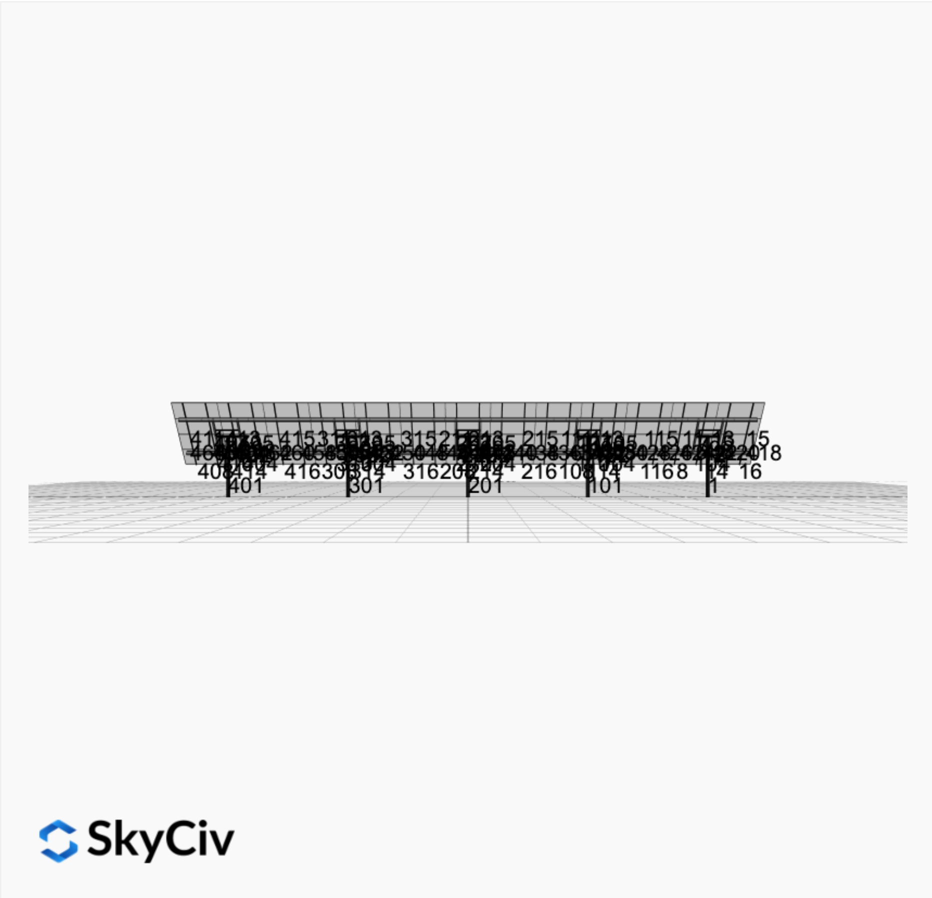
Project Details

Project Name: Table to Farm Compost - V3Jb
Date: Mon Oct 14 2024
Location: 735 Co Rd 236, Durango, CO 81301, USA
Number of Modules: 52
Unique ID: 5P-19.75-6TOP-HD-45-L-4Hx13W-81B4
Number of Poles: 5
Dealer: ______________________________
Date Sold: ______________________________



Array Dimensions N/S	13.87 ft
Array Dimensions E/W	95.55 ft
Winter Tilt Angle	46
Front Edge Clearance	5 ft

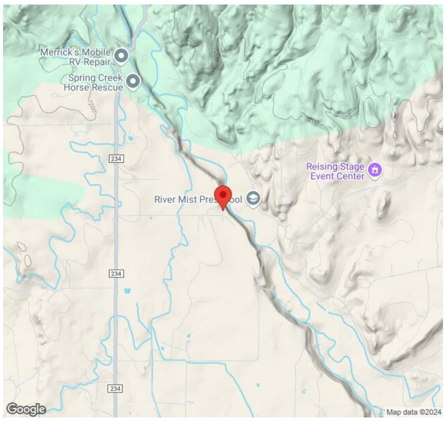
MT Solar Bill of Materials (5P-19.75-6TOP-HD-45-L-4Hx13W-81B4)

Part	Short Description	BOM Qty
MTS-PC-6	6IN Pole Cap Assembly	5
MTS-HF-HD	H-Frame Assembly-HD	5
MTS-HD-Wing-45	45IN HD Wing	4
MTS-HD-Splice-90	90IN HD Splice	8
MTS-HD-Splice-57	57IN HD Splice	8
MTS-CLAMP-HOOK-4PK	Hook Clamp	13

Rail Bill of Materials

Part	Qty
Rails (164in)	26
Rail Attachment	52
Module Mid Clamp	78
Module End Clamp	52
Ground Lug	13

Site Details:



Site Address: 735 Co Rd 236, Durango, CO 81301, USA

Array Specification

Duty Classification:	HD
Module Width:	41.10 in
Module Length:	87.20in
Number of Rows:	4
Number of Columns:	13
Total Number of Modules:	52
Winter Tilt Angle:	46
Front Edge Clearance:	5
Total Array Height at Tilt:	14.97 ft
Total Frame Length:	94.00 ft
Frame Weight:	4916 lbs
Array Dimensions N/S:	13.87 ft
Array Dimensions E/W:	95.55 ft
Rail Length:	166.40 in
Rail Spacing:	3.68 ft

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	9.99 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: 5.25 ft Pile 2: 5.50 ft Pile 3: 5.50 ft Pile 4: 5.50 ft Pile 5: 5.25 ft
Foundation Volume:	16.000 y^3

Site Info

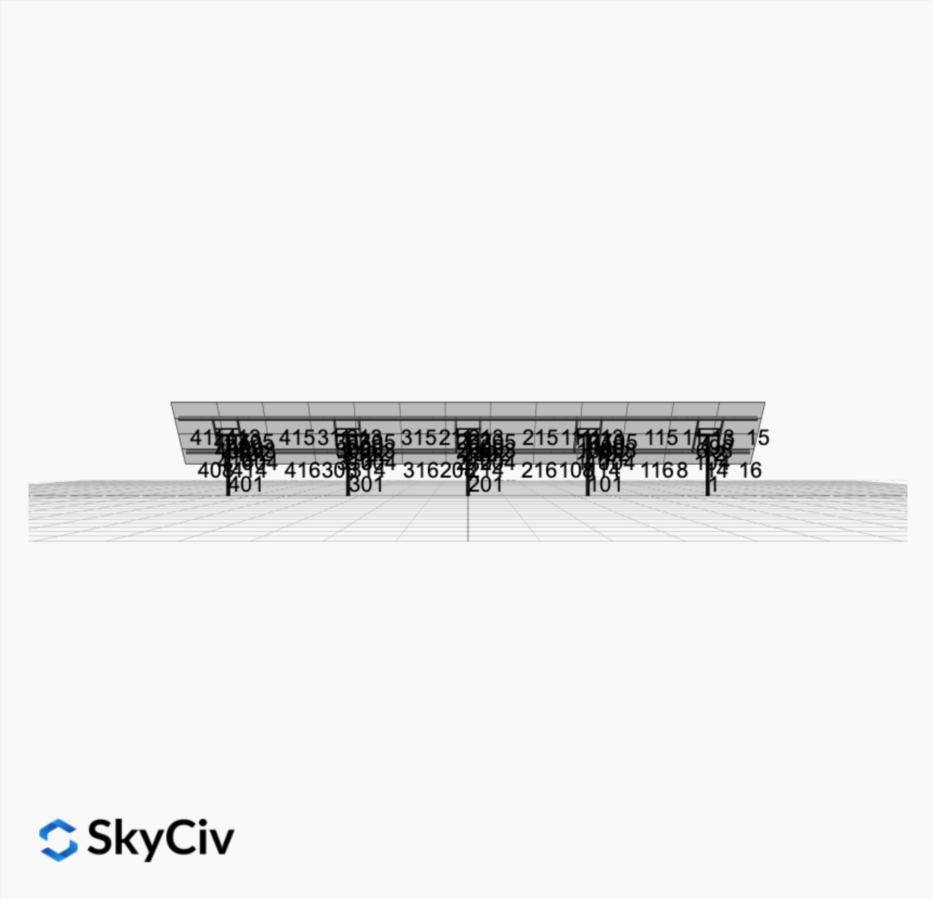
Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	735 Co Rd 236, Durango, CO 81301, USA
Wind Speed:	98 mph
Snow Load:	95 psf

AutoDesigner Input

{"wind_speed_override":98,"snow_load_override":95,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"","designer_email":"","designer_phone":"","project_id":"Table to Farm Compost - V3Jb","site_address":"735 Co Rd 236, Durango, CO 81301, USA","module_width":41.1,"module_length":87.2,"number_rows":"4","number_columns":13,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":46,"ground_clearance":5,"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)

