Project Details

Project Name: MTSOLAR_B8B88854D6E4 CrystalineRock - V1Jb

Location: 3 Whatley Farm Rd, Topsham, ME 04086, USA

Unique ID: 4P-19.75-8TOP-XD-45-L-5Hx10W-A516

Dealer: ______________________________

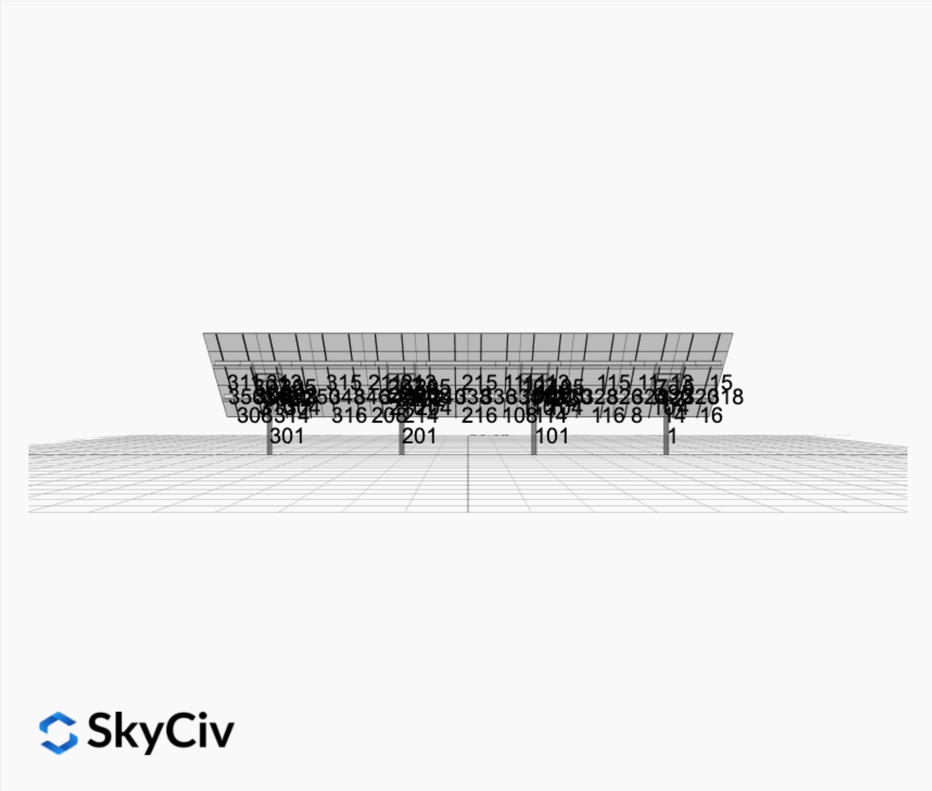
Date: Thu May 29 2025

Number of Modules: 50

Number of Poles: 4

Date Sold:

____



Array Dimensions N/S	18.96 ft
Array Dimensions E/W	75.58 ft
Winter Tilt Angle	40
Front Edge Clearance	5 ft

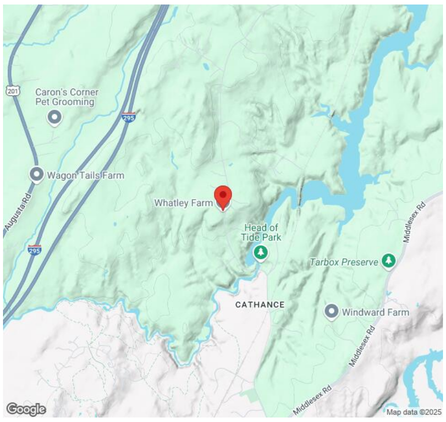
MT Solar Bill of Materials (4P-19.75-8TOP-XD-45-L-5Hx10W-A516)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-45	45IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-ANGLE-4PK	Angle Clamp	10

Rail Bill of Materials

Part	Qty
Rails (228in)	20
Rail Attachment	80
Module Mid Clamp	80
Module End Clamp	40
Ground Lug	10

Site Details:



Site Address: 3 Whatley Farm Rd, Topsham, ME 04086, USA

Array Specification

Duty Classification:	XD
Module Width:	45.00 in
Module Length:	89.70in
Number of Rows:	5
Number of Columns:	10
Total Number of Modules:	50
Winter Tilt Angle:	40
Front Edge Clearance:	5
Total Array Height at Tilt:	17.19 ft
Total Frame Length:	74.25 ft
Module Info/Notes:	
Array Dimensions N/S:	18.96 ft
Array Dimensions E/W:	75.58 ft
Rail Length:	227.50 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	11.09 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 4.25 ft Pile 2: 4.50 ft Pile 3: 4.50 ft Pile 4: 4.25 ft
Foundation Volume:	10.370 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	crystaline
Site Location:	3 Whatley Farm Rd, Topsham, ME 04086, USA
Wind Speed:	104 mph

Snow Load:	60 psf

Design Disclaimer

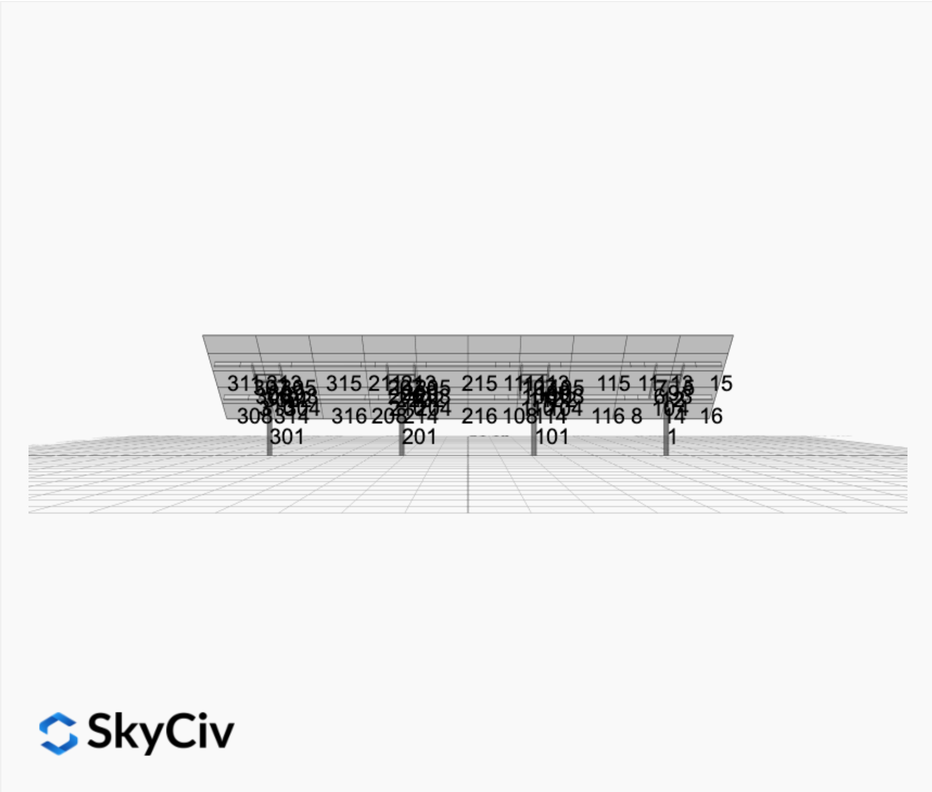
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

