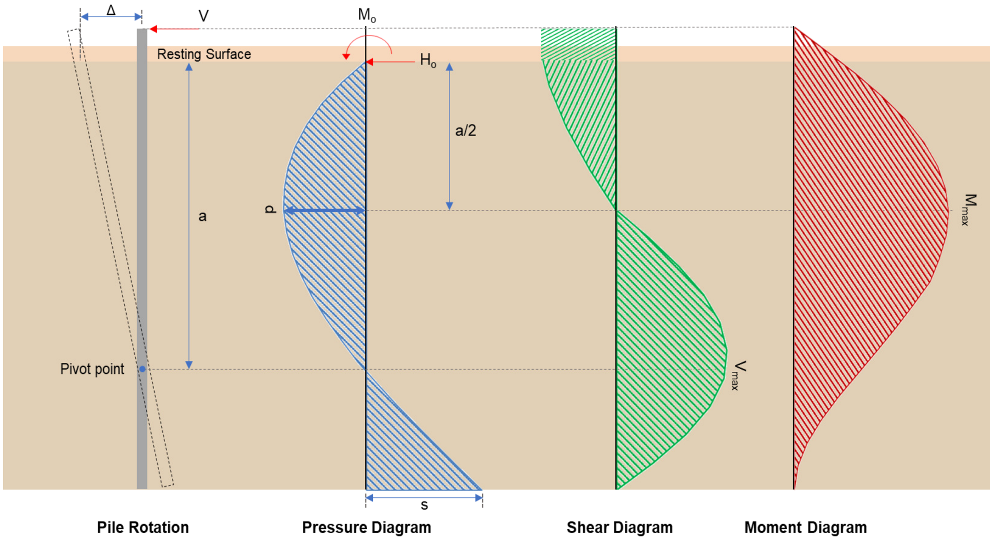
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.011555\ \mathrm{kip/ft^2}\right)}{\left(1.2\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0096288$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.164\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.1408\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(89.529\ \mathrm{kipft}) + ((-7.164\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 14.256\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.256\ \mathrm{kipft/ft})}{(-1.1408\ \mathrm{kip/ft})}$$

$$E = 12.497\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.256\ \mathrm{kipft/ft}) \times (8\ \mathrm{ft})) + \left(3 \times (-1.1408\ \mathrm{kip/ft}) \times (8\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (14.256 \text{ kipft/ft})) + (4 \times (-1.1408 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5327 \text{ ft}$$

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

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

$$V_{max} = ((-1.1408 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.497 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.5327 \text{ ft})}{(8 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.497 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.5327 \text{ ft})}{(8 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 15.622 \text{ kip}$$

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

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

$$M_{max} = ((-1.1408 \text{ kip/ft}) \times (48 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(12.497 \text{ ft})}{(8 \text{ ft})} + \frac{(5.5327 \text{ ft})}{2 \times (8 \text{ ft})}\right) - \left[\left(\frac{4 \times (12.497 \text{ ft})}{(8 \text{ ft})} + 3\right) \times \left(\frac{(5.5327 \text{ ft})}{2 \times (8 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.497 \text{ ft})}{(8 \text{ ft})} + 2\right) \times \left(\frac{(5.5327 \text{ ft})}{2 \times (8 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 59.178 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.717 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.11417 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.199 \text{ kipft}) + ((-0.717 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.35016 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.35016 \text{ kipft/ft})}{(-0.11417 \text{ kip/ft})}$$

$$E = 3.0669 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.35016 \text{ kipft/ft}) \times (8 \text{ ft})) + \left(3 \times (-0.11417 \text{ kip/ft}) \times (8 \text{ ft})^2\right)}{(6 \times (0.35016 \text{ kipft/ft})) + (4 \times (-0.11417 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.7566 \text{ ft}$$