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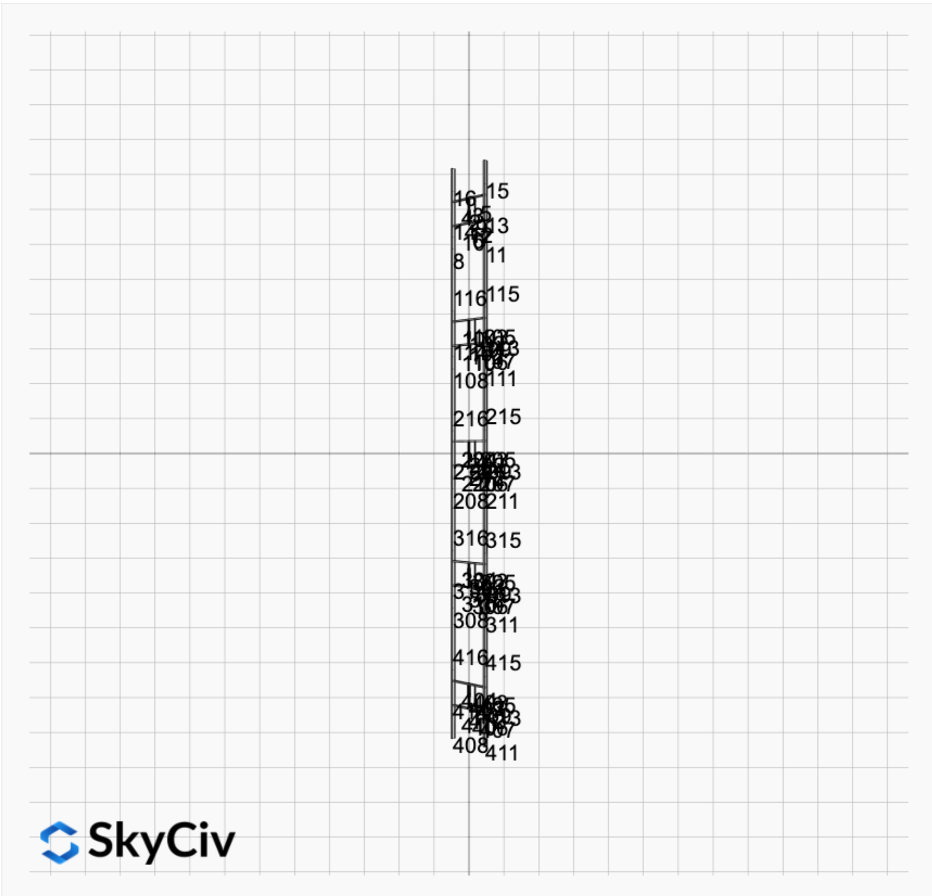
4.82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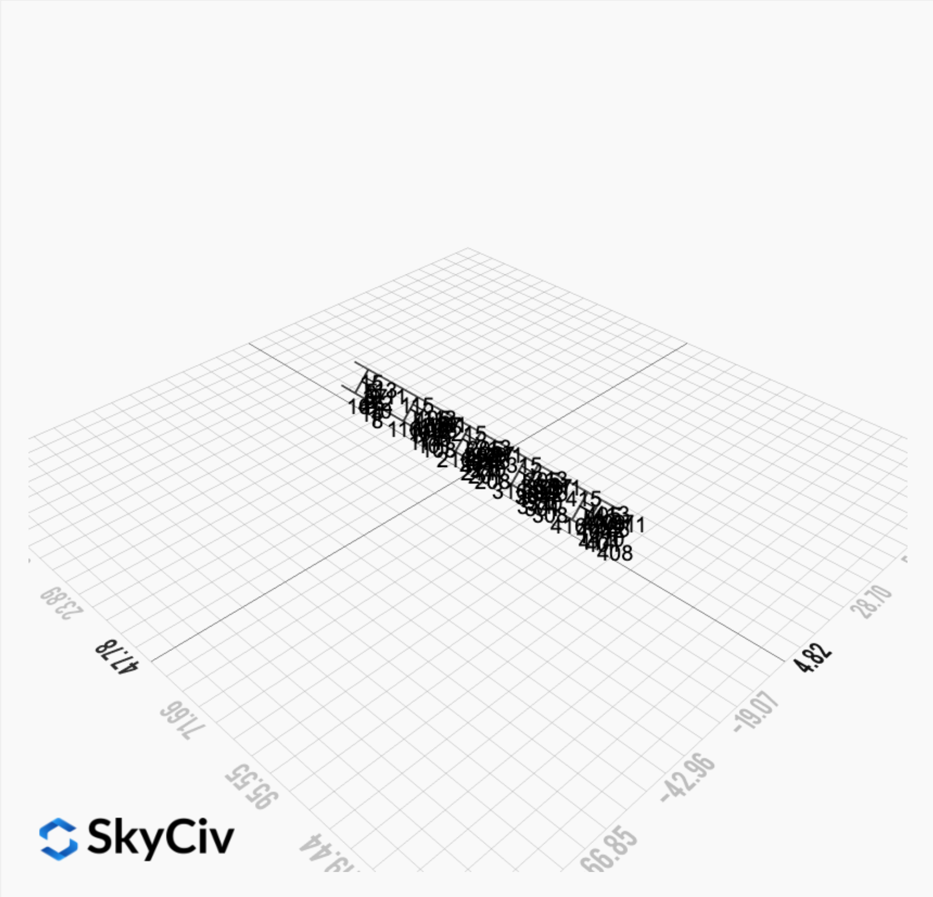
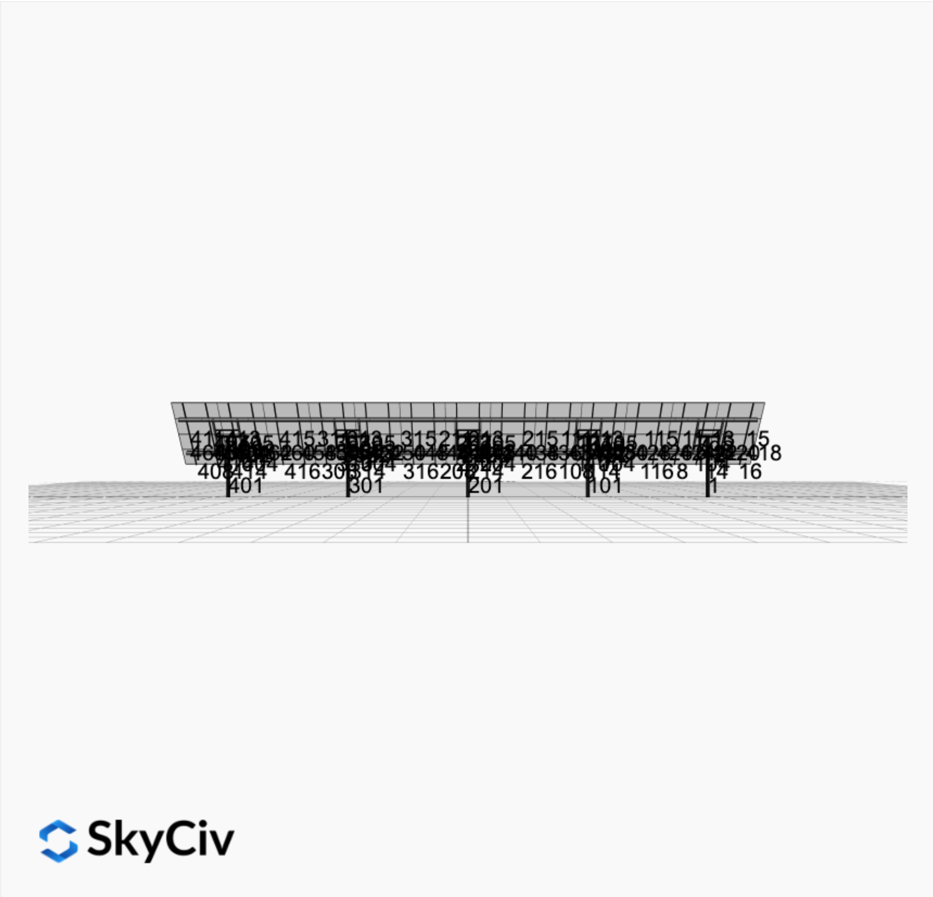
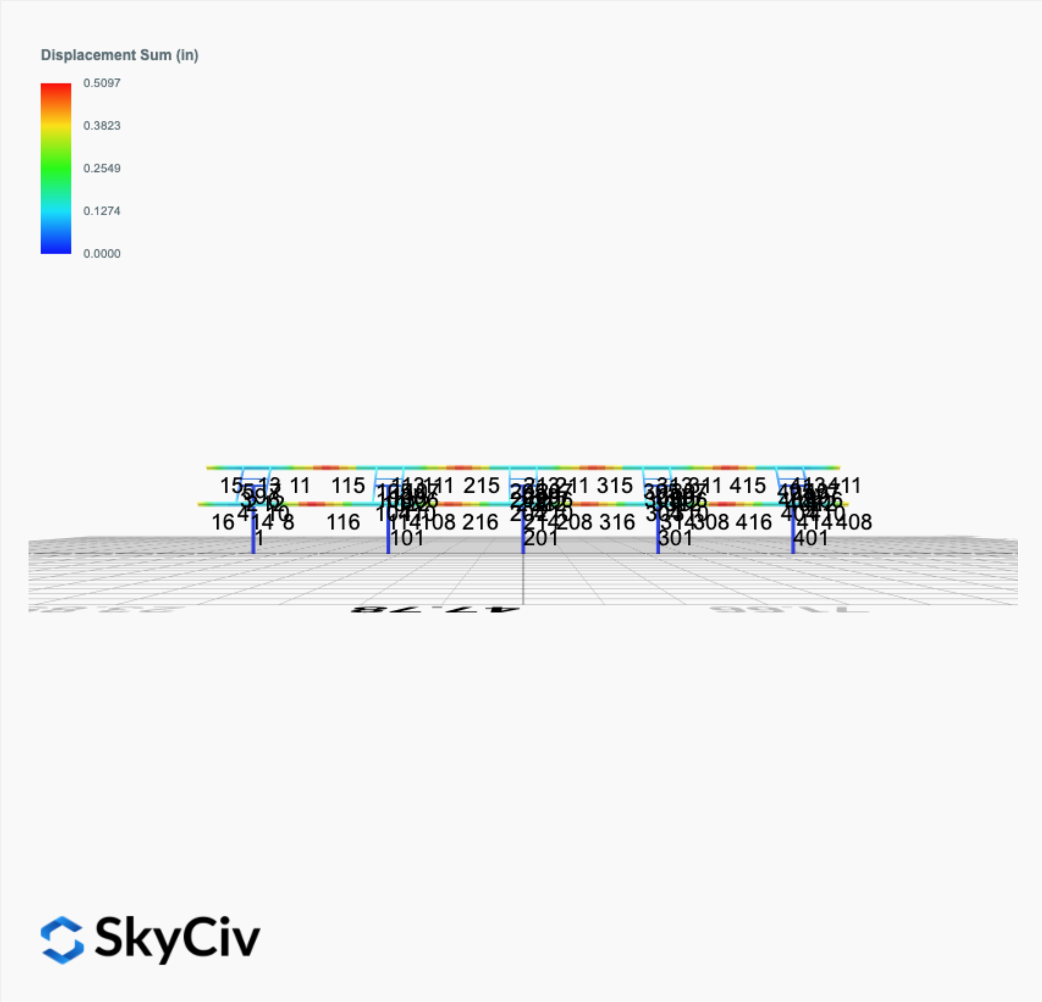
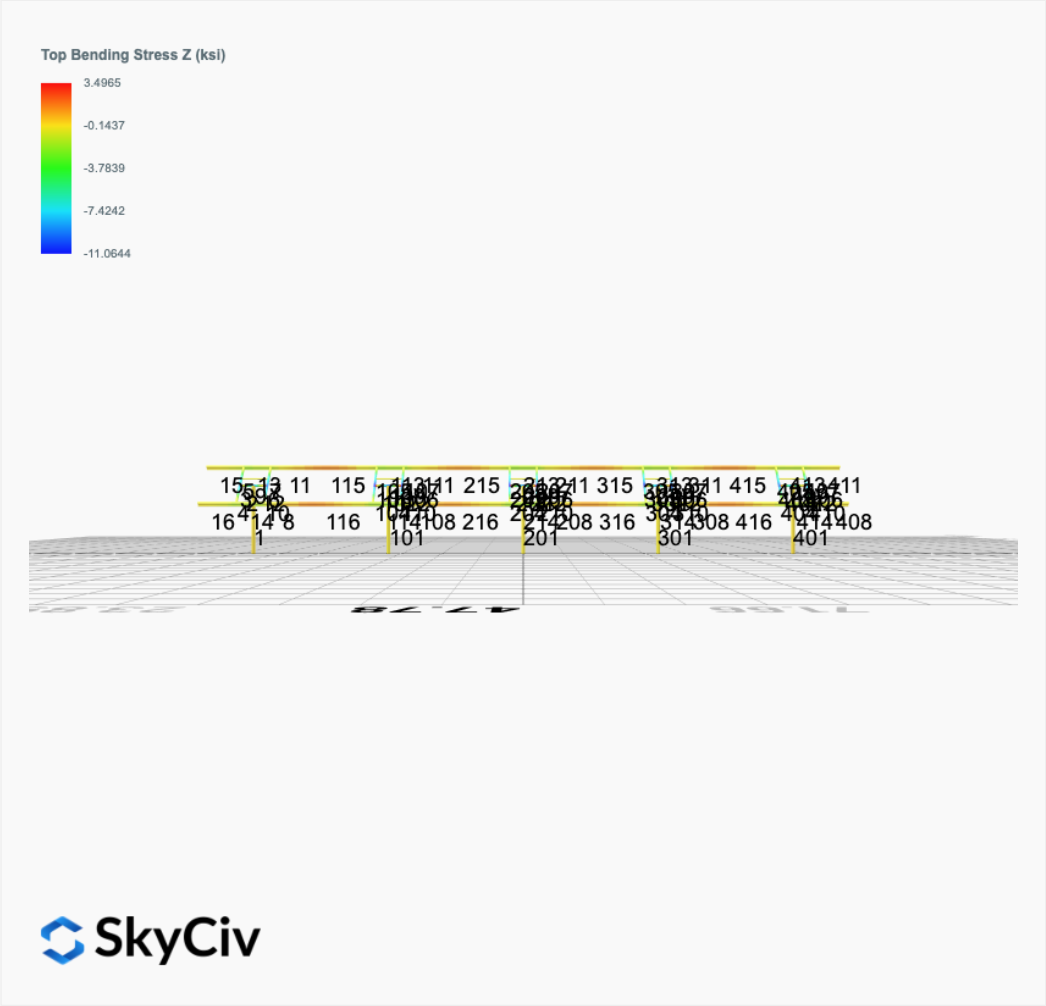
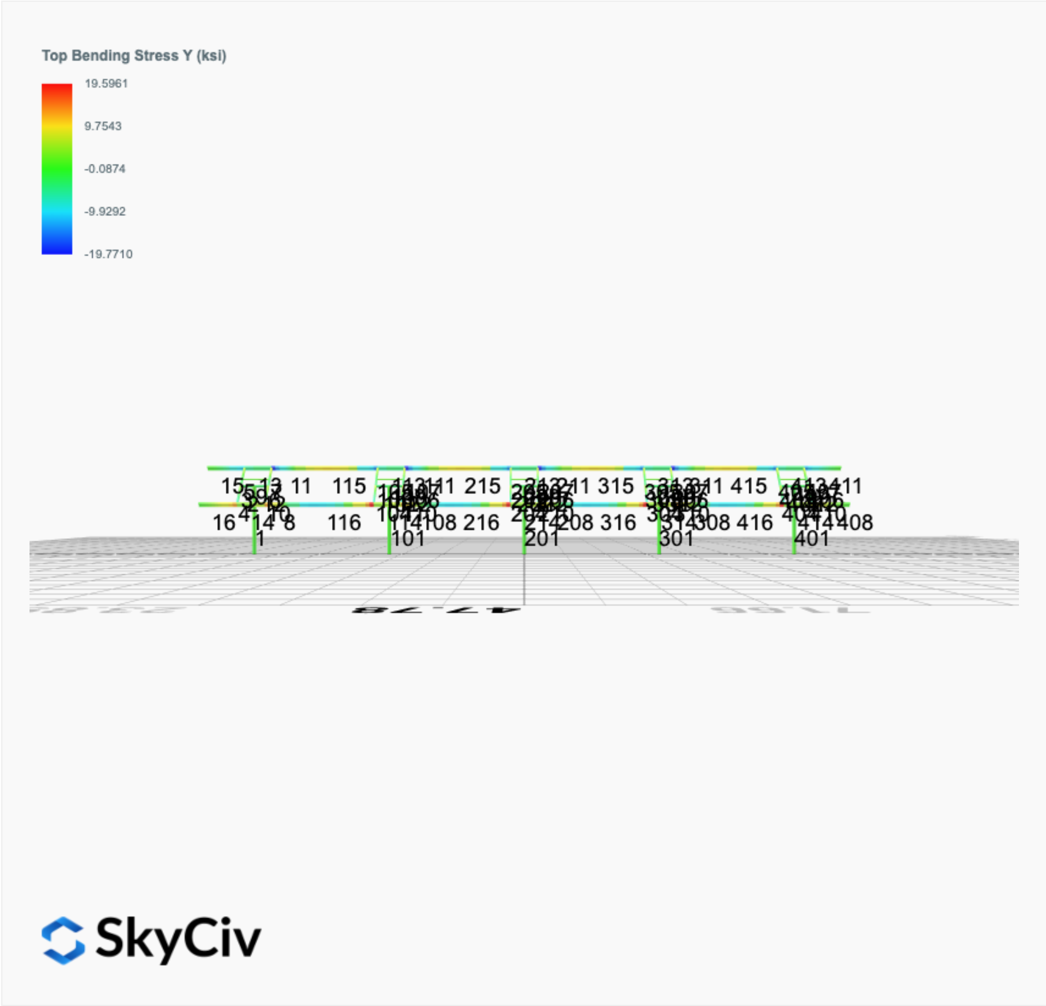