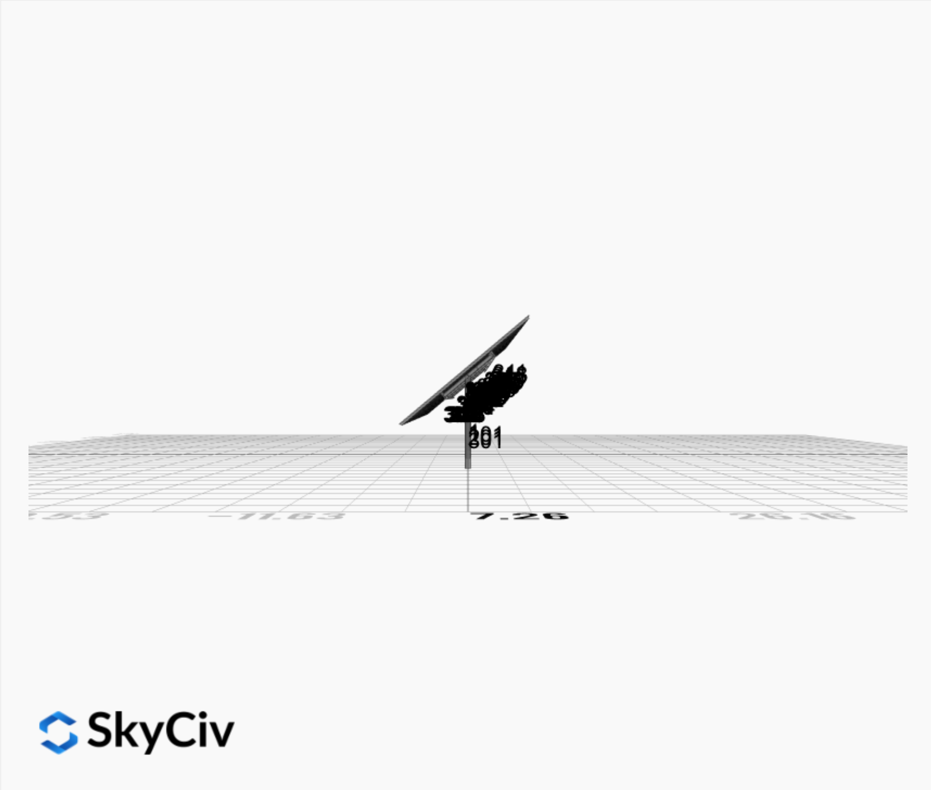
AutoDesigner Input

{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"","designer_email":"jnickwh@gmail.com","designer_phone":"2077510706","project_id":"MTSOLAR_B8B88854D6E4 CrystalineRock - V1Jb","site_address":"3 Whatley Farm Rd, Topsham, ME 04086, USA","module_info":"","module_width":45,"module_length":89.7,"number_rows":"5","number_columns":10,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":40,"ground_clearance":5,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"crystaline","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}

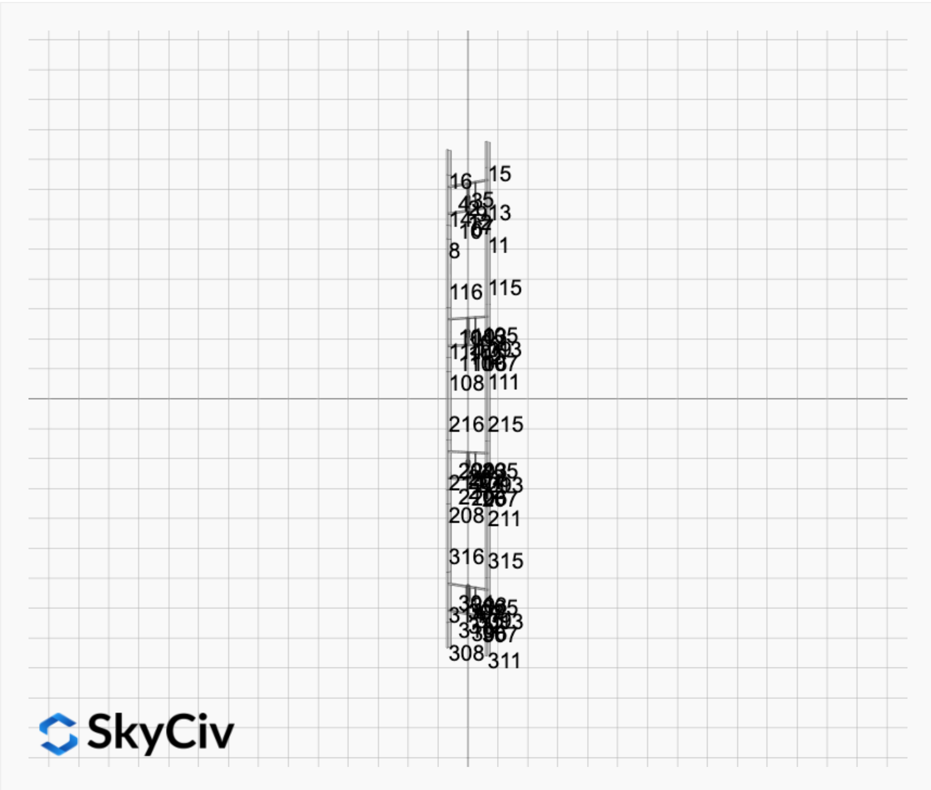
Design Notes:

- 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)