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

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

$$V_{max} = ((-0.11417\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.0669\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7566\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.0669\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7566\ \mathrm{ft})}{(8\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.61533\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.11417\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8\ \mathrm{ft})) \times \left[\left(\frac{(3.0669\ \mathrm{ft})}{(8\ \mathrm{ft})} + \frac{(5.7566\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (3.0669\ \mathrm{ft})}{(8\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.7566\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.0669\ \mathrm{ft})}{(8\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.7566\ \mathrm{ft})}{2 \times (8\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.1366\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,
$f_{yk} = 60\ \mathrm{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304\ \mathrm{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.158\ \mathrm{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.159\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.159\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.158\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0049185$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 13.158 \text{ kip} \rightarrow 13158 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13158 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.24 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.24 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.24 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - 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)

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.24 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.24 \text{ kip}$$

Considering x-direction:

$V_{max} = 15.622 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(15.622\ \mathrm{kip})}{(111.24\ \mathrm{kip})}$$ $$Ratio = 0.14044$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $V_{max} = 0.61533\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.61533\ \mathrm{kip})}{(111.24\ \mathrm{kip})}$$ $$Ratio = 0.0055317$$	Status: **PASS** Ratio: **0.010**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 59.178\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(59.178\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.23709$$	Status: **PASS** Ratio: **0.240**
	Considering z-direction: $M_{max} = 2.1366\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(2.1366\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.00856$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

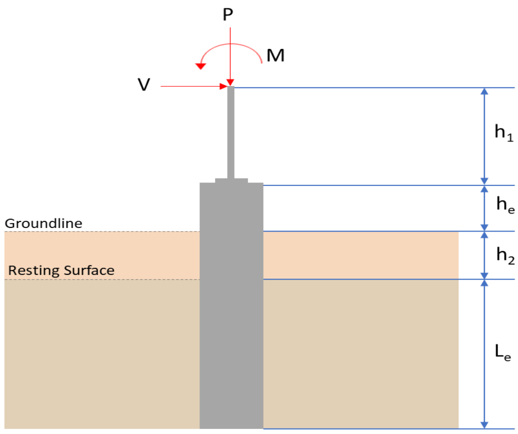
SkyCiv Foundation Design

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)	11.637	17.188
V_x (kip)	-5.644	-9.423
V_z (kip)	-0.026	-0.043
M_x (kipft)	-0.079	-0.123
M_z (kipft)	69.965	117.976

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,

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

$$H_o = \frac{(-5.644\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.89873\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(69.965 \text{ kipft}) + ((-5.644 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.141 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.7835 \text{ ft}$ - 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,

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

$$M_o = \frac{(0.079 \text{ kipft}) + ((-0.026 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

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

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.91971 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7835 \text{ ft}), (0.91971 \text{ ft})]$$

$$L_{e,req} = 7.784 \text{ ft}$$

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

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

$$Ratio = \frac{(7.784 \text{ ft})}{(8.5 \text{ ft})}$$

$$Ratio = 0.91576$$

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

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

$$q = \frac{(11.637 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.72731 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.72731 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.36366$$

Status: **PASS**
Ratio: **0.360**

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:

$H_o = -0.89873 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 11.141 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.141 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (11.141 \text{ kipft/ft})) + (4 \times (-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8889 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (11.141 \text{ kipft/ft})) + (3 \times (-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 \times [(3 \times (11.141 \text{ kipft/ft})) + (2 \times (-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.26807 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (11.141 \text{ kipft/ft})) + ((-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 1.216 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8889 \text{ ft})}{2}$$

$$p_a = 0.44167 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26807\ \mathrm{kip/ft^2}\right)}{\left(0.44167\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.60694$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.216\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95373$$

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

Considering z-direction:

$H_o = -0.0041401\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.01258\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.01258\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.01258\ \mathrm{kipft/ft})) + (4 \times (-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.1278\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.01258\ \mathrm{kipft/ft})) + (3 \times (-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (0.01258\ \mathrm{kipft/ft})) + (2 \times (-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = -0.00097089\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.01258\ \mathrm{kipft/ft})) + ((-0.0041401\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = -0.00083309\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.1278\ \mathrm{ft})}{2}$$

$$p_a = 0.45958\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00097089\ \mathrm{kip/ft^2}\right)}{\left(0.45958\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0021125$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