23.89
47.78
71.66
95.55
28.70
4.82
-19.07
-42.96
-66.85



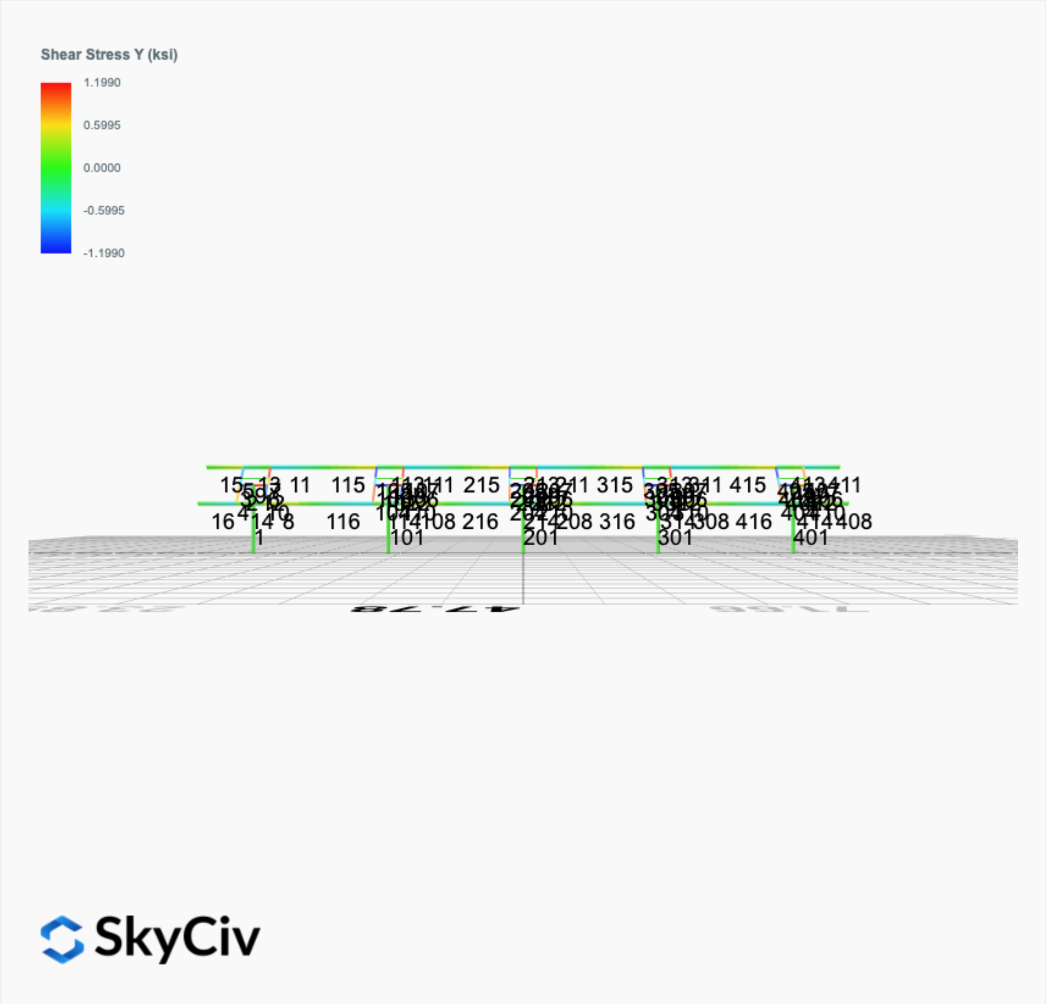
FEM Results (Envelope Worst Case for each member)

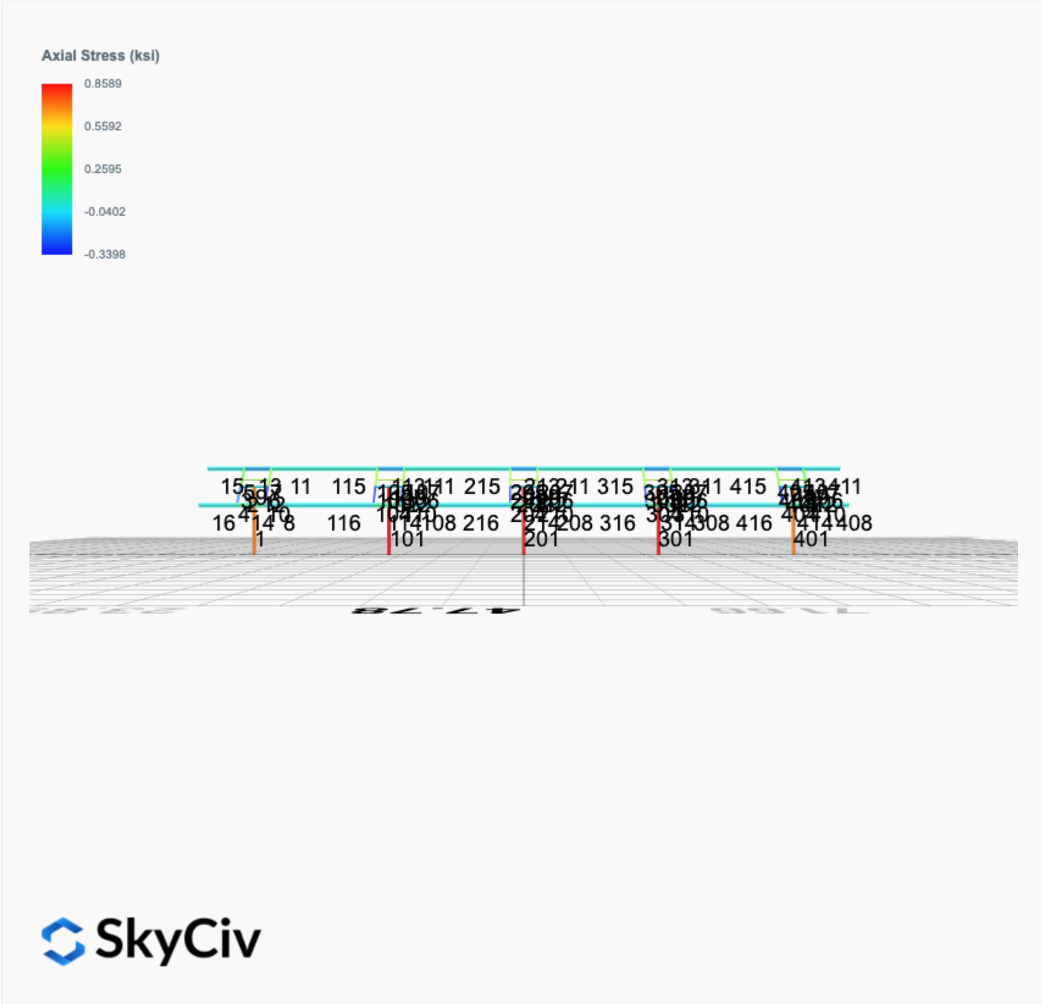



Top Bending Stress Z (ksi)
3.4965
-0.1437
-3.7839
-7.4242
-11.0644
SkyCiv



Top Bending Stress Y (ksi)
19.5961
9.7543
-0.0874
-9.9292
-19.7710
SkyCiv


Shear Stress Y (ksi)
1.1990
0.5995
0.0000
-0.5995
-1.1990
SkyCiv


Axial Stress (ksi)
0.8589
0.5592
0.2595
-0.0402
-0.3398

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	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 2. D + L	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 3. D + (S or Lr or R)	0.0286	6.0371	0.0979	0.3103	-0.0493	-0.2159
ULS: 3. D + (S or Lr or R)	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0233	4.9944	0.0797	0.2527	-0.0401	-0.1733
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 5b. D + 0.7E	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0233	4.9944	0.0797	0.2527	-0.0401	-0.1733
ULS: 8. 0.6D + 0.7E	0.0045	1.1198	0.0152	0.0479	-0.0075	-0.0273
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.4015	3.2084	0.0777	0.2378	-0.1615	14.3050
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.4150	0.5248	-0.0257	-0.0731	0.1322	-14.0045
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0334	6.0009	0.1191	0.3711	-0.1519	10.5896
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0233	4.9944	0.0797	0.2527	-0.0401	-0.1733
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0790	3.9882	0.0415	0.1379	0.0684	-10.6426
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0233	4.9944	0.0797	0.2527	-0.0401	-0.1733
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0492	2.8729	0.0646	0.1983	-0.1242	10.7174
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0631	0.8602	-0.0130	-0.0349	0.0960	-10.5148
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0074	1.8664	0.0253	0.0799	-0.0125	-0.0454
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.4044	2.4618	0.0676	0.2058	-0.1565	14.3232
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0045	1.1198	0.0152	0.0479	-0.0075	-0.0273
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.4120	-0.2217	-0.0358	-0.1051	0.1372	-13.9864
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0045	1.1198	0.0152	0.0479	-0.0075	-0.0273

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	10.0318
Shear X	-2.3675
Shear Z	0.1935
Moment X	0.6085
Moment Y (Twist)	0.2884
Moment Z	24.4824

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	6.0371
Shear X	-1.4150
Shear Z	0.1191
Moment X	0.3711
Moment Y (Twist)	0.1615
Moment Z	14.3232

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	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783
ULS: 2. D + L	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783
ULS: 3. D + (S or Lr or R)	-0.0259	6.8792	-0.0033	-0.0109	0.0070	0.2698
ULS: 3. D + (S or Lr or R)	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0211	5.6807	-0.0027	-0.0089	0.0057	0.2219
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783
ULS: 5b. D + 0.7E	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0211	5.6807	-0.0027	-0.0089	0.0057	0.2219
ULS: 8. 0.6D + 0.7E	-0.0040	1.2511	-0.0005	-0.0017	0.0011	0.0470
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.5908	3.6301	0.0117	0.0342	-0.0432	16.0499
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5786	0.5398	-0.0124	-0.0366	0.0435	-15.4356
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2091	6.8393	0.0068	0.0189	-0.0281	12.2007
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0211	5.6807	-0.0027	-0.0089	0.0057	0.2219
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1679	4.5216	-0.0113	-0.0342	0.0369	-11.4135
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0211	5.6807	-0.0027	-0.0089	0.0057	0.2219
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1948	3.2439	0.0086	0.0249	-0.0320	12.0570
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783

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 uplift Case A only	1.1822	0.9261	-0.0095	-0.0282	0.0331	-11.5572
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0067	2.0852	-0.0009	-0.0029	0.0019	0.0783
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.5881	2.7960	0.0121	0.0353	-0.0440	16.0186
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0040	1.2511	-0.0005	-0.0017	0.0011	0.0470
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5813	-0.2943	-0.0120	-0.0355	0.0428	-15.4670
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0040	1.2511	-0.0005	-0.0017	0.0011	0.0470

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	11.4587
Shear X	-2.6554
Shear Z	-0.0230
Moment X	-0.0683
Moment Y (Twist)	0.0794
Moment Z	27.6321

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	6.8792
Shear X	-1.5908
Shear Z	-0.0124
Moment X	-0.0366
Moment Y (Twist)	0.0440
Moment Z	16.0499