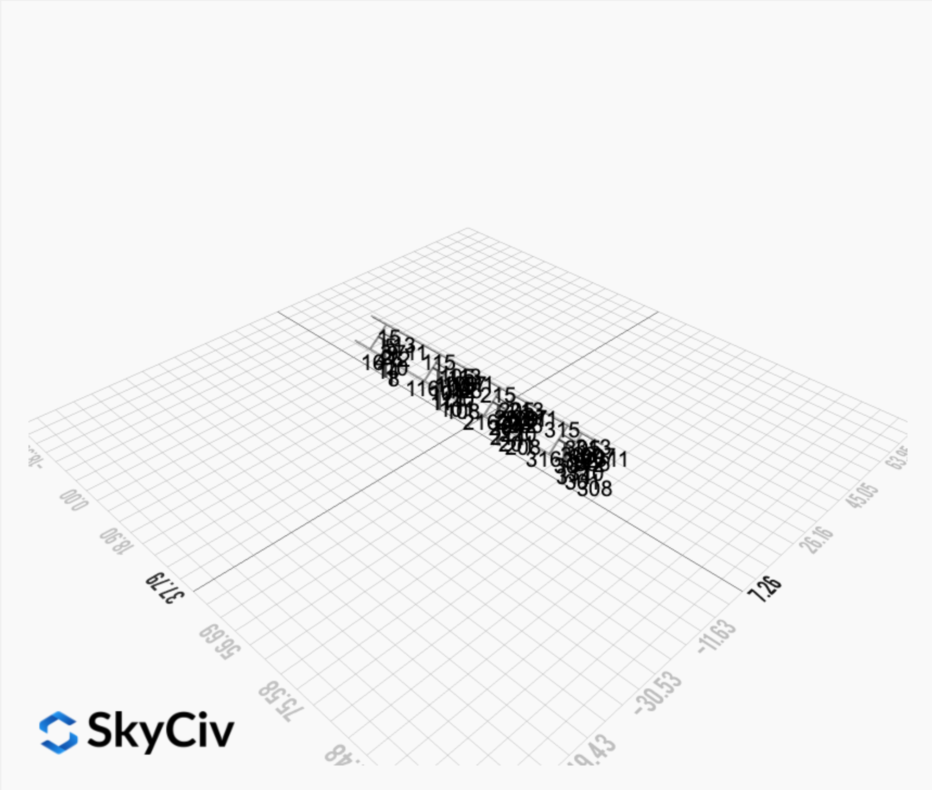


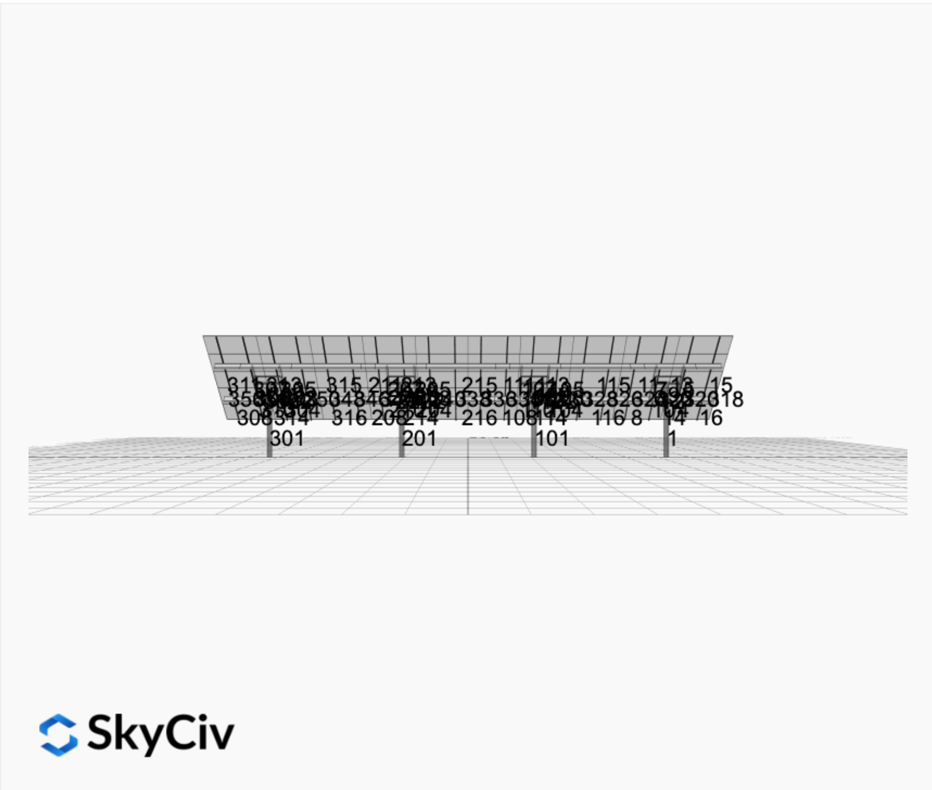


-11.63
7.26

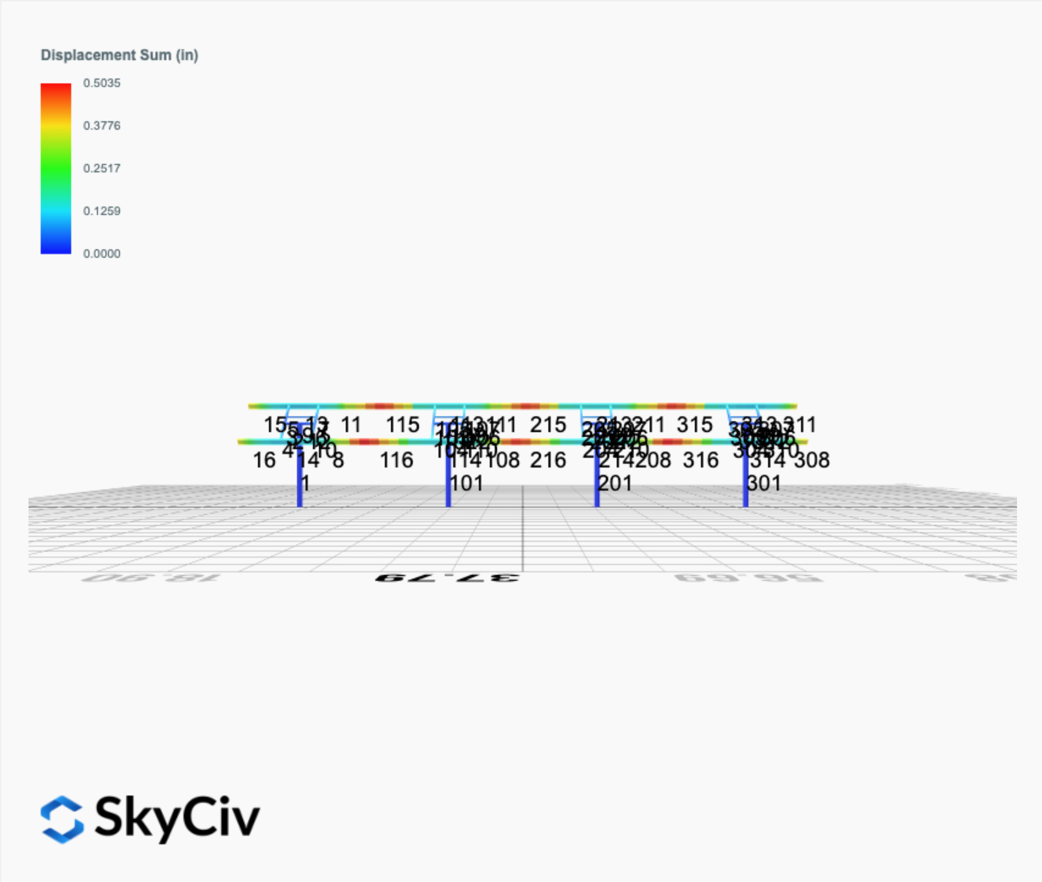


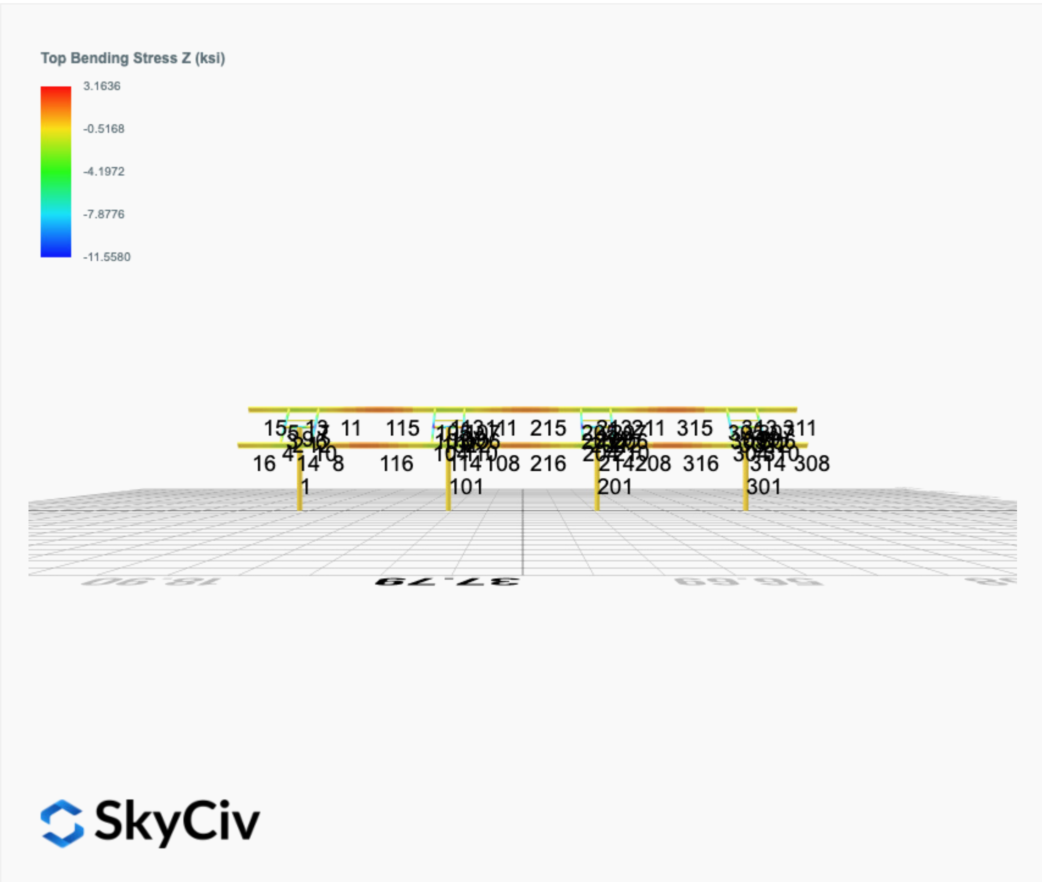
16
15
13
8
11
116
115
108
111
216
215
208
211
316
315
308
311