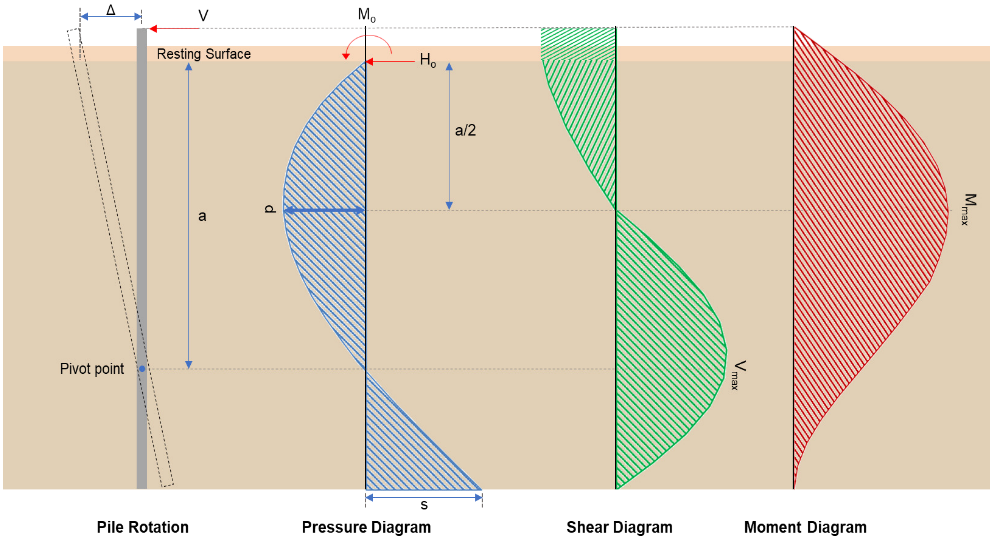
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.00083309\ \mathrm{kip/ft^2})}{(1.275\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.00065341$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-9.423\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.5005\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(117.98\ \mathrm{kipft}) + ((-9.423\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 18.786\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(18.786\ \mathrm{kipft/ft})}{(-1.5005\ \mathrm{kip/ft})}$$

$$E = 12.52\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (18.786\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-1.5005\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (18.786 \text{ kipft/ft})) + (4 \times (-1.5005 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8874 \text{ ft}$$

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

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

$$V_{max} = ((-1.5005 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.52 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.8874 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.52 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.8874 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 19.601 \text{ kip}$$

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

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

$$M_{max} = ((-1.5005 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(12.52 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.8874 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (12.52 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.8874 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.52 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.8874 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 78.681 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.043 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0068471 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.123 \text{ kipft}) + ((-0.043 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.019586 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.019586 \text{ kipft/ft})}{(-0.0068471 \text{ kip/ft})}$$

$$E = 2.8605 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.019586 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.0068471 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.019586 \text{ kipft/ft})) + (4 \times (-0.0068471 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 6.1374 \text{ ft}$$

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

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

$$V_{max} = ((-0.0068471\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.8605\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1374\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.8605\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1374\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.034669\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.0068471\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.5\ \mathrm{ft})) \times \left[\left(\frac{(2.8605\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + \frac{(6.1374\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (2.8605\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1374\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.8605\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1374\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.12668\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,
$f_{yk} = 60\ \mathrm{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304\ \mathrm{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(17.188\ \mathrm{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.025\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-84.025\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(17.188\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.006425$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,$P = 17.188 \text{ kip} \rightarrow 17188 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(17188 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.78 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.78 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.78 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - 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)

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\,\left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((120.78 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.59 \text{ kip}$$

Considering x-direction:

$V_{max} = 19.601 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(19.601\ \text{kip})}{(111.59\ \text{kip})}$$

$$Ratio = 0.17565$$

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

Considering z-direction:

$V_{max} = 0.034669\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.034669\ \text{kip})}{(111.59\ \text{kip})}$$

$$Ratio = 0.0003107$$

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:
$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$