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	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 2. D + L	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 3. D + (S or Lr or R)	-0.0055	6.8497	0.0000	-0.0000	0.0000	0.1423
ULS: 3. D + (S or Lr or R)	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0044	5.6567	0.0000	-0.0000	0.0000	0.1180
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 5b. D + 0.7E	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0044	5.6567	0.0000	-0.0000	0.0000	0.1180
ULS: 8. 0.6D + 0.7E	-0.0008	1.2465	0.0000	0.0000	0.0000	0.0270
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.6001	3.6282	0.0000	0.0000	0.0000	16.2594
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5975	0.5272	0.0000	0.0000	0.0000	-15.6895
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2035	6.8197	0.0000	-0.0000	0.0000	12.2789
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0044	5.6567	0.0000	-0.0000	0.0000	0.1180
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1948	4.4939	0.0000	-0.0000	0.0000	-11.6828
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0044	5.6567	0.0000	-0.0000	0.0000	0.1180
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2004	3.2406	0.0000	0.0000	0.0000	12.2058
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1978	0.9148	0.0000	0.0000	0.0000	-11.7559
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0014	2.0776	0.0000	0.0000	0.0000	0.0449
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.5996	2.7972	0.0000	0.0000	0.0000	16.2415
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0008	1.2465	0.0000	0.0000	0.0000	0.0270
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5981	-0.3038	0.0000	0.0000	0.0000	-15.7075
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0008	1.2465	0.0000	0.0000	0.0000	0.0270

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	11.4220
Shear X	-2.6681
Shear Z	0.0000
Moment X	-0.0001
Moment Y (Twist)	0.0002
Moment Z	27.9888

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	6.8497
Shear X	-1.6001
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	16.2594

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	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 2. D + L	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 3. D + (S or Lr or R)	-0.0259	6.8792	0.0033	0.0108	-0.0069	0.2698
ULS: 3. D + (S or Lr or R)	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0211	5.6807	0.0027	0.0089	-0.0057	0.2219
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 5b. D + 0.7E	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0211	5.6807	0.0027	0.0089	-0.0057	0.2219
ULS: 8. 0.6D + 0.7E	-0.0040	1.2511	0.0005	0.0017	-0.0011	0.0470
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.5908	3.6301	-0.0117	-0.0342	0.0432	16.0499
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5786	0.5398	0.0124	0.0366	-0.0435	-15.4356
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2091	6.8393	-0.0068	-0.0189	0.0282	12.2007
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0211	5.6807	0.0027	0.0089	-0.0057	0.2219
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1679	4.5216	0.0113	0.0342	-0.0369	-11.4135
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0211	5.6807	0.0027	0.0089	-0.0057	0.2219
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1948	3.2439	-0.0086	-0.0249	0.0320	12.0570
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1822	0.9261	0.0095	0.0282	-0.0331	-11.5572
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0067	2.0852	0.0009	0.0029	-0.0019	0.0783
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.5881	2.7960	-0.0121	-0.0353	0.0440	16.0186
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0040	1.2511	0.0005	0.0017	-0.0011	0.0470
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5813	-0.2943	0.0120	0.0355	-0.0428	-15.4670
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0040	1.2511	0.0005	0.0017	-0.0011	0.0470

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	11.4587
Shear X	-2.6555
Shear Z	0.0230
Moment X	0.0685
Moment Y (Twist)	0.0792
Moment Z	27.6323

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	6.8792
Shear X	-1.5908
Shear Z	0.0124
Moment X	0.0366
Moment Y (Twist)	0.0440
Moment Z	16.0499

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	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 2. D + L	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 3. D + (S or Lr or R)	0.0286	6.0371	-0.0979	-0.3104	0.0494	-0.2159
ULS: 3. D + (S or Lr or R)	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0233	4.9944	-0.0797	-0.2528	0.0402	-0.1733
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 5b. D + 0.7E	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0233	4.9944	-0.0797	-0.2528	0.0402	-0.1733
ULS: 8. 0.6D + 0.7E	0.0045	1.1198	-0.0152	-0.0479	0.0075	-0.0273
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.4015	3.2084	-0.0777	-0.2378	0.1615	14.3050
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.4150	0.5248	0.0257	0.0731	-0.1322	-14.0045

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0334	6.0009	-0.1191	-0.3712	0.1519	10.5896
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0233	4.9944	-0.0797	-0.2528	0.0402	-0.1733
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0790	3.9882	-0.0415	-0.1380	-0.0683	-10.6426
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0233	4.9944	-0.0797	-0.2528	0.0402	-0.1733
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0492	2.8729	-0.0646	-0.1983	0.1242	10.7174
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0631	0.8602	0.0130	0.0349	-0.0960	-10.5148
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0074	1.8664	-0.0253	-0.0799	0.0125	-0.0454
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.4044	2.4618	-0.0676	-0.2058	0.1565	14.3232
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0045	1.1198	-0.0152	-0.0479	0.0075	-0.0273
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.4120	-0.2217	0.0358	0.1051	-0.1372	-13.9864
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0045	1.1198	-0.0152	-0.0479	0.0075	-0.0273

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	10.0318
Shear X	-2.3675
Shear Z	-0.1935
Moment X	-0.6089
Moment Y (Twist)	0.2884
Moment Z	24.4831

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	6.0371
Shear X	-1.4150
Shear Z	-0.1191
Moment X	-0.3712
Moment Y (Twist)	0.1615
Moment Z	14.3232

Project Details

Design Code: AISC 360-16 LRFD
Provision: LRFD
Country: United States

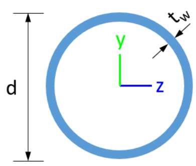
User Name: sales@mtsolar.us
Project Name: Table to Farm Compost - V3Jb
Unit System: imperial

Design Input Information

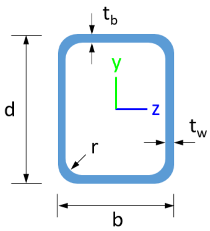
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

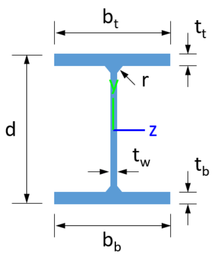
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
7	6in Pipe Sch 40	6.63	0.28					



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



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

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

2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	20.97	20.97	9.99	-	300	200	1
2	5	2.00	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.14,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.13,1.19,1.18,1.19,1.17,1.19	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.62,1.68,1.67,1.69,1.65,1.69,1.67,1.67,1.67,1.68,1.69,1.59,1.69,1.67,1.69,1.66,1.69	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.63,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.68,1.67,1.68,1.66,1.68	300	200	1
6	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.18,1.19	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
8	19	1.33	1.33	2.05	1.66,1.66,1.66,1.66,1.66,1.66,1.63,1.66,1.42,1.66,1.62,1.66,1.57,1.66,1.65,1.66,1.69,1.66,1.63,1.66,1.47,1.66,1.61,1.66,1.59,1.66	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.67,1.67,1.68,1.69,1.60,1.69,1.67,1.69,1.66,1.69	300	200	1
11	19	1.33	1.33	2.05	1.71,1.71,1.71,1.71,1.71,1.71,1.83,1.71,2.29,1.71,1.87,1.71,2.06,1.71,1.76,1.71,1.64,1.71,1.83,1.71,2.21,1.71,1.88,1.71,2.02,1.71	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.11,1.18,1.11,1.10,1.11,1.08,1.11,1.11,1.11,1.12,1.11,1.10,1.11,1.13,1.11,1.10,1.11,1.09,1.11	300	200	1
14	19	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.14,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.11,1.11	300	200	1
15	19	7.88	7.88	3.75	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	19	7.88	7.88	3.75	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	7	20.97	20.97	9.99	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.14,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.13,1.19,1.18,1.19,1.17,1.19	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.60,1.68,1.67,1.68,1.66,1.68	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.68,1.67,1.68,1.66,1.68	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.19,1.18,1.19,1.18,1.19	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
108	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.09,1.67,2.09,2.07,2.09,2.06,2.09,2.08,2.09,2.09,2.09,2.08,2.09,1.84,2.09,2.07,2.09,2.07,2.09	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.61,1.68,1.67,1.68,1.66,1.68	300	200	1
111	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.04,2.08,1.29,2.08,1.96,2.08,1.70,2.08,2.07,2.08,2.10,2.08,2.04,2.08,1.38,2.08,1.94,2.08,1.76,2.08	300	200	1
112	5	2.00	1.30	2.00	-	300	200	1

113	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,3.36,1.05,1.06,1.05,1.08,1.05,1.05,1.05,1.04,1.05,1.06,1.05,1.34,1.05,1.06,1.05,1.08,1.05	300	200	1
114	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.12,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.09,1.04,1.05,1.04,1.06,1.04	300	200	1
115	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.15,1.08,1.15,1.12,1.15,1.10,1.15,1.14,1.15,1.16,1.15,1.13,1.15,1.08,1.15,1.12,1.15,1.10,1.15	300	200	1
116	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.15,1.15	300	200	1
201	7	20.97	20.97	9.99	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.19,1.18,1.19,1.17,1.19	300	200	1
204	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.61,1.69,1.67,1.69,1.66,1.69	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.19,1.18,1.19,1.17,1.19	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
208	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.09,2.08,2.10,2.08,2.09,2.08,2.09,2.08,2.09,2.08,2.08,2.08,2.09,2.08,2.10,2.08,2.09,2.08,2.09,2.08	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.61,1.69,1.67,1.69,1.66,1.69	300	200	1
211	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.07,2.09,1.35,2.09,2.06,2.09,1.83,2.09,2.08,2.09,2.11,2.09,2.07,2.09,1.46,2.09,2.06,2.09,1.89,2.09	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.07,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.06,1.04,1.04,1.04,1.04,1.04	300	200	1
214	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04	300	200	1
215	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.10,1.16,1.15,1.16,1.13,1.16,1.15,1.16,1.17,1.16,1.15,1.16,1.11,1.16,1.14,1.16,1.14,1.16	300	200	1
216	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16,1.16	300	200	1
301	7	20.97	20.97	9.99	-	300	200	1
302	5	2.00	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.19,1.18,1.19,1.18,1.19	300	200	1
304	16	2.44	2.44	3.75	1.69,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.61,1.68,1.67,1.68,1.66,1.68	300	200	1
305	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.14,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.13,1.19,1.18,1.19,1.17,1.19	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.64,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.68,1.67,1.68,1.66,1.68	300	200	1
308	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,1.71,2.07,2.06,2.07,2.04,2.07,2.07,2.07,2.08,2.07,2.07,2.07,1.83,2.07,2.06,2.07,2.06,2.07	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.60,1.68,1.67,1.68,1.66,1.68	300	200	1
311	19	1.33	1.33	2.05	2.06,2.06,2.06,2.06,2.06,2.06,1.75,2.06,1.13,2.06,1.69,2.06,1.47,2.06,1.92,2.06,2.09,2.06,1.75,2.06,1.21,2.06,1.67,2.06,1.52,2.06	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,3.35,1.05,1.06,1.05,1.08,1.05,1.05,1.05,1.04,1.05,1.06,1.05,1.34,1.05,1.06,1.05,1.08,1.05	300	200	1
314	19	4.88	4.00	7.5	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.11,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.0	30	20	1

314	19	4.88	4.00	0	9,1.04,1.05,1.04,1.06,1.04	0	0	1
315	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.08,1.15,1.14,1.15,1.12,1.15,1.15,1.15,1.16,1.15,1.14,1.15,1.09,1.15,1.14,1.15,1.13,1.15	300	200	1
316	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.11,1.16,1.15,1.16,1.14,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.13,1.16,1.15,1.16,1.15,1.16	300	200	1
401	7	20.97	20.97	9.99	-	300	200	1
402	5	1.30	1.30	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.18,1.19	300	200	1
404	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.63,1.68,1.67,1.69,1.65,1.69,1.67,1.67,1.67,1.67,1.68,1.69,1.60,1.69,1.67,1.69,1.66,1.69	300	200	1
405	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.63,1.68,1.67,1.68,1.66,1.68	300	200	1
406	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.14,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.12,1.19,1.18,1.19,1.17,1.19	300	200	1
407	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.63,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.62,1.68,1.67,1.68,1.66,1.68	300	200	1
408	19	7.88	7.88	3.75	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	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.62,1.68,1.67,1.69,1.65,1.69,1.67,1.67,1.67,1.67,1.68,1.69,1.59,1.69,1.67,1.69,1.66,1.69	300	200	1
411	19	7.88	7.88	3.75	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	5	2.00	1.30	2.00	-	300	200	1
413	19	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.11,1.18,1.11,1.10,1.11,1.08,1.11,1.11,1.11,1.12,1.11,1.10,1.11,1.13,1.11,1.10,1.11,1.09,1.11	300	200	1
414	19	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.14,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.13,1.11,1.11,1.11,1.11,1.11	300	200	1
415	19	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.12,1.27,1.12,1.14,1.12,1.15,1.12,1.13,1.12,1.11,1.12,1.13,1.12,1.21,1.12,1.14,1.12,1.15,1.12	300	200	1
416	19	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.09,1.12,1.11,1.12,1.11,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.10,1.12,1.11,1.12,1.11,1.12	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	251.16	100.24	42.30	42.30	75.35	75.35
2	198.33	194.54	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	123.95	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	123.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	24.85	6.12	40.24	43.62
14	133.20	85.85	25.42	6.12	40.24	43.62
15	133.20	52.83	32.87	6.12	40.24	43.62
16	133.20	52.83	32.87	6.12	40.24	43.62
101	251.16	100.24	42.30	42.30	75.35	75.35
102	198.33	196.72	21.95	21.95	59.50	59.50