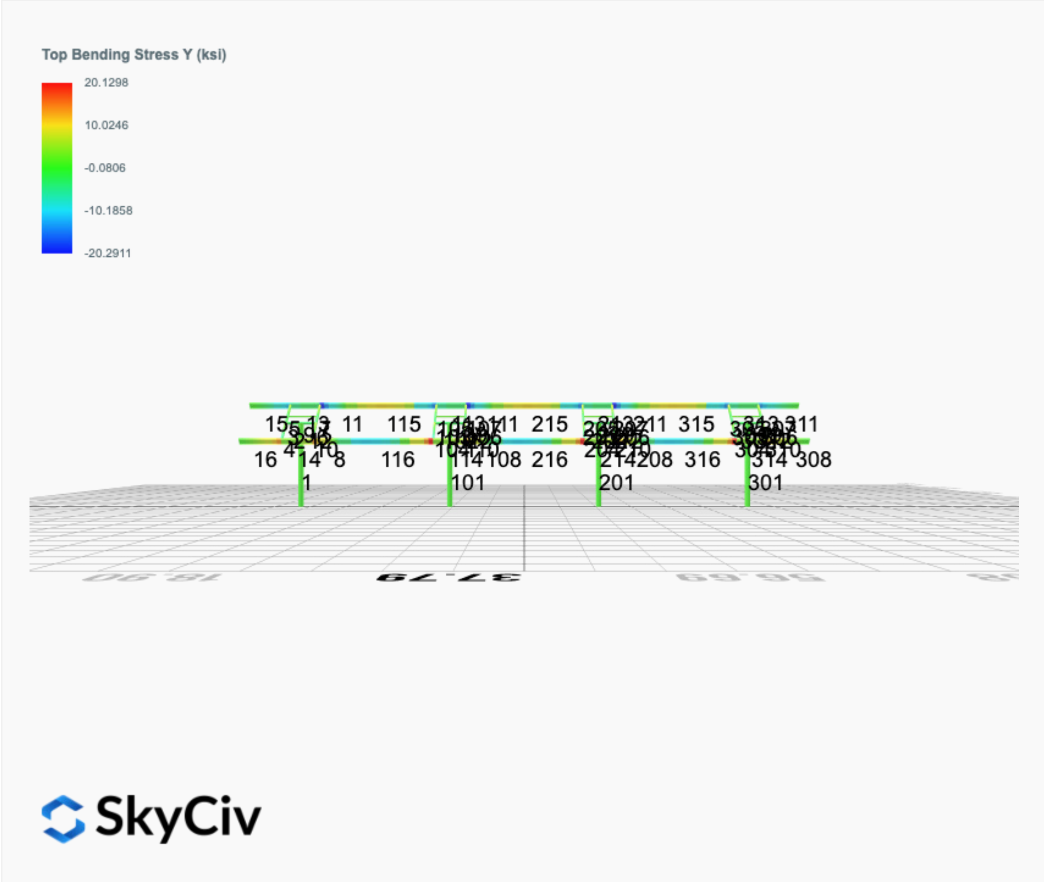


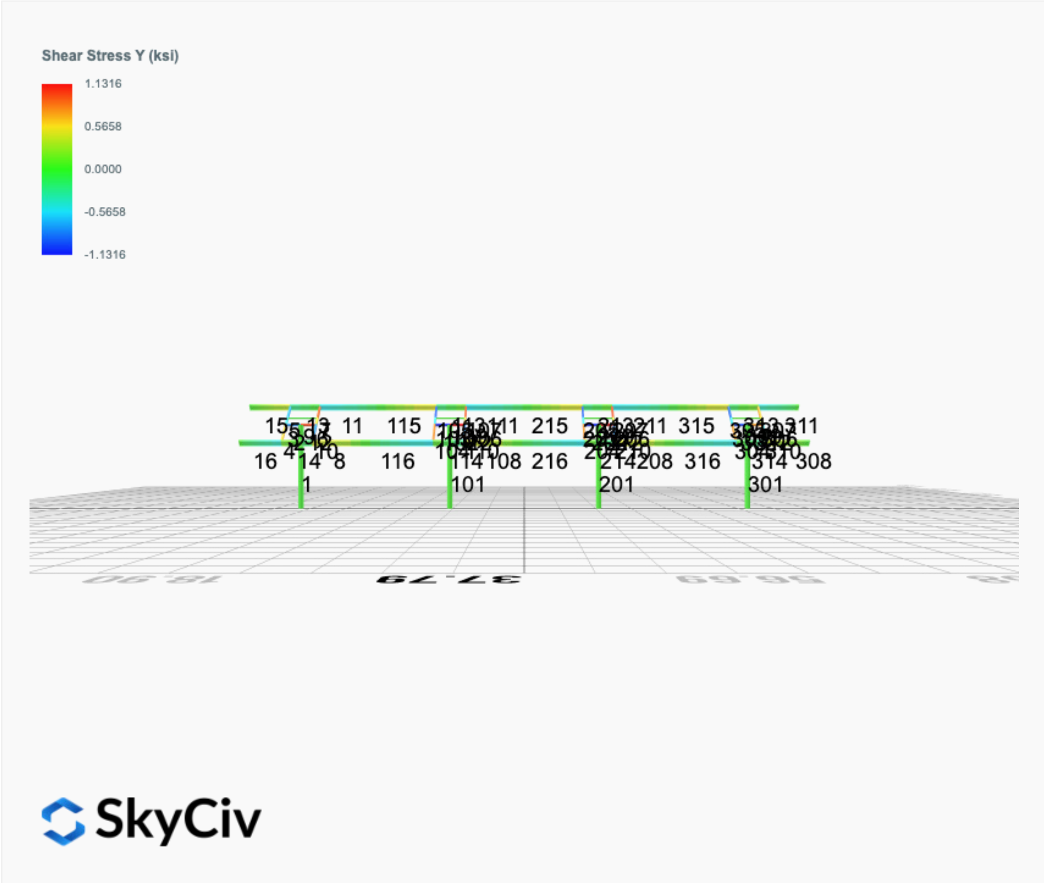


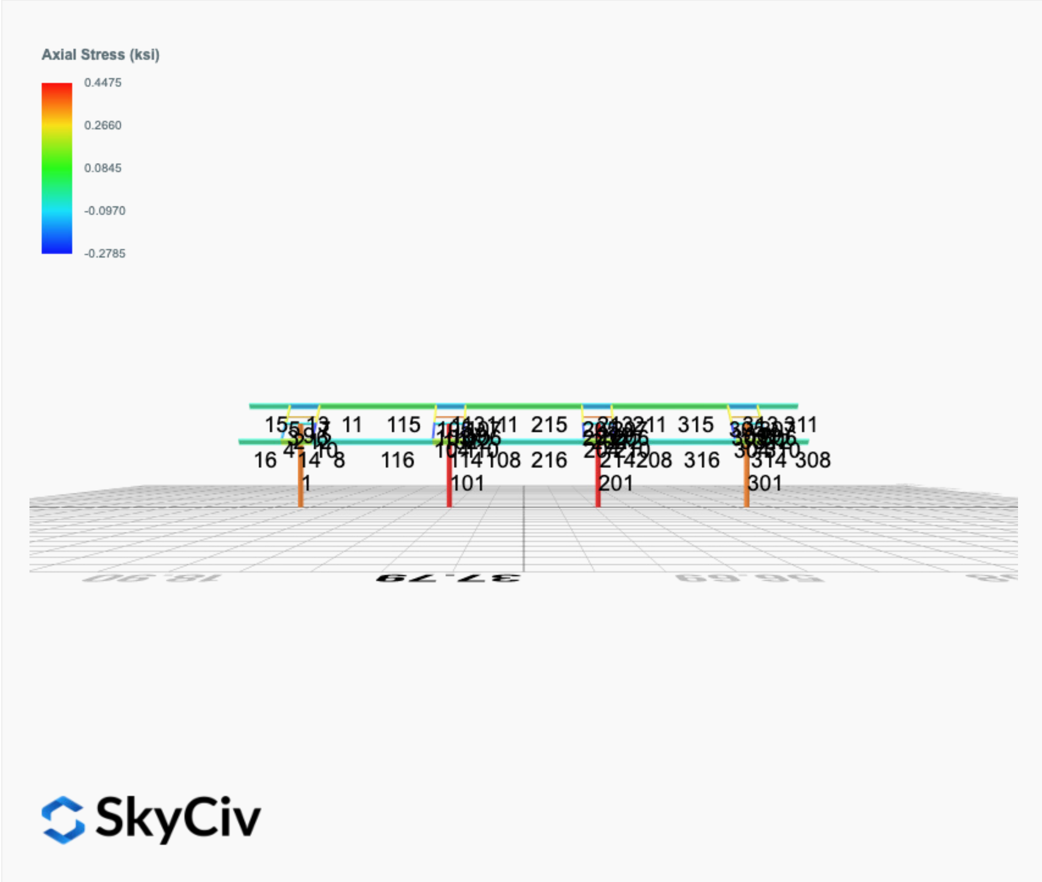
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
20.1298
10.0246
-0.0806
-10.1858
-20.2911
SkyCiv


Shear Stress Y (ksi)
1.1316
0.5658
0.0000
-0.5658
-1.1316
SkyCiv


Axial Stress (ksi)
0.4475
0.2660
0.0845
-0.0970
-0.2785

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	0.0097	2.6399	0.0314	0.1008	0.0018	-0.0754
ULS: 2. D + L	0.0097	2.6399	0.0314	0.1008	0.0018	-0.0754
ULS: 3. D + (S or Lr or R)	0.0354	7.6005	0.1148	0.3692	0.0048	-0.3225
ULS: 3. D + (S or Lr or R)	0.0097	2.6399	0.0314	0.1008	0.0018	-0.0754
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0290	6.3603	0.0940	0.3021	0.0041	-0.2608
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0097	2.6399	0.0314	0.1008	0.0018	-0.0754
ULS: 5b. D + 0.7E	0.0097	2.6399	0.0314	0.1008	0.0018	-0.0754
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0290	6.3603	0.0940	0.3021	0.0041	-0.2608
ULS: 8. 0.6D + 0.7E	0.0058	1.5839	0.0189	0.0605	0.0011	-0.0452
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.8300	8.3692	0.1789	0.5319	-0.5815	55.9196
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.8300	8.3692	0.1789	0.5319	-0.5815	55.9196
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.8617	-1.9230	-0.0804	-0.2256	0.4444	-41.9169
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.2973	-1.2445	-0.0793	-0.2219	0.4451	-47.0675
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6008	10.6573	0.2046	0.6254	-0.4333	41.7355
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6008	10.6573	0.2046	0.6254	-0.4333	41.7355