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

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

14.5.2.1b $\phi M_{n,2}$

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 78.681\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(78.681\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.31523$$

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

Considering z-direction:

$M_{max} = 0.12668\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.12668 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00050755$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

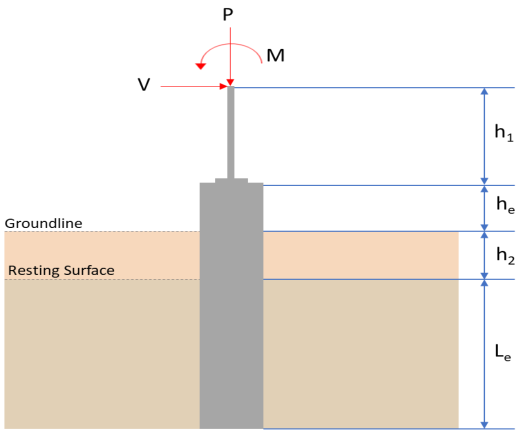
SkyCiv Foundation Design

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)	11.469	16.964
V_x (kip)	-5.594	-9.326
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	69.990	117.893

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,

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

$$H_o = \frac{(-5.594 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.89076 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(70 \text{ kipft}) + ((-5.594 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.145 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.8007 \text{ ft}$ - 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,

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

$$L_{e,req} = MAX[(7.8007 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 7.801 \text{ ft}$$

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

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

$$Ratio = \frac{(7.801 \text{ ft})}{(8.5 \text{ ft})}$$

$$Ratio = 0.91776$$

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

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

$$q = \frac{(11.469 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.71681 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.71681 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.35841$$

Status: **PASS**
Ratio: **0.360**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 2.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.89076\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 11.145\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.145\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-0.89076\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (11.145\ \mathrm{kipft/ft})) + (4 \times (-0.89076\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8875\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (11.145\ \mathrm{kipft/ft})) + (3 \times (-0.89076\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]^2}{(8.5\ \mathrm{ft})^2 \times [(3 \times (11.145\ \mathrm{kipft/ft})) + (2 \times (-0.89076\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}$$

$$p = 0.27131\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (11.145\ \mathrm{kipft/ft})) + ((-0.89076\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))]}{(8.5\ \mathrm{ft})^2}$$

$$s = 1.2223\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8875\ \mathrm{ft})}{2}$$

$$p_a = 0.44156\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27131\ \mathrm{kip/ft^2}\right)}{\left(0.44156\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.61444$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

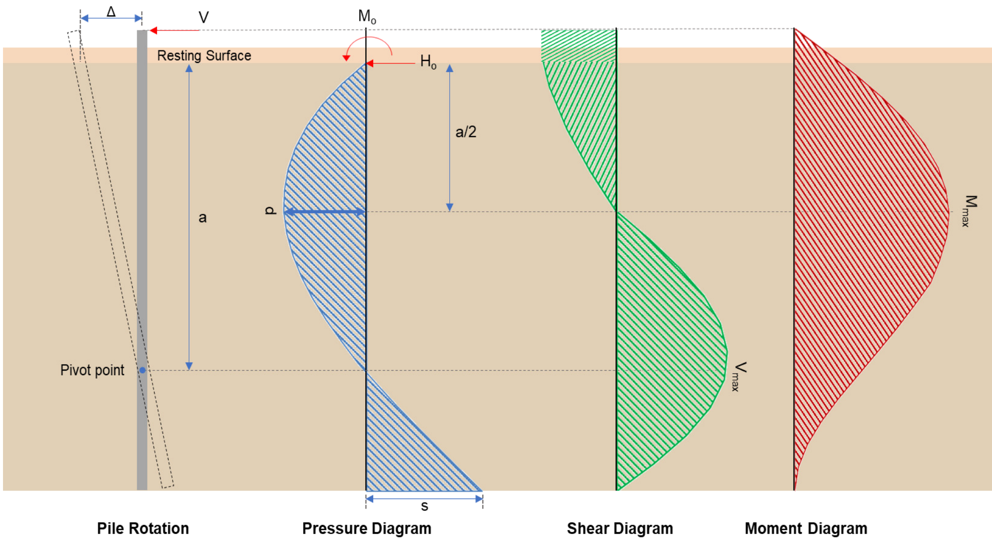
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2223\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95865$$