103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	123.95	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	123.95	32.87	6.12	40.24	43.62
112	198.33	194.54	21.95	21.95	59.50	59.50
113	133.20	85.85	23.83	6.12	40.24	43.62
114	133.20	85.85	23.83	6.12	40.24	43.62
115	133.20	69.16	16.76	6.12	40.24	43.62
116	133.20	69.16	17.52	6.12	40.24	43.62
201	251.16	100.24	42.30	42.30	75.35	75.35
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	123.95	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	123.95	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	23.73	6.12	40.24	43.62
214	133.20	85.85	23.74	6.12	40.24	43.62
215	133.20	69.16	16.96	6.12	40.24	43.62
216	133.20	69.16	17.88	6.12	40.24	43.62
301	251.16	100.24	42.30	42.30	75.35	75.35
302	198.33	194.54	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	123.95	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	123.95	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	85.85	23.83	6.12	40.24	43.62
314	133.20	85.85	23.83	6.12	40.24	43.62
315	133.20	69.16	16.71	6.12	40.24	43.62
316	133.20	69.16	17.25	6.12	40.24	43.62
401	251.16	100.24	42.30	42.30	75.35	75.35
402	198.33	196.72	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28

407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	52.83	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	52.83	32.87	6.12	40.24	43.62
412	198.33	194.54	21.95	21.95	59.50	59.50
413	133.20	85.85	24.84	6.12	40.24	43.62
414	133.20	85.85	25.43	6.12	40.24	43.62
415	133.20	69.16	17.24	6.12	40.24	43.62
416	133.20	69.16	16.93	6.12	40.24	43.62

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	0.100	0.579	0.031	0.031	0.003	0.623	#13	0.560	Not Required	Pass
2	0.004	0.307	0.113	0.075	0.020	0.406	#21	0.054	Not Required	Pass
3	0.012	0.428	0.056	0.042	0.004	0.490	#21	0.045	Not Required	Pass
4	0.011	0.425	0.182	0.043	0.039	0.557	#21	0.080	Not Required	Pass
5	0.012	0.265	0.180	0.042	0.045	0.310	#21	0.074	Not Required	Pass
6	0.015	0.481	0.110	0.048	0.022	0.598	#21	0.045	Not Required	Pass
7	0.015	0.299	0.253	0.047	0.064	0.364	#21	0.074	Not Required	Pass
8	0.002	0.061	0.218	0.032	0.025	0.223	#23	0.095	Not Required	Pass
9	0.017	0.036	0.067	0.002	0.002	0.087	#21	0.204	Not Required	Pass
10	0.016	0.467	0.241	0.047	0.052	0.627	#21	0.080	Not Required	Pass
11	0.003	0.057	0.224	0.033	0.025	0.228	#23	0.095	Not Required	Pass
12	0.003	0.367	0.127	0.090	0.023	0.475	#21	0.035	Not Required	Pass
13	0.008	0.145	0.577	0.042	0.032	0.681	#21	0.286	Not Required	Pass
14	0.011	0.143	0.569	0.041	0.032	0.661	#21	0.190	Not Required	Pass
15	0.000	0.046	0.202	0.020	0.015	0.248	#21	Not Required	Not Required	Pass
16	0.000	0.046	0.202	0.020	0.015	0.248	#21	Not Required	Not Required	Pass
101	0.114	0.653	0.004	0.035	0.000	0.692	#13	0.560	Not Required	Pass
102	0.004	0.385	0.135	0.094	0.022	0.505	#21	0.035	Not Required	Pass
103	0.015	0.517	0.093	0.051	0.014	0.618	#21	0.045	Not Required	Pass
104	0.015	0.520	0.244	0.052	0.052	0.692	#21	0.080	Not Required	Pass
105	0.015	0.321	0.254	0.051	0.064	0.387	#21	0.074	Not Required	Pass
106	0.015	0.523	0.093	0.052	0.014	0.622	#21	0.045	Not Required	Pass
107	0.015	0.325	0.249	0.052	0.063	0.391	#21	0.074	Not Required	Pass
108	0.003	0.041	0.217	0.033	0.025	0.243	#21	0.095	Not Required	Pass
109	0.020	0.029	0.050	0.001	0.000	0.087	#21	0.204	Not Required	Pass
110	0.015	0.519	0.240	0.052	0.051	0.686	#21	0.080	Not Required	Pass
111	0.004	0.045	0.223	0.033	0.025	0.246	#21	0.095	Not Required	Pass
112	0.004	0.387	0.139	0.094	0.023	0.509	#21	0.054	Not Required	Pass
113	0.008	0.155	0.586	0.043	0.032	0.722	#21	0.286	Not Required	Pass
114	0.012	0.167	0.580	0.044	0.032	0.728	#21	0.286	Not Required	Pass
115	0.006	0.204	0.320	0.033	0.025	0.528	#21	0.473	Not Required	Pass
116	0.002	0.201	0.320	0.034	0.025	0.522	#21	0.473	Not Required	Pass
201	0.114	0.662	0.000	0.035	0.000	0.699	#13	0.560	Not Required	Pass
202	0.004	0.385	0.138	0.094	0.022	0.505	#21	0.035	Not Required	Pass
203	0.015	0.521	0.093	0.052	0.014	0.622	#21	0.045	Not Required	Pass
204	0.015	0.514	0.239	0.051	0.051	0.683	#21	0.080	Not Required	Pass
205	0.015	0.324	0.248	0.051	0.062	0.389	#21	0.074	Not Required	Pass

205	0.015	0.324	0.248	0.051	0.062	0.389	#21	0.074	Not Required	Pass
206	0.015	0.521	0.093	0.052	0.014	0.622	#21	0.045	Not Required	Pass
207	0.015	0.324	0.249	0.051	0.062	0.389	#21	0.074	Not Required	Pass
208	0.003	0.041	0.217	0.033	0.025	0.246	#21	0.095	Not Required	Pass
209	0.019	0.027	0.050	0.001	0.000	0.087	#21	0.204	Not Required	Pass
210	0.015	0.514	0.239	0.051	0.051	0.683	#21	0.080	Not Required	Pass
211	0.004	0.043	0.222	0.033	0.025	0.250	#21	0.095	Not Required	Pass
212	0.004	0.385	0.138	0.094	0.022	0.505	#21	0.035	Not Required	Pass
213	0.008	0.163	0.575	0.043	0.032	0.726	#21	0.286	Not Required	Pass
214	0.012	0.168	0.568	0.042	0.032	0.720	#21	0.286	Not Required	Pass
215	0.006	0.181	0.320	0.033	0.025	0.504	#21	0.473	Not Required	Pass
216	0.003	0.175	0.319	0.033	0.025	0.495	#21	0.473	Not Required	Pass
301	0.114	0.653	0.004	0.035	0.000	0.692	#13	0.560	Not Required	Pass
302	0.004	0.387	0.139	0.094	0.023	0.509	#21	0.054	Not Required	Pass
303	0.015	0.523	0.093	0.052	0.014	0.622	#21	0.045	Not Required	Pass
304	0.015	0.519	0.240	0.052	0.051	0.686	#21	0.080	Not Required	Pass
305	0.015	0.325	0.249	0.052	0.063	0.391	#21	0.074	Not Required	Pass
306	0.015	0.517	0.093	0.051	0.014	0.618	#21	0.045	Not Required	Pass
307	0.015	0.321	0.254	0.051	0.064	0.387	#21	0.074	Not Required	Pass
308	0.002	0.048	0.226	0.034	0.025	0.251	#21	0.095	Not Required	Pass
309	0.020	0.029	0.050	0.001	0.000	0.087	#21	0.204	Not Required	Pass
310	0.015	0.520	0.244	0.052	0.052	0.692	#21	0.080	Not Required	Pass
311	0.003	0.054	0.231	0.033	0.025	0.249	#21	0.095	Not Required	Pass
312	0.004	0.385	0.135	0.094	0.022	0.505	#21	0.035	Not Required	Pass
313	0.008	0.155	0.587	0.043	0.032	0.722	#21	0.286	Not Required	Pass
314	0.012	0.167	0.580	0.044	0.032	0.728	#21	0.286	Not Required	Pass
315	0.006	0.181	0.320	0.033	0.025	0.505	#21	0.473	Not Required	Pass
316	0.003	0.175	0.319	0.033	0.025	0.495	#21	0.473	Not Required	Pass
401	0.100	0.579	0.031	0.031	0.003	0.623	#13	0.560	Not Required	Pass
402	0.003	0.367	0.127	0.090	0.023	0.475	#21	0.035	Not Required	Pass
403	0.015	0.481	0.110	0.048	0.022	0.598	#21	0.045	Not Required	Pass
404	0.016	0.467	0.241	0.047	0.052	0.627	#21	0.080	Not Required	Pass
405	0.015	0.299	0.253	0.047	0.064	0.364	#21	0.074	Not Required	Pass
406	0.012	0.428	0.056	0.042	0.004	0.490	#21	0.045	Not Required	Pass
407	0.012	0.265	0.180	0.042	0.045	0.310	#21	0.074	Not Required	Pass
408	0.000	0.046	0.202	0.020	0.015	0.248	#21	Not Required	Not Required	Pass
409	0.017	0.036	0.067	0.002	0.002	0.087	#21	0.204	Not Required	Pass
410	0.011	0.425	0.182	0.043	0.039	0.557	#21	0.080	Not Required	Pass
411	0.000	0.046	0.202	0.020	0.015	0.248	#21	Not Required	Not Required	Pass
412	0.004	0.307	0.113	0.075	0.020	0.406	#21	0.054	Not Required	Pass
413	0.008	0.145	0.577	0.042	0.032	0.681	#21	0.190	Not Required	Pass
414	0.011	0.143	0.569	0.041	0.032	0.661	#21	0.286	Not Required	Pass
415	0.006	0.208	0.320	0.033	0.025	0.529	#21	0.473	Not Required	Pass
416	0.002	0.206	0.319	0.032	0.025	0.526	#21	0.473	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

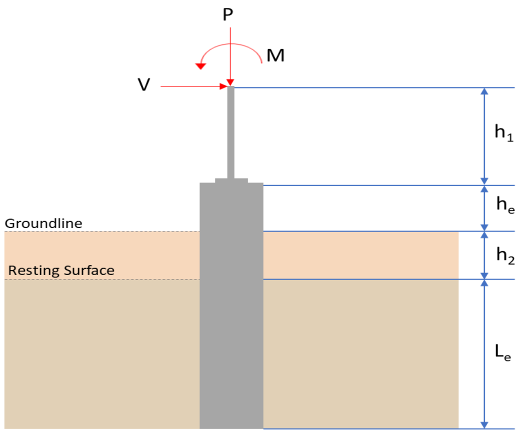
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 5.25$ 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)	6.037	10.032
V_x (kip)	-1.415	-2.367
V_z (kip)	0.119	0.193
M_x (kipft)	0.371	0.608
M_z (kipft)	14.323	24.482

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,

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

$$H_o = \frac{(-1.415\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.22532\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(14.323\text{ kipft}) + ((-1.415\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 2.2807\text{ kipft/ft}$$

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:
$L_{e,x} = 4.8832\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.119\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.018949\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.371\text{ kipft}) + ((0.119\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.059076\text{ kipft/ft}$$

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:
$L_{e,z} = 1.9029\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.8832\text{ ft}), (1.9029\text{ ft})]$$

$$L_{e,req} = 4.883\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.25\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 5.25\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.883\text{ ft})}{(5.25\text{ ft})}$$

$$Ratio = 0.9301$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.037 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.37731 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.37731 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.18866$$

Status: **PASS**
Ratio: **0.190**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.3125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.22532 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 2.2807 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.2807 \text{ kipft/ft}) \times (5.25 \text{ ft})) + \left(3 \times (-0.22532 \text{ kip/ft}) \times (5.25 \text{ ft})^2\right)}{(6 \times (2.2807 \text{ kipft/ft})) + (4 \times (-0.22532 \text{ kip/ft}) \times (5.25 \text{ ft}))}$$

$$a = 3.6124 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.2807 \text{ kipft/ft})) + (3 \times (-0.22532 \text{ kip/ft}) \times (5.25 \text{ ft}))]^2}{(5.25 \text{ ft})^2 \times [(3 \times (2.2807 \text{ kipft/ft})) + (2 \times (-0.22532 \text{ kip/ft}) \times (5.25 \text{ ft}))]}$$

$$p = 0.18888 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.2807 \text{ kipft/ft})) + ((-0.22532 \text{ kip/ft}) \times (5.25 \text{ ft}))]}{(5.25 \text{ ft})^2}$$

$$s = 0.73547 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.6124 \text{ ft})}{2}$$

$$p_a = 0.27093 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18888\ \mathrm{kip/ft^2}\right)}{\left(0.27093\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.69714$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.25\ \mathrm{ft})$$

$$p_s = 0.7875\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.73547\ \mathrm{kip/ft^2}\right)}{\left(0.7875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93392$$