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9180	2.9382	0.0101	0.0573	0.3361	-31.6419
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4947	3.4471	0.0109	0.0601	0.3365	-35.5049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6201	6.9368	0.1421	0.4241	-0.4357	41.9209
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6201	6.9368	0.1421	0.4241	-0.4357	41.9209
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8987	-0.7823	-0.0525	-0.1440	0.3338	-31.4565
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4754	-0.2734	-0.0516	-0.1412	0.3342	-35.3195
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.8339	7.3132	0.1664	0.4915	-0.5822	55.9498
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.8339	7.3132	0.1664	0.4915	-0.5822	55.9498
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.8578	-2.9790	-0.0930	-0.2659	0.4437	-41.8868
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.2934	-2.3004	-0.0919	-0.2622	0.4444	-47.0374

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	15.8803
Shear X	-8.0662
Shear Z	0.3277
Moment X	0.9811
Moment Y (Twist)	0.9768
Moment Z	94.3085

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.6573
Shear X	-4.8339
Shear Z	0.2046
Moment X	0.6254
Moment Y (Twist)	0.5822
Moment Z	55.9498

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	-0.0097	2.9252	-0.0005	-0.0017	0.0010	0.1306
ULS: 2. D + L	-0.0097	2.9252	-0.0005	-0.0017	0.0010	0.1306
ULS: 3. D + (S or Lr or R)	-0.0354	8.6365	-0.0016	-0.0060	0.0035	0.4366
ULS: 3. D + (S or Lr or R)	-0.0097	2.9252	-0.0005	-0.0017	0.0010	0.1306
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0290	7.2087	-0.0013	-0.0049	0.0029	0.3601