Status: PASS
Ratio: 0.960



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-9.326\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.485\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(117.89\ \text{kipft}) + ((-9.326\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 18.773\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(18.773\ \text{kipft/ft})}{(-1.485\ \text{kip/ft})}$$

$$E = 12.641\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (18.773\ \text{kipft/ft}) \times (8.5\ \text{ft})) + \left(3 \times (-1.485\ \text{kip/ft}) \times (8.5\ \text{ft})^2\right)}{(6 \times (18.773\ \text{kipft/ft})) + (4 \times (-1.485\ \text{kip/ft}) \times (8.5\ \text{ft}))}$$

$$a = 5.8859\ \text{ft}$$

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

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

$$V_{max} = ((-1.485\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.641\ \text{ft})}{(8.5\ \text{ft})} + 3\right) \times \left(\frac{(5.8859\ \text{ft})}{(8.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.641\ \text{ft})}{(8.5\ \text{ft})} + 2\right) \times \left(\frac{(5.8859\ \text{ft})}{(8.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 19.549 \text{ kip}$$

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

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

$$M_{max} = ((-1.485 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(12.641 \text{ ft})}{(8.5 \text{ ft})} + \frac{(5.8859 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (12.641 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(5.8859 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.641 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(5.8859 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 78.508 \text{ kipft}$$

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,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(16.964 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.032 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.032 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

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

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

	$$s_{rebar} = Max\left[1.5, (1.5 \times (0.625\ \text{in}))\right]$$ $$s_{rebar} = 1.5\ \text{in}$$ **Ties:**	
25.7.2.2 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), Min\,(D, b)\right]$$ $$s_{ties} = Min\left[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), Min\,((48\ \text{in}), (48\ \text{in}))\right]$$ $$s_{ties} = 10\ \text{in}$$ **Summary:** Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(16.964\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0063412$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 22.5.5.1.3 22.5.5.1.1 22.5.5.1.1(a)	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$ 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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $V_{c,max}$ - 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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 16.964\ \text{kip} \rightarrow 16964\ \text{lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \frac{P}{6\ A_g}\right]\ b_w\ d$$	

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(16964 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.75 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.75 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.75 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - 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)

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\, \left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((120.75 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.57 \text{ kip}$$

Considering x-direction:

$V_{max} = 19.549 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(19.549 \text{ kip})}{(111.57 \text{ kip})}$$

$$Ratio = 0.17522$$

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

14.5.2.1b	**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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 78.508 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(78.508 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.31453$$	Status: **PASS** Ratio: **0.310**

REFERENCES	CALCULATIONS	RESULTS

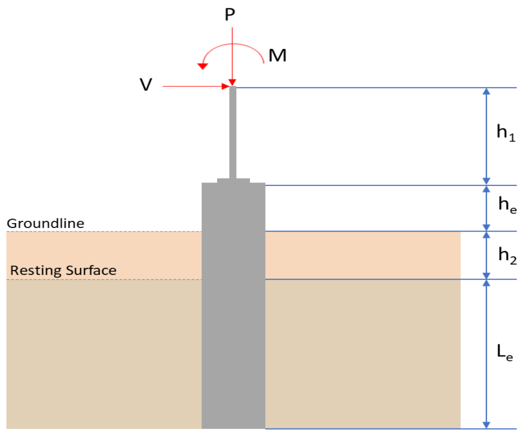
SkyCiv Foundation Design

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)	11.637	17.188
V_x (kip)	-5.644	-9.423
V_z (kip)	0.026	0.043
M_x (kipft)	0.079	0.123
M_z (kipft)	69.965	117.976