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

Considering z-direction:

$H_o = 0.018949\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.059076\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.059076\ \mathrm{kipft/ft}) \times (5.25\ \mathrm{ft})) + \left(3 \times (0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft})^2\right)}{(6 \times (0.059076\ \mathrm{kipft/ft})) + (4 \times (0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))}$$

$$a = 3.7314\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.059076\ \mathrm{kipft/ft})) + (3 \times (0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))]^{\ 2}}{(5.25\ \mathrm{ft})^2 \times [(3 \times (0.059076\ \mathrm{kipft/ft})) + (2 \times (0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))]}$$

$$p = 0.020684\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.059076\ \mathrm{kipft/ft})) + ((0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))]}{(5.25\ \mathrm{ft})^2}$$

$$s = 0.047376\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.7314\ \mathrm{ft})}{2}$$

$$p_a = 0.27985\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.020684\ \mathrm{kip/ft^2}\right)}{\left(0.27985\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.07391$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.25\ \mathrm{ft})$$

$$p_s = 0.7875\ \mathrm{kip/ft^2}$$

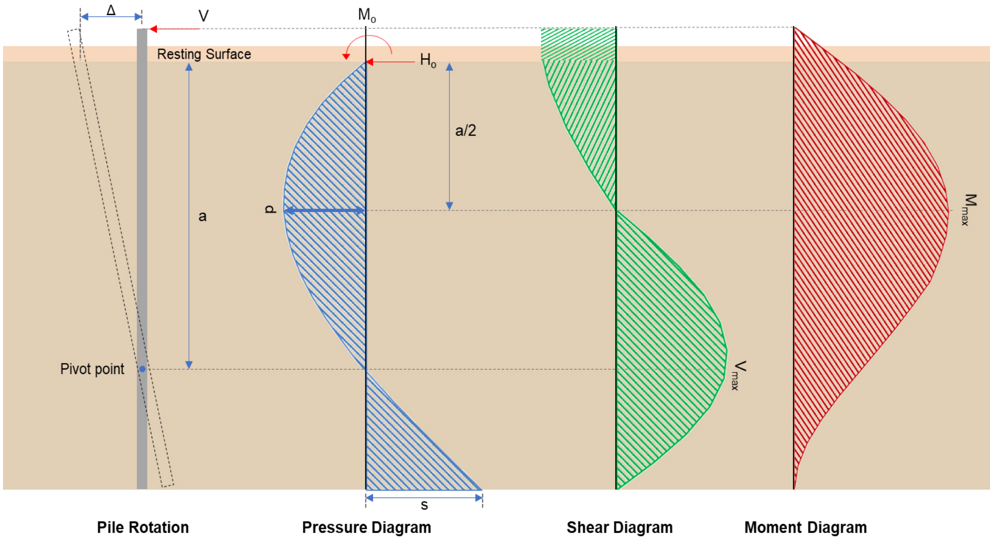
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.047376\ \mathrm{kip/ft^2})}{(0.7875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.060161$$

Status: **PASS**
Ratio: **0.060**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.367\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.37691\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(24.482\ \mathrm{kipft}) + ((-2.367\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 3.8984\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.8984\ \mathrm{kipft/ft})}{(-0.37691\ \mathrm{kip/ft})}$$

$$E = 10.343\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.8984\ \mathrm{kipft/ft}) \times (5.25\ \mathrm{ft})) + \left(3 \times (-0.37691\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (3.8984\ \text{kipft/ft})) + (4 \times (-0.37691\ \text{kip/ft}) \times (5.25\ \text{ft}))}$$

$$a = 3.6106\ \text{ft}$$

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

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

$$V_{max} = ((-0.37691\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.343\ \text{ft})}{(5.25\ \text{ft})} + 3\right) \times \left(\frac{(3.6106\ \text{ft})}{(5.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.343\ \text{ft})}{(5.25\ \text{ft})} + 2\right) \times \left(\frac{(3.6106\ \text{ft})}{(5.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.251\ \text{kip}$$

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

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

$$M_{max} = ((-0.37691\ \text{kip/ft}) \times (48\ \text{in}) \times (5.25\ \text{ft})) \times \left[\left(\frac{(10.343\ \text{ft})}{(5.25\ \text{ft})} + \frac{(3.6106\ \text{ft})}{2 \times (5.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (10.343\ \text{ft})}{(5.25\ \text{ft})} + 3\right) \times \left(\frac{(3.6106\ \text{ft})}{2 \times (5.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.343\ \text{ft})}{(5.25\ \text{ft})} + 2\right) \times \left(\frac{(3.6106\ \text{ft})}{2 \times (5.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 15.689\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.193\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.030732\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.608\ \text{kipft}) + ((0.193\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.096815\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.096815\ \text{kipft/ft})}{(0.030732\ \text{kip/ft})}$$

$$E = 3.1503\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.096815\ \text{kipft/ft}) \times (5.25\ \text{ft})) + \left(3 \times (0.030732\ \text{kip/ft}) \times (5.25\ \text{ft})^2\right)}{(6 \times (0.096815\ \text{kipft/ft})) + (4 \times (0.030732\ \text{kip/ft}) \times (5.25\ \text{ft}))}$$

$$a = 3.7303\ \text{ft}$$

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

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

$$V_{max} = ((0.030732\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.1503\ \text{ft})}{(5.25\ \text{ft})} + 3\right) \times \left(\frac{(3.7303\ \text{ft})}{(5.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.1503\ \text{ft})}{(5.25\ \text{ft})} + 2\right) \times \left(\frac{(3.7303\ \text{ft})}{(5.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.21221\ \text{kip}$$

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

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

$$M_{max} = ((0.030732\ \text{kip/ft}) \times (48\ \text{in}) \times (5.25\ \text{ft})) \times \left[\left(\frac{(3.1503\ \text{ft})}{(5.25\ \text{ft})} + \frac{(3.7303\ \text{ft})}{2 \times (5.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.1503\ \text{ft})}{(5.25\ \text{ft})} + 3\right) \times \left(\frac{(3.7303\ \text{ft})}{2 \times (5.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.1503\ \text{ft})}{(5.25\ \text{ft})} + 2\right) \times \left(\frac{(3.7303\ \text{ft})}{2 \times (5.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.49934\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.032\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.263\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\,[(-84.263\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

	$$Ratio = 0.96556$$	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 $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[(2304\ \text{in}^2) - (4.2951\ \text{in}^2)\right]\right) + \left((60\ \text{ksi}) \times (4.2951\ \text{in}^2)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(10.032\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.00375$$	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:** $b_w = 48\ \text{in}$ - 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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 10.032\ \text{kip} \rightarrow 10032\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(10032\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.82\ \text{kip}$$

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.82\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.82\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.82\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 110.97\ \text{kip}$$

Considering x-direction:

$V_{max} = 6.251\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.251\ \text{kip})}{(110.97\ \text{kip})}$$

$$Ratio = 0.056333$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.21221\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.21221\ \text{kip})}{(110.97\ \text{kip})}$$

$$Ratio = 0.0019124$$

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:

$M_{max} = 15.689\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.689\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.062857$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$M_{max} = 0.49934\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.49934 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0020006$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

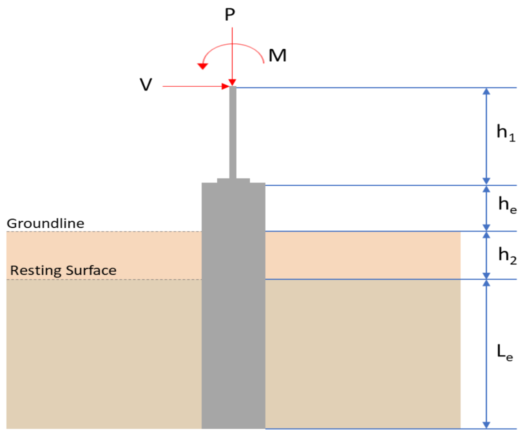
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48\ \text{in}$ - Pile width

$D = 48\ \text{in}$ - Pile depth

$L = 5.25\ \text{ft}$ - 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)	6.037	10.032
V_x (kip)	-1.415	-2.367
V_z (kip)	-0.119	-0.193
M_x (kipft)	-0.371	-0.609
M_z (kipft)	14.323	24.483

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,

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

$$H_o = \frac{(-1.415\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.22532\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(14.323 \text{ kipft}) + ((-1.415 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.2807 \text{ kipft/ft}$$

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:
$L_{e,x} = 4.8832 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.119 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.018949 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.371 \text{ kipft}) + ((-0.119 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.059076 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.4539 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.8832 \text{ ft}), (1.4539 \text{ ft})]$$

$$L_{e,req} = 4.883 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.25 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.883 \text{ ft})}{(5.25 \text{ ft})}$$

$$Ratio = 0.9301$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.037\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.37731\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.37731\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.18866$$

Status: **PASS**
Ratio: **0.190**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.3125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.22532\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.2807\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.2807\ \text{kipft/ft}) \times (5.25\ \text{ft})) + \left(3 \times (-0.22532\ \text{kip/ft}) \times (5.25\ \text{ft})^2\right)}{(6 \times (2.2807\ \text{kipft/ft})) + (4 \times (-0.22532\ \text{kip/ft}) \times (5.25\ \text{ft}))}$$

$$a = 3.6124\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.2807\ \text{kipft/ft})) + (3 \times (-0.22532\ \text{kip/ft}) \times (5.25\ \text{ft}))]^2}{(5.25\ \text{ft})^2 \times [(3 \times (2.2807\ \text{kipft/ft})) + (2 \times (-0.22532\ \text{kip/ft}) \times (5.25\ \text{ft}))]}$$

$$p = 0.18888\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.2807\ \text{kipft/ft})) + ((-0.22532\ \text{kip/ft}) \times (5.25\ \text{ft}))]}{(5.25\ \text{ft})^2}$$

$$s = 0.73547\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.6124\ \text{ft})}{2}$$

$$p_a = 0.27093\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.18888\ \mathrm{kip/ft^2}\right)}{\left(0.27093\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.69714$$	Status: **PASS** Ratio: **0.700**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (5.25\ \mathrm{ft})$$ $$p_s = 0.7875\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(0.73547\ \mathrm{kip/ft^2}\right)}{\left(0.7875\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.93392$$	Status: **PASS** Ratio: **0.930**
	Considering z-direction: $H_o = -0.018949\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.059076\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.059076\ \mathrm{kipft/ft}) \times (5.25\ \mathrm{ft})) + \left(3 \times (-0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft})^2\right)}{(6 \times (0.059076\ \mathrm{kipft/ft})) + (4 \times (-0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))}$$ $$a = 3.7314\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.059076\ \mathrm{kipft/ft})) + (3 \times (-0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))]^{\,2}}{(5.25\ \mathrm{ft})^2 \times [(3 \times (0.059076\ \mathrm{kipft/ft})) + (2 \times (-0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))]}$$ $$p = -0.0048343\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.059076\ \mathrm{kipft/ft})) + ((-0.018949\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft}))]}{(5.25\ \mathrm{ft})^2}$$ $$s = 0.0040643\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.7314\ \mathrm{ft})}{2}$$ $$p_a = 0.27985\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.0048343\ \mathrm{kip/ft^2}\right)}{\left(0.27985\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = -0.017274$$

Status: **PASS**
Ratio: **-0.020**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.25\ \mathrm{ft})$$

$$p_s = 0.7875\ \mathrm{kip/ft^2}$$

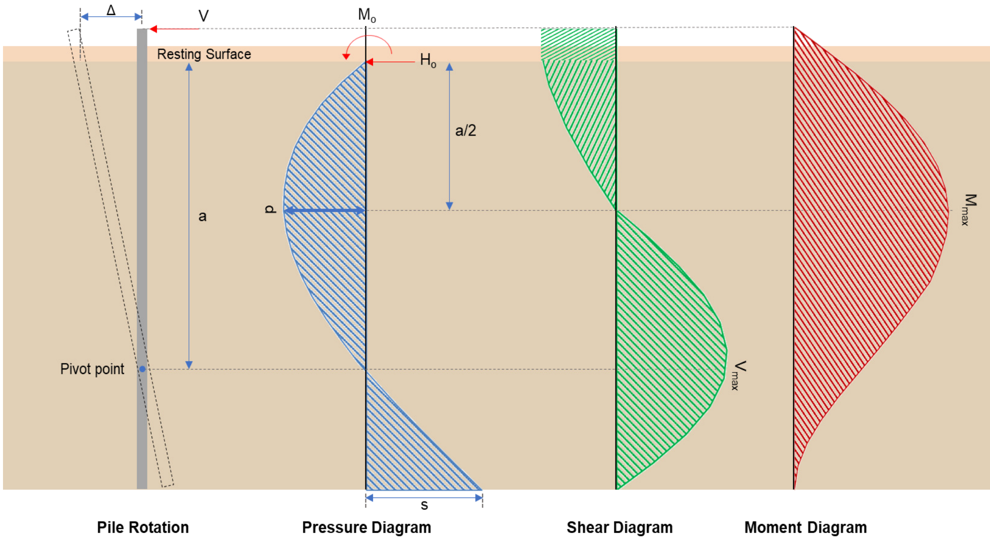
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0040643\ \mathrm{kip/ft^2})}{(0.7875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.005161$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.367\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.37691\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(24.483\ \mathrm{kipft}) + ((-2.367\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 3.8986\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.8986\ \mathrm{kipft/ft})}{(-0.37691\ \mathrm{kip/ft})}$$

$$E = 10.343\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.8986\ \mathrm{kipft/ft}) \times (5.25\ \mathrm{ft})) + \left(3 \times (-0.37691\ \mathrm{kip/ft}) \times (5.25\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (3.8986 \text{ kipft/ft})) + (4 \times (-0.37691 \text{ kip/ft}) \times (5.25 \text{ ft}))}$$

$$a = 3.6106 \text{ ft}$$

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

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

$$V_{max} = ((-0.37691 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.343 \text{ ft})}{(5.25 \text{ ft})} + 3\right) \times \left(\frac{(3.6106 \text{ ft})}{(5.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.343 \text{ ft})}{(5.25 \text{ ft})} + 2\right) \times \left(\frac{(3.6106 \text{ ft})}{(5.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 6.2513 \text{ kip}$$