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0097	2.9252	-0.0005	-0.0017	0.0010	0.1306
ULS: 5b. D + 0.7E	-0.0097	2.9252	-0.0005	-0.0017	0.0010	0.1306
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0290	7.2087	-0.0013	-0.0049	0.0029	0.3601
ULS: 8. 0.6D + 0.7E	-0.0058	1.7551	-0.0003	-0.0010	0.0006	0.0783
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.5133	9.5226	0.0253	0.0717	-0.1263	63.5491
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.5133	9.5226	0.0253	0.0717	-0.1263	63.5491
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.3819	-2.3362	-0.0178	-0.0508	0.0885	-47.1666
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.7019	-1.5318	-0.0241	-0.0693	0.1164	-52.6179
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.1567	12.1567	0.0180	0.0501	-0.0926	47.9240
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1567	12.1567	0.0180	0.0501	-0.0926	47.9240
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2647	3.2626	-0.0144	-0.0418	0.0685	-35.1127
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7547	3.8659	-0.0191	-0.0557	0.0894	-39.2013
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.1374	7.8733	0.0189	0.0533	-0.0945	47.6944
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1374	7.8733	0.0189	0.0533	-0.0945	47.6944
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2840	-1.0208	-0.0135	-0.0385	0.0666	-35.3423
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7740	-0.4176	-0.0182	-0.0524	0.0875	-39.4308
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-5.5094	8.3525	0.0255	0.0723	-0.1267	63.4968
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-5.5094	8.3525	0.0255	0.0723	-0.1267	63.4968
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.3858	-3.5063	-0.0177	-0.0502	0.0881	-47.2188
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.7058	-2.7019	-0.0240	-0.0686	0.1160	-52.6702

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	18.1451
Shear X	-9.1946
Shear Z	0.0435
Moment X	0.1225
Moment Y (Twist)	0.2166
Moment Z	107.4656

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	12.1567
Shear X	-5.5133
Shear Z	0.0255
Moment X	0.0723
Moment Y (Twist)	0.1267
Moment Z	63.5491

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	-0.0097	2.9252	0.0005	0.0017	-0.0009	0.1306
ULS: 2. D + L	-0.0097	2.9252	0.0005	0.0017	-0.0009	0.1306
ULS: 3. D + (S or Lr or R)	-0.0354	8.6365	0.0016	0.0060	-0.0034	0.4366
ULS: 3. D + (S or Lr or R)	-0.0097	2.9252	0.0005	0.0017	-0.0009	0.1306
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0290	7.2087	0.0013	0.0049	-0.0028	0.3601
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0097	2.9252	0.0005	0.0017	-0.0009	0.1306
ULS: 5b. D + 0.7E	-0.0097	2.9252	0.0005	0.0017	-0.0009	0.1306
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0290	7.2087	0.0013	0.0049	-0.0028	0.3601
ULS: 8. 0.6D + 0.7E	-0.0058	1.7551	0.0003	0.0010	-0.0006	0.0783
ULS: 5a. D + 0.6W_Wind downforce Case A only	-5.5133	9.5226	-0.0253	-0.0717	0.1263	63.5491
ULS: 5a. D + 0.6W_Wind downforce Case B only	-5.5133	9.5226	-0.0253	-0.0717	0.1263	63.5491
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.3819	-2.3362	0.0178	0.0508	-0.0884	-47.1666
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.7019	-1.5318	0.0241	0.0693	-0.1164	-52.6179

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.1567	12.1567	-0.0180	-0.0501	0.0927	47.9240
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1567	12.1567	-0.0180	-0.0501	0.0927	47.9240
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2647	3.2626	0.0144	0.0418	-0.0684	-35.1127
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7547	3.8659	0.0191	0.0556	-0.0893	-39.2013
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.1374	7.8733	-0.0189	-0.0533	0.0945	47.6944
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-4.1374	7.8733	-0.0189	-0.0533	0.0945	47.6944
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2840	-1.0208	0.0135	0.0385	-0.0666	-35.3423
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.7740	-0.4176	0.0182	0.0524	-0.0875	-39.4308
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-5.5094	8.3525	-0.0255	-0.0723	0.1267	63.4968
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-5.5094	8.3525	-0.0255	-0.0723	0.1267	63.4968
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.3858	-3.5063	0.0177	0.0502	-0.0881	-47.2188
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.7058	-2.7019	0.0240	0.0686	-0.1160	-52.6702

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	18.1451
Shear X	-9.1947
Shear Z	-0.0435
Moment X	-0.1227
Moment Y (Twist)	0.2171
Moment Z	107.4658

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	12.1567
Shear X	-5.5133
Shear Z	-0.0255
Moment X	-0.0723
Moment Y (Twist)	0.1267
Moment Z	63.5491

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	0.0097	2.6399	-0.0314	-0.1008	-0.0017	-0.0754
ULS: 2. D + L	0.0097	2.6399	-0.0314	-0.1008	-0.0017	-0.0754
ULS: 3. D + (S or Lr or R)	0.0354	7.6005	-0.1148	-0.3694	-0.0047	-0.3225
ULS: 3. D + (S or Lr or R)	0.0097	2.6399	-0.0314	-0.1008	-0.0017	-0.0754
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0290	6.3603	-0.0940	-0.3023	-0.0040	-0.2607
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0097	2.6399	-0.0314	-0.1008	-0.0017	-0.0754
ULS: 5b. D + 0.7E	0.0097	2.6399	-0.0314	-0.1008	-0.0017	-0.0754
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0290	6.3603	-0.0940	-0.3023	-0.0040	-0.2607
ULS: 8. 0.6D + 0.7E	0.0058	1.5839	-0.0189	-0.0605	-0.0010	-0.0452
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.8300	8.3692	-0.1789	-0.5319	0.5815	55.9196
ULS: 5a. D + 0.6W_Wind downforce Case B only	-4.8300	8.3692	-0.1789	-0.5319	0.5815	55.9196
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.8617	-1.9230	0.0804	0.2256	-0.4444	-41.9169
ULS: 5a. D + 0.6W_Wind uplift Case B only	3.2973	-1.2445	0.0793	0.2219	-0.4450	-47.0675
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6008	10.6573	-0.2046	-0.6256	0.4334	41.7356
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6008	10.6573	-0.2046	-0.6256	0.4334	41.7356
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9180	2.9382	-0.0101	-0.0575	-0.3360	-31.6418
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4947	3.4471	-0.0109	-0.0603	-0.3365	-35.5048
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.6201	6.9368	-0.1421	-0.4241	0.4357	41.9209
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-3.6201	6.9368	-0.1421	-0.4241	0.4357	41.9209
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8987	-0.7823	0.0525	0.1440	-0.3337	-31.4565
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	2.4754	-0.2734	0.0516	0.1412	-0.3342	-35.3195

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.8339	7.3132	-0.1664	-0.4915	0.5822	55.9498
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-4.8339	7.3132	-0.1664	-0.4915	0.5822	55.9498
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.8578	-2.9790	0.0930	0.2659	-0.4437	-41.8868
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	3.2934	-2.3004	0.0919	0.2622	-0.4443	-47.0374

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	15.8802
Shear X	-8.0662
Shear Z	-0.3277
Moment X	-0.9813
Moment Y (Twist)	0.9772
Moment Z	94.3099

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.6573
Shear X	-4.8339
Shear Z	-0.2046
Moment X	-0.6256
Moment Y (Twist)	0.5822
Moment Z	55.9498