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,

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

$$H_o = \frac{(-5.644\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.89873\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(69.965 \text{ kipft}) + ((-5.644 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.141 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.7835 \text{ ft}$ - 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,

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

$$M_o = \frac{(0.079 \text{ kipft}) + ((0.026 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

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

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 1.0846 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7835 \text{ ft}), (1.0846 \text{ ft})]$$

$$L_{e,req} = 7.784 \text{ ft}$$

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

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

$$Ratio = \frac{(7.784 \text{ ft})}{(8.5 \text{ ft})}$$

$$Ratio = 0.91576$$

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

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

$$q = \frac{(11.637 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.72731 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.72731 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.36366$$

Status: **PASS**
Ratio: **0.360**

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:

$H_o = -0.89873 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 11.141 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.141 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (11.141 \text{ kipft/ft})) + (4 \times (-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$

$$a = 5.8889 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (11.141 \text{ kipft/ft})) + (3 \times (-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft}))]^2}{(8.5 \text{ ft})^2 \times [(3 \times (11.141 \text{ kipft/ft})) + (2 \times (-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$

$$p = 0.26807 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (11.141 \text{ kipft/ft})) + ((-0.89873 \text{ kip/ft}) \times (8.5 \text{ ft}))]}{(8.5 \text{ ft})^2}$$

$$s = 1.216 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8889 \text{ ft})}{2}$$

$$p_a = 0.44167 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.26807 \text{ kip/ft}^2\right)}{\left(0.44167 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.60694$$	Status: **PASS** Ratio: **0.610**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\, L_e$$ $$p_s = (150 \text{ psf/ft}) \times (8.5 \text{ ft})$$ $$p_s = 1.275 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.216 \text{ kip/ft}^2\right)}{\left(1.275 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.95373$$	Status: **PASS** Ratio: **0.950**
	Considering z-direction: $H_o = 0.0041401 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.01258 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (0.01258 \text{ kipft/ft}) \times (8.5 \text{ ft})) + \left(3 \times (0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft})^2\right)}{(6 \times (0.01258 \text{ kipft/ft})) + (4 \times (0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))}$$ $$a = 6.1278 \text{ ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.01258 \text{ kipft/ft})) + (3 \times (0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))]^{\,2}}{(8.5 \text{ ft})^2 \times [(3 \times (0.01258 \text{ kipft/ft})) + (2 \times (0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft}))]}$$ $$p = 0.0023332 \text{ kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.01258 \text{ kipft/ft})) + ((0.0041401 \text{ kip/ft}) \times (8.5 \text{ ft})]}{(8.5 \text{ ft})^2}$$ $$s = 0.0050118 \text{ kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\, \frac{a}{2}$$ $$p_a = (150 \text{ psf/ft}) \times \frac{(6.1278 \text{ ft})}{2}$$ $$p_a = 0.45958 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.0023332 \text{ kip/ft}^2\right)}{\left(0.45958 \text{ kip/ft}^2\right)}$$	