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

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

$$M_{max} = ((-0.37691 \text{ kip/ft}) \times (48 \text{ in}) \times (5.25 \text{ ft})) \times \left[\left(\frac{(10.343 \text{ ft})}{(5.25 \text{ ft})} + \frac{(3.6106 \text{ ft})}{2 \times (5.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (10.343 \text{ ft})}{(5.25 \text{ ft})} + 3\right) \times \left(\frac{(3.6106 \text{ ft})}{2 \times (5.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.343 \text{ ft})}{(5.25 \text{ ft})} + 2\right) \times \left(\frac{(3.6106 \text{ ft})}{2 \times (5.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 15.69 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.193 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.030732 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.609 \text{ kipft}) + ((-0.193 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.096975 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.096975 \text{ kipft/ft})}{(-0.030732 \text{ kip/ft})}$$

$$E = 3.1554 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.096975 \text{ kipft/ft}) \times (5.25 \text{ ft})) + \left(3 \times (-0.030732 \text{ kip/ft}) \times (5.25 \text{ ft})^2\right)}{(6 \times (0.096975 \text{ kipft/ft})) + (4 \times (-0.030732 \text{ kip/ft}) \times (5.25 \text{ ft}))}$$

$$a = 3.7301 \text{ ft}$$

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

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

$$V_{max} = ((-0.030732\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.1554\ \text{ft})}{(5.25\ \text{ft})} + 3\right) \times \left(\frac{(3.7301\ \text{ft})}{(5.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.1554\ \text{ft})}{(5.25\ \text{ft})} + 2\right) \times \left(\frac{(3.7301\ \text{ft})}{(5.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.21242\ \text{kip}$$

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

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

$$M_{max} = ((-0.030732\ \text{kip/ft}) \times (48\ \text{in}) \times (5.25\ \text{ft})) \times \left[\left(\frac{(3.1554\ \text{ft})}{(5.25\ \text{ft})} + \frac{(3.7301\ \text{ft})}{2 \times (5.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.1554\ \text{ft})}{(5.25\ \text{ft})} + 3\right) \times \left(\frac{(3.7301\ \text{ft})}{2 \times (5.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.1554\ \text{ft})}{(5.25\ \text{ft})} + 2\right) \times \left(\frac{(3.7301\ \text{ft})}{2 \times (5.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.4999\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.032\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.263\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.263\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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**	
	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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(10.032\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.00375$$	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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,$P = 10.032 \text{ kip} \rightarrow 10032 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(10032 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.82 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.82 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.82 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.82 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.97 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.2513 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.2513 \text{ kip})}{(110.97 \text{ kip})}$$

$$Ratio = 0.056335$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.21242 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.21242 \text{ kip})}{(110.97 \text{ kip})}$$

$$Ratio = 0.0019143$$

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:
$\phi M_{n,1}$

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

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

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

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:

$M_{max} = 15.69 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.69 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.062859$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$M_{max} = 0.4999 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.4999\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0020028$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

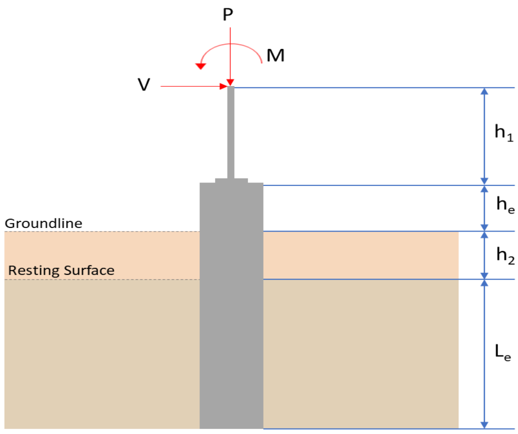
SkyCiv Foundation Design

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
$L = 5.5$ 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)	6.879	11.459
V_x (kip)	-1.591	-2.655
V_z (kip)	-0.012	-0.023
M_x (kipft)	-0.037	-0.068
M_z (kipft)	16.050	27.632

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,

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

$$H_o = \frac{(-1.591 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.25334 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.05\ \text{kipft}) + ((-1.591\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 2.5557\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.0381\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.037\ \text{kipft}) + ((-0.012\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0058917\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.72914\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.0381\ \text{ft}), (0.72914\ \text{ft})]$$

$$L_{e,req} = 5.038\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.038\ \text{ft})}{(5.5\ \text{ft})}$$

$$Ratio = 0.916$$

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

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

$$q = \frac{(6.879\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.42994\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.42994\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.21497$$

Status: **PASS**
Ratio: **0.210**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.25334\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.5557\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.5557\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (-0.25334\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (2.5557\ \text{kipft/ft})) + (4 \times (-0.25334\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.7888\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.5557\ \text{kipft/ft})) + (3 \times (-0.25334\ \text{kip/ft}) \times (5.5\ \text{ft}))]^2}{(5.5\ \text{ft})^2 \times [(3 \times (2.5557\ \text{kipft/ft})) + (2 \times (-0.25334\ \text{kip/ft}) \times (5.5\ \text{ft}))]}$$

$$p = 0.1855\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.5557\ \text{kipft/ft})) + ((-0.25334\ \text{kip/ft}) \times (5.5\ \text{ft}))]}{(5.5\ \text{ft})^2}$$

$$s = 0.73747\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.7888\ \text{ft})}{2}$$

$$p_a = 0.28416\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.1855\ \mathrm{kip/ft^2}\right)}{\left(0.28416\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.6528$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.73747\ \mathrm{kip/ft^2}\right)}{\left(0.825\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.8939$$

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

Considering z-direction:

$H_o = -0.0019108\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0058917\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0058917\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.0019108\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{(6 \times (0.0058917\ \mathrm{kipft/ft})) + (4 \times (-0.0019108\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.9156\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0058917\ \mathrm{kipft/ft})) + (3 \times (-0.0019108\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]^{\ 2}}{(5.5\ \mathrm{ft})^2 \times [(3 \times (0.0058917\ \mathrm{kipft/ft})) + (2 \times (-0.0019108\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}$$

$$p = -0.00047\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0058917\ \mathrm{kipft/ft})) + ((-0.0019108\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}{(5.5\ \mathrm{ft})^2}$$

$$s = 0.00025267\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.9156\ \mathrm{ft})}{2}$$

$$p_a = 0.29367\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00047\ \mathrm{kip/ft^2}\right)}{\left(0.29367\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0016004$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

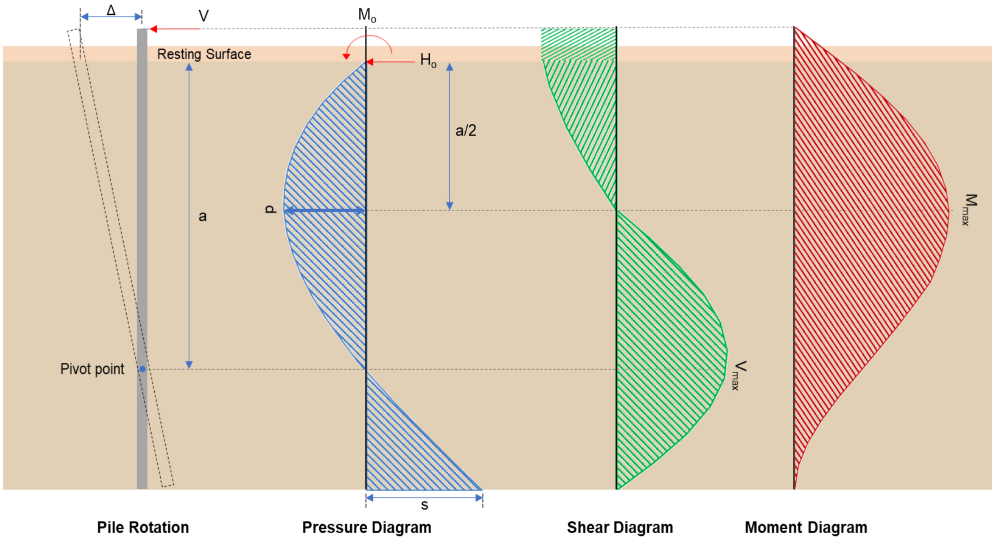
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00025267\ \mathrm{kip/ft^2})}{(0.825\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.00030627$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.655\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.42277\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.632\ \mathrm{kipft}) + ((-2.655\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 4.4\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.4\ \mathrm{kipft/ft})}{(-0.42277\ \mathrm{kip/ft})}$$

$$E = 10.408\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.4\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.42277\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (4.4\ \text{kipft/ft})) + (4 \times (-0.42277\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.7861\ \text{ft}$$

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

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

$$V_{max} = ((-0.42277\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.408\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.7861\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.408\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.7861\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.7784\ \text{kip}$$

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

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

$$M_{max} = ((-0.42277\ \text{kip/ft}) \times (48\ \text{in}) \times (5.5\ \text{ft})) \times \left[\left(\frac{(10.408\ \text{ft})}{(5.5\ \text{ft})} + \frac{(3.7861\ \text{ft})}{2 \times (5.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (10.408\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.7861\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.408\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.7861\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 17.795\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.023\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0036624\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.068\ \text{kipft}) + ((-0.023\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.010828\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.010828\ \text{kipft/ft})}{(-0.0036624\ \text{kip/ft})}$$

$$E = 2.9565\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.010828\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (-0.0036624\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (0.010828\ \text{kipft/ft})) + (4 \times (-0.0036624\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.9204\ \text{ft}$$

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

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

$$V_{max} = ((-0.0036624\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.9565\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.9204\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.9565\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.9204\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.023685\ \text{kip}$$

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

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

$$M_{max} = ((-0.0036624\ \text{kip/ft}) \times (48\ \text{in}) \times (5.5\ \text{ft})) \times \left[\left(\frac{(2.9565\ \text{ft})}{(5.5\ \text{ft})} + \frac{(3.9204\ \text{ft})}{2 \times (5.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.9565\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.9204\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.9565\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.9204\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.057939\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.459\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.215\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.215\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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 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

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

$$Ratio = \frac{(11.459\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0042834$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.459 \text{ kip} \rightarrow 11459 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11459 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.01 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.01 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.01 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.01 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.09 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.7784 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.7784\ \text{kip})}{(111.09\ \text{kip})}$$

$$Ratio = 0.061017$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.023685\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.023685\ \text{kip})}{(111.09\ \text{kip})}$$

$$Ratio = 0.0002132$$

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:

$M_{max} = 17.795\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(17.795\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.071294$$

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

Considering z-direction:

$M_{max} = 0.057939\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.057939\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.00023213$$		Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

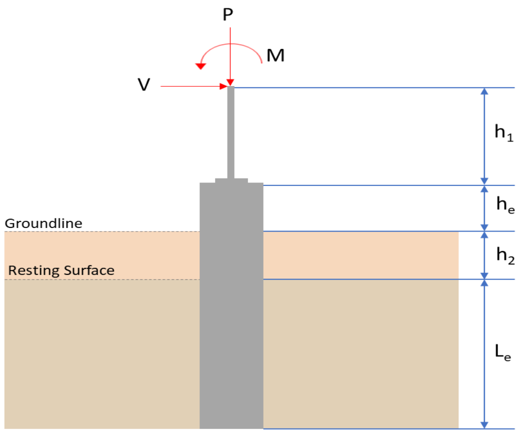
SkyCiv Foundation Design

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
$L = 5.5$ 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)	6.850	11.422
V_x (kip)	-1.600	-2.668
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	16.259	27.989