Project Details

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

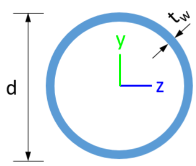
User Name: sales@mtsolar.us
Project Name: MTSOLAR_B8B88854D6E4 CrystalineRock - V1Jb
Unit System: imperial

Design Input Information

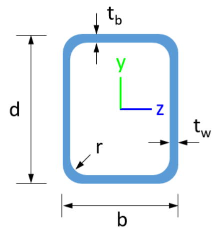
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

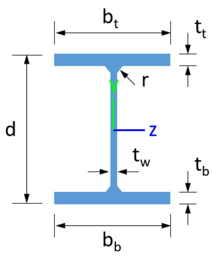
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
10	8in Pipe Sch 80	8.63	0.50					



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



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

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

3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	23.30	23.30	11.09	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.82,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.06,1.67,1.67,1.66,1.65	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
8	20	1.33	1.33	2.05	1.68,1.68,1.68,1.68,1.68,1.68,1.66,1.66,1.65,1.15,1.66,1.66,1.66,1.44,1.67,1.67,1.72,1.74,1.66,1.66,1.66,1.00,1.66,1.66,1.66,1.47	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.41,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.29,1.67,1.67,1.66,1.66	300	200	1
11	20	1.33	1.33	2.05	1.71,1.71,1.71,1.71,1.71,1.71,1.79,1.79,1.85,1.91,1.80,1.80,1.81,1.87,1.75,1.75,1.59,1.29,1.78,1.78,1.85,1.90,1.80,1.80,1.80,1.86	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.11,1.11,1.11,1.13,1.11,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.11	300	200	1
14	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.34,1.10,1.10,1.11,1.06,1.11,1.11,1.12,1.13,1.11,1.11,1.11,1.27,1.10,1.10,1.11,1.04	300	200	1
15	20	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	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33	300	200	1
101	10	23.30	23.30	11.09	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,2.81,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.16,1.67,1.67,1.66,1.66	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
108	20	1.33	1.33	2.05	2.08,2.08,2.08,2.09,2.08,2.08,2.08,2.08,2.07,1.96,2.08,2.08,2.08,2.08,2.08,2.08,2.10,2.09,2.08,2.08,2.07,1.73,2.08,2.08,2.08,2.08	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.23,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.19,1.67,1.67,1.66,1.66	300	200	1
111	20	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,1.95,1.95,1.73,1.76,1.91,1.91,1.83,1.84,2.06,2.06,2.29,1.45,1.96,1.96,1.74,1.77,1.91,1.91,1.86,1.85	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.04,1.04,1.04,1.05,1.04,1.04,1.05,1.05,1.06,1.06,1.05,1.05,1.06,1.06,1.05,1.05,1.03,1.02,1.05,1.05,1.06,1.06,1.05,1.05,1.06,1.06	300	200	1
114	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.09,1.05,1.05,1.05,1.06,1.05,1.05,1.04,1.04,1.05,1.05,1.05,1.08,1.05,1.05,1.05,1.05	300	200	1
115	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.13,1.12,1.12,1.13,1.13,1.12,1.12,1.14,1.14,1.19,1.53,1.13,1.13,1.12,1.12,1.13,1.13,1.12,1.12	300	200	1
116	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,2.55,1.15,1.15,1.15,1.16,1.15,1.15,1.16,1.15,1.15,1.15,1.15,1.47,1.15,1.15,1.15,1.16	300	200	1
201	10	23.30	23.30	11.09	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.24,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.19,1.67,1.67,1.66,1.66	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
208	20	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.06,2.06,2.06,1.18,2.06,2.06,2.06,2.08,2.07,2.07,2.08,2.07,2.06,2.06,2.06,2.32,2.06,2.06,2.06,2.08	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,2.80,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.16,1.67,1.67,1.66,1.66	300	200	1
211	20	1.33	1.33	2.05	2.06,2.06,2.06,2.06,2.06,2.06,1.78,1.78,1.60,1.62,1.75,1.75,1.69,1.68,1.89,1.89,2.35,1.60,1.78,1.78,1.61,1.63,1.74,1.74,1.70,1.69	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.04,1.04,1.04,1.05,1.04,1.04,1.05,1.05,1.06,1.06,1.05,1.05,1.06,1.06,1.05,1.05,1.03,1.02,1.05,1.05,1.06,1.06,1.05,1.05,1.06,1.06	300	200	1
214	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.09,1.05,1.05,1.05,1.05,1.05,1.05,1.04,1.04,1.05,1.05,1.05,1.08,1.05,1.05,1.05,1.05	300	200	1
215	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.13,1.13,1.14,1.14,1.13,1.13,1.14,1.14,1.20,2.73,1.14,1.14,1.13,1.13,1.14,1.14,1.13,1.13	300	200	1
216	20	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.15,1.34,1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.16,1.15,1.15,1.15,1.12,1.15,1.15,1.15,1.15	300	200	1
301	10	23.30	23.30	11.09	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.41,1.67,1.67,1.66,1.65,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.29,1.67,1.67,1.66,1.66	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
308	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.82,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.65,2.06,1.67,1.67,1.66,1.65	300	200	1
311	20	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
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.11,1.11,1.11,1.13,1.11,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.11	300	200	1
314	20	4.88	4.00	7.5	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.34,1.10,1.10,1.11,1.06,1.11,1.11,1.11,1.13,1.11,1.11,1.1	30	20	1

314	20	4.88	4.00	0	1,1.27,1.10,1.10,1.11,1.04	0	0	1
315	20	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.13,1.14,1.14,1.13,1.13,1.13,1.14,1.13,1.13,1.11,1.12,1.13,1.13,1.14,1.14,1.13,1.13,1.13,1.14	300	200	1
316	20	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,2.13,1.12,1.12,1.12,1.10,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.21,1.12,1.12,1.12,1.10	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	574.32	288.12	123.94	123.94	172.30	172.30
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	33.49	6.46	56.26	44.91
14	159.30	97.43	31.92	6.46	56.26	44.91
15	159.30	55.15	46.90	6.46	56.26	44.91
16	159.30	55.15	46.90	6.46	56.26	44.91
101	574.32	288.12	123.94	123.94	172.30	172.30
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	31.25	6.46	56.26	44.91
114	159.30	97.43	31.66	6.46	56.26	44.91
115	159.30	75.13	21.47	6.46	56.26	44.91
116	159.30	75.13	22.08	6.46	56.26	44.91
201	574.32	288.12	123.94	123.94	172.30	172.30
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91