$$Ratio = 0.0050769$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

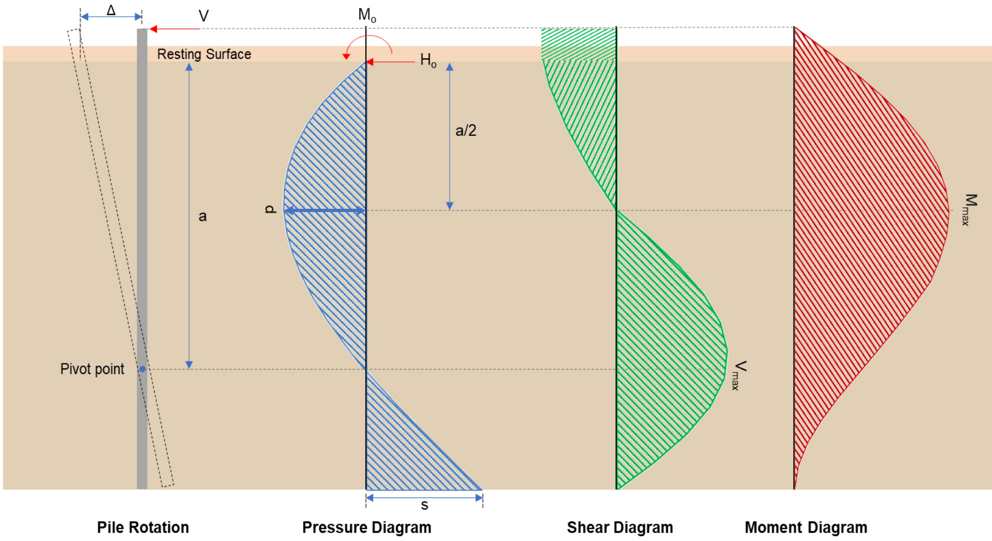
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0050118\ \mathrm{kip/ft^2}\right)}{\left(1.275\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0039308$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-9.423\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.5005\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(117.98\ \mathrm{kipft}) + ((-9.423\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 18.786\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(18.786\ \mathrm{kipft/ft})}{(-1.5005\ \mathrm{kip/ft})}$$

$$E = 12.52\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (18.786\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (-1.5005\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (18.786\ \mathrm{kipft/ft})) + (4 \times (-1.5005\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 5.8874\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.5005\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.52\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.8874\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.52\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.8874\ \mathrm{ft})}{(8.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 19.601\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.5005\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.5\ \mathrm{ft})) \times \left[\left(\frac{(12.52\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + \frac{(5.8874\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (12.52\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.8874\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.52\ \mathrm{ft})}{(8.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.8874\ \mathrm{ft})}{2 \times (8.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 78.681\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.043\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0068471\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.123\ \mathrm{kipft}) + ((0.043\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.019586\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.019586\ \mathrm{kipft/ft})}{(0.0068471\ \mathrm{kip/ft})}$$

$$E = 2.8605\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.019586\ \mathrm{kipft/ft}) \times (8.5\ \mathrm{ft})) + \left(3 \times (0.0068471\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft})^2\right)}{(6 \times (0.019586\ \mathrm{kipft/ft})) + (4 \times (0.0068471\ \mathrm{kip/ft}) \times (8.5\ \mathrm{ft}))}$$

$$a = 6.1374\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.0068471 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.8605 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1374 \text{ ft})}{(8.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.8605 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1374 \text{ ft})}{(8.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.034669 \text{ kip}$$

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

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

$$M_{max} = ((0.0068471 \text{ kip/ft}) \times (48 \text{ in}) \times (8.5 \text{ ft})) \times \left[\left(\frac{(2.8605 \text{ ft})}{(8.5 \text{ ft})} + \frac{(6.1374 \text{ ft})}{2 \times (8.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.8605 \text{ ft})}{(8.5 \text{ ft})} + 3\right) \times \left(\frac{(6.1374 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.8605 \text{ ft})}{(8.5 \text{ ft})} + 2\right) \times \left(\frac{(6.1374 \text{ ft})}{2 \times (8.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.12668 \text{ kipft}$$

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,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(17.188 \text{ kip})}{(0.65) \times (0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.025 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.025 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

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

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(17.188\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.006425$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.188 \text{ kip} \rightarrow 17188 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(17188 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.78 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.78 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.78 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,

22.5.1.2 $V_{s,a}$ - 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)

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\,\left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((120.78 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.59 \text{ kip}$$

Considering x-direction:

$V_{max} = 19.601 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(19.601 \text{ kip})}{(111.59 \text{ kip})}$$

$$Ratio = 0.17565$$

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

Considering z-direction:

$V_{max} = 0.034669 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.034669 \text{ kip})}{(111.59 \text{ kip})}$$

$$Ratio = 0.0003107$$

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:
$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$

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

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

14.5.2.1b $\phi M_{n,2}$

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 78.681 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(78.681 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.31523$$

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

Considering z-direction:

$M_{max} = 0.12668 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.12668 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00050755$$	Status: **PASS** Ratio: **0.000**