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,

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

$$H_o = \frac{(-1.6 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.25478 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.259 \text{ kipft}) + ((-1.6 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.589 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.0623 \text{ ft}$ - 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,

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

$$L_{e,req} = MAX[(5.0623 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 5.062 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.062 \text{ ft})}{(5.5 \text{ ft})}$$

$$Ratio = 0.92036$$

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

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

$$q = \frac{(6.85 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.42812 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.42812 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.21406$$

Status: **PASS**
Ratio: **0.210**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.25478\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.589\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.589\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.25478\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{(6 \times (2.589\ \mathrm{kipft/ft})) + (4 \times (-0.25478\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.7882\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.589\ \mathrm{kipft/ft})) + (3 \times (-0.25478\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]^2}{(5.5\ \mathrm{ft})^2 \times [(3 \times (2.589\ \mathrm{kipft/ft})) + (2 \times (-0.25478\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}$$

$$p = 0.18903\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.589\ \mathrm{kipft/ft})) + ((-0.25478\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}{(5.5\ \mathrm{ft})^2}$$

$$s = 0.74911\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.7882\ \mathrm{ft})}{2}$$

$$p_a = 0.28411\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18903\ \mathrm{kip/ft^2}\right)}{\left(0.28411\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.66532$$

Status: **PASS**
Ratio: **0.670**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

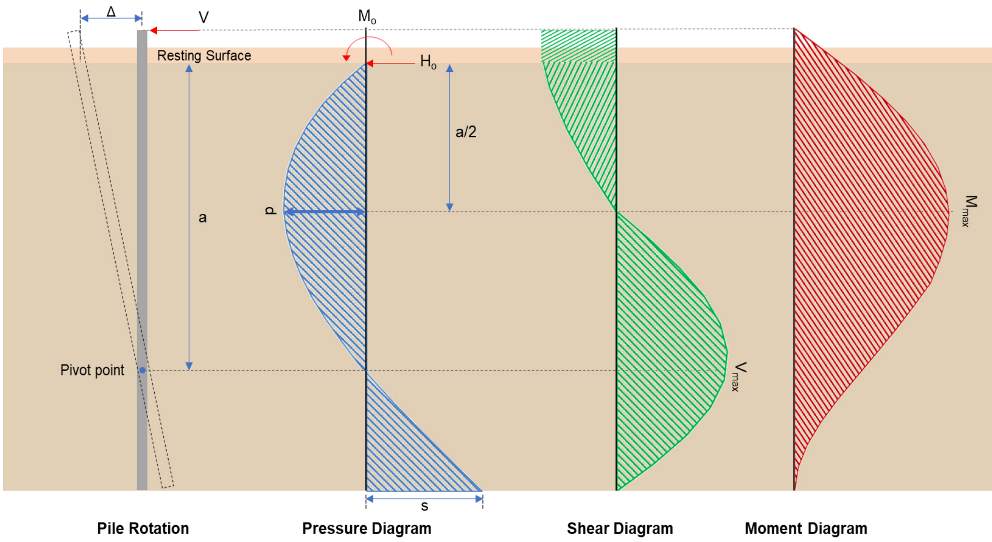
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.74911\ \mathrm{kip/ft^2}\right)}{\left(0.825\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90801$$

Status: PASS
Ratio: 0.910



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.668\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.42484\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.989\ \text{kipft}) + ((-2.668\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.4568\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.4568\ \text{kipft/ft})}{(-0.42484\ \text{kip/ft})}$$

$$E = 10.491\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.4568\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (-0.42484\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (4.4568\ \text{kipft/ft})) + (4 \times (-0.42484\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.7854\ \text{ft}$$

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

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

$$V_{max} = ((-0.42484\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.491\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.7854\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.491\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.7854\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 6.8571\ \text{kip}$$

$$V_{max} = 0.6571 \text{ kip}$$

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

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

$$M_{max} = ((-0.42484 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(10.491 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7854 \text{ ft})}{2 \times (5.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (10.491 \text{ ft})}{(5.5 \text{ ft})} + 3\right) \times \left(\frac{(3.7854 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.491 \text{ ft})}{(5.5 \text{ ft})} + 2\right) \times \left(\frac{(3.7854 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 18.007 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.422 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.217 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.217 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

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 $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(11.422 \text{ kip})}{(2675.2 \text{ kip})}$$ $$Ratio = 0.0042696$$	Status: **PASS** Ratio: **0.000**
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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.422 \text{ kip} \rightarrow 11422 \text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$	

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11422 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.01 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.01 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.01 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.01 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.09 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.8571 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.8571 \text{ kip})}{(111.09 \text{ kip})}$$

$$Ratio = 0.061727$$

Status: **PASS**
Ratio: **0.060**

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:** $M_{max} = 18.007\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(18.007\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.072144$$	Status: **PASS** Ratio: **0.070**

REFERENCES	CALCULATIONS	RESULTS

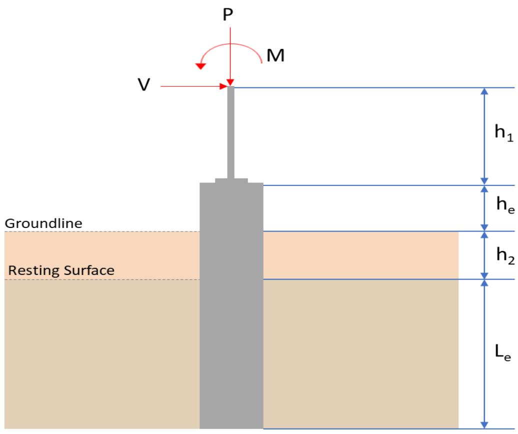
SkyCiv Foundation Design

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

$L = 5.5$ 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)	6.879	11.459
V_x (kip)	-1.591	-2.655
V_z (kip)	0.012	0.023
M_x (kipft)	0.037	0.068
M_z (kipft)	16.050	27.632

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,

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

$$H_o = \frac{(-1.591 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.25334 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.05\text{ kipft}) + ((-1.591\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 2.5557\text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.0381\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.037\text{ kipft}) + ((0.012\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.0058917\text{ kipft/ft}$$

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:
$L_{e,z} = 0.82719\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.0381\text{ ft}), (0.82719\text{ ft})]$$

$$L_{e,req} = 5.038\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.038\text{ ft})}{(5.5\text{ ft})}$$

$$Ratio = 0.916$$

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

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

$$q = \frac{(6.879 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.42994 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.42994 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.21497$$

Status: **PASS**
Ratio: **0.210**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.25334 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 2.5557 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.5557 \text{ kipft/ft}) \times (5.5 \text{ ft})) + \left(3 \times (-0.25334 \text{ kip/ft}) \times (5.5 \text{ ft})^2\right)}{(6 \times (2.5557 \text{ kipft/ft})) + (4 \times (-0.25334 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7888 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.5557 \text{ kipft/ft})) + (3 \times (-0.25334 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.5557 \text{ kipft/ft})) + (2 \times (-0.25334 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.1855 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.5557 \text{ kipft/ft})) + ((-0.25334 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.73747 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7888 \text{ ft})}{2}$$

$$p_a = 0.28416 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.1855 \text{ kip/ft}^2\right)}{\left(0.28416 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.6528$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$$

$$p_s = 0.825 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.73747 \text{ kip/ft}^2\right)}{\left(0.825 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.8939$$

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

Considering z-direction:

$H_o = 0.0019108 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0058917 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0058917 \text{ kipft/ft}) \times (5.5 \text{ ft})) + \left(3 \times (0.0019108 \text{ kip/ft}) \times (5.5 \text{ ft})^2\right)}{(6 \times (0.0058917 \text{ kipft/ft})) + (4 \times (0.0019108 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9156 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0058917 \text{ kipft/ft})) + (3 \times (0.0019108 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.0058917 \text{ kipft/ft})) + (2 \times (0.0019108 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.001945 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0058917 \text{ kipft/ft})) + ((0.0019108 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.0044218 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9156 \text{ ft})}{2}$$

$$p_a = 0.29367 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.001945 \text{ kip/ft}^2\right)}{\left(0.29367 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.0066231$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

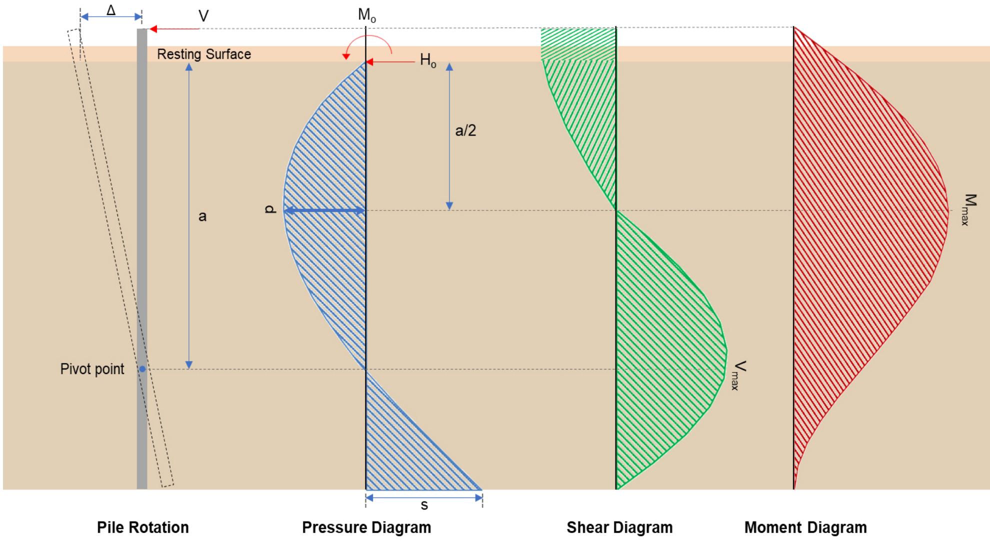
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0044218\ \mathrm{kip/ft^2})}{(0.825\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0053597$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.655\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.42277\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.632\ \mathrm{kipft}) + ((-2.655\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 4.4\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.4\ \mathrm{kipft/ft})}{(-0.42277\ \mathrm{kip/ft})}$$

$$E = 10.408\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.4\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.42277\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (4.4 \text{ kipft/ft})) + (4 \times (-0.42277 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7861 \text{ ft}$$

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

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

$$V_{max} = ((-0.42277 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.408 \text{ ft})}{(5.5 \text{ ft})} + 3\right) \times \left(\frac{(3.7861 \text{ ft})}{(5.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.408 \text{ ft})}{(5.5 \text{ ft})} + 2\right) \times \left(\frac{(3.7861 \text{ ft})}{(5.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 6.7784 \text{ kip}$$

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

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

$$M_{max} = ((-0.42277 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(10.408 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7861 \text{ ft})}{2 \times (5.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (10.408 \text{ ft})}{(5.5 \text{ ft})} + 3\right) \times \left(\frac{(3.7861 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.408 \text{ ft})}{(5.5 \text{ ft})} + 2\right) \times \left(\frac{(3.7861 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 17.795 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.023 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0036624 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.068 \text{ kipft}) + ((0.023 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.010828 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.010828 \text{ kipft/ft})}{(0.0036624 \text{ kip/ft})}$$

$$E = 2.9565 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.010828 \text{ kipft/ft}) \times (5.5 \text{ ft})) + \left(3 \times (0.0036624 \text{ kip/ft}) \times (5.5 \text{ ft})^2\right)}{(6 \times (0.010828 \text{ kipft/ft})) + (4 \times (0.0036624 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9204 \text{ ft}$$

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

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

$$V_{max} = ((0.0036624\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.9565\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.9204\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right.\right.$$
$$\left.\left. + \left[4 \times \left(\frac{3 \times (2.9565\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.9204\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]\right]$$

$$V_{max} = 0.023685\ \text{kip}$$

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

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

$$M_{max} = ((0.0036624\ \text{kip/ft}) \times (48\ \text{in}) \times (5.5\ \text{ft})) \times \left[\left(\frac{(2.9565\ \text{ft})}{(5.5\ \text{ft})} + \frac{(3.9204\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)\right.$$
$$\left. - \left[\left(\frac{4 \times (2.9565\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.9204\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.9565\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.9204\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.057939\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.459\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.215\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.215\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

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 Since longitudinal reinforcement is $\leq$ No. 10⌀: Use #3(0.375 in)
25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

$$Ratio = \frac{(11.459\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0042834$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.459 \text{ kip} \rightarrow 11459 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11459 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.01 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.01 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.01 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.01 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.09 \text{ kip}$$

Considering x-direction:

$V_{max} = 6.7784 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.7784 \text{ kip})}{(111.09 \text{ kip})}$$

$$Ratio = 0.061017$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.023685 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.023685 \text{ kip})}{(111.09 \text{ kip})}$$

$$Ratio = 0.0002132$$

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:

$M_{max} = 17.795 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(17.795 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.071294$$

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

Considering z-direction:

$M_{max} = 0.057939 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.057939\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.00023213$$	Status: **PASS** Ratio: **0.000**