212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	31.26	6.46	56.26	44.91
214	159.30	97.43	31.65	6.46	56.26	44.91
215	159.30	75.13	21.71	6.46	56.26	44.91
216	159.30	75.13	21.62	6.46	56.26	44.91
301	574.32	288.12	123.94	123.94	172.30	172.30
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	55.15	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	55.15	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	33.48	6.46	56.26	44.91
314	159.30	97.43	31.89	6.46	56.26	44.91
315	159.30	75.13	21.44	6.46	56.26	44.91
316	159.30	75.13	21.12	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.055	0.761	0.021	0.047	0.002	0.795	#13	0.486	Not Required	Pass
2	0.004	0.404	0.266	0.093	0.051	0.667	#13	0.036	Not Required	Pass
3	0.010	0.733	0.047	0.072	0.003	0.757	#13	0.046	Not Required	Pass
4	0.009	0.689	0.164	0.069	0.037	0.758	#13	0.082	Not Required	Pass
5	0.010	0.455	0.159	0.072	0.041	0.470	#13	0.076	Not Required	Pass
6	0.013	0.837	0.094	0.084	0.018	0.888	#13	0.046	Not Required	Pass
7	0.013	0.520	0.222	0.083	0.057	0.547	#13	0.076	Not Required	Pass
8	0.002	0.089	0.231	0.048	0.026	0.238	#24	0.102	Not Required	Pass
9	0.017	0.067	0.078	0.002	0.002	0.142	#13	0.206	Not Required	Pass
10	0.013	0.769	0.214	0.077	0.047	0.815	#13	0.082	Not Required	Pass
11	0.003	0.089	0.237	0.052	0.026	0.242	#24	0.102	Not Required	Pass
12	0.003	0.498	0.302	0.110	0.056	0.800	#13	0.054	Not Required	Pass
13	0.007	0.248	0.601	0.067	0.033	0.747	#21	0.306	Not Required	Pass
14	0.011	0.231	0.593	0.062	0.033	0.720	#21	0.204	Not Required	Pass
15	0.000	0.072	0.207	0.032	0.016	0.269	#21	Not Required	Not Required	Pass
16	0.000	0.068	0.207	0.030	0.016	0.267	#21	Not Required	Not Required	Pass
101	0.063	0.867	0.003	0.053	0.000	0.898	#13	0.486	Not Required	Pass
102	0.004	0.511	0.321	0.116	0.060	0.829	#13	0.036	Not Required	Pass
103	0.013	0.882	0.078	0.087	0.011	0.923	#13	0.046	Not Required	Pass
104	0.013	0.844	0.217	0.084	0.047	0.920	#13	0.082	Not Required	Pass
105	0.013	0.548	0.223	0.087	0.057	0.575	#13	0.076	Not Required	Pass
106	0.013	0.902	0.078	0.090	0.011	0.941	#13	0.046	Not Required	Pass
107	0.013	0.560	0.218	0.089	0.056	0.588	#13	0.076	Not Required	Pass
108	0.003	0.062	0.225	0.049	0.026	0.261	#21	0.102	Not Required	Pass
109	0.020	0.068	0.061	0.001	0.000	0.134	#13	0.206	Not Required	Pass
110	0.013	0.850	0.210	0.085	0.046	0.916	#13	0.082	Not Required	Pass

110	0.013	0.850	0.210	0.085	0.046	0.916	#13	0.082	Not Required	Pass
111	0.003	0.080	0.230	0.052	0.026	0.260	#21	0.102	Not Required	Pass
112	0.004	0.521	0.328	0.117	0.062	0.850	#13	0.036	Not Required	Pass
113	0.008	0.247	0.607	0.067	0.034	0.799	#21	0.306	Not Required	Pass
114	0.012	0.265	0.602	0.065	0.034	0.804	#21	0.306	Not Required	Pass
115	0.006	0.375	0.325	0.052	0.026	0.645	#21	0.507	Not Required	Pass
116	0.003	0.341	0.325	0.051	0.026	0.625	#21	0.507	Not Required	Pass
201	0.063	0.867	0.003	0.053	0.000	0.898	#13	0.486	Not Required	Pass
202	0.004	0.521	0.328	0.117	0.062	0.850	#13	0.036	Not Required	Pass
203	0.013	0.902	0.078	0.090	0.011	0.941	#13	0.046	Not Required	Pass
204	0.013	0.850	0.210	0.085	0.046	0.916	#13	0.082	Not Required	Pass
205	0.013	0.560	0.218	0.089	0.056	0.588	#13	0.076	Not Required	Pass
206	0.013	0.882	0.078	0.087	0.011	0.923	#13	0.046	Not Required	Pass
207	0.013	0.548	0.223	0.087	0.057	0.575	#13	0.076	Not Required	Pass
208	0.002	0.073	0.238	0.051	0.026	0.268	#21	0.102	Not Required	Pass
209	0.020	0.068	0.061	0.001	0.000	0.134	#13	0.206	Not Required	Pass
210	0.013	0.844	0.217	0.084	0.047	0.920	#13	0.082	Not Required	Pass
211	0.003	0.090	0.242	0.052	0.026	0.265	#21	0.102	Not Required	Pass
212	0.004	0.511	0.321	0.116	0.060	0.829	#13	0.036	Not Required	Pass
213	0.008	0.247	0.607	0.067	0.034	0.799	#21	0.306	Not Required	Pass
214	0.012	0.265	0.602	0.065	0.034	0.803	#21	0.306	Not Required	Pass
215	0.006	0.353	0.325	0.052	0.026	0.619	#21	0.507	Not Required	Pass
216	0.004	0.300	0.325	0.049	0.026	0.588	#21	0.507	Not Required	Pass
301	0.055	0.761	0.021	0.047	0.002	0.795	#13	0.486	Not Required	Pass
302	0.003	0.498	0.302	0.110	0.056	0.800	#13	0.054	Not Required	Pass
303	0.013	0.837	0.094	0.084	0.018	0.888	#13	0.046	Not Required	Pass
304	0.013	0.769	0.214	0.076	0.047	0.815	#13	0.082	Not Required	Pass
305	0.013	0.520	0.222	0.083	0.057	0.547	#13	0.076	Not Required	Pass
306	0.010	0.734	0.047	0.072	0.003	0.757	#13	0.046	Not Required	Pass
307	0.010	0.455	0.159	0.072	0.041	0.470	#13	0.076	Not Required	Pass
308	0.000	0.068	0.207	0.030	0.016	0.267	#21	Not Required	Not Required	Pass
309	0.017	0.067	0.078	0.002	0.002	0.142	#13	0.206	Not Required	Pass
310	0.009	0.689	0.164	0.069	0.037	0.758	#13	0.082	Not Required	Pass
311	0.000	0.072	0.207	0.032	0.016	0.269	#21	Not Required	Not Required	Pass
312	0.004	0.404	0.266	0.093	0.051	0.667	#13	0.036	Not Required	Pass
313	0.007	0.248	0.600	0.067	0.033	0.747	#21	0.204	Not Required	Pass
314	0.011	0.231	0.593	0.062	0.033	0.720	#21	0.306	Not Required	Pass
315	0.006	0.375	0.325	0.052	0.026	0.647	#21	0.507	Not Required	Pass
316	0.003	0.349	0.324	0.048	0.026	0.631	#21	0.507	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis

S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P, M_z, M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

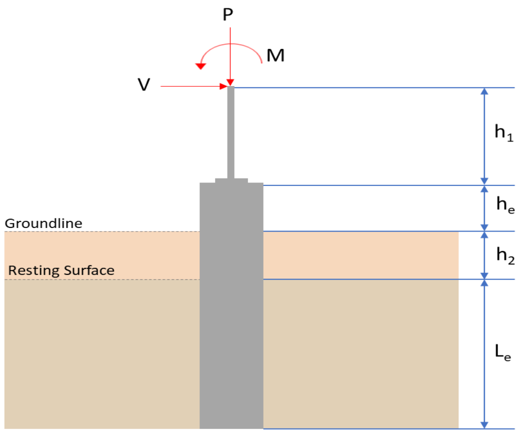
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 4.25$ 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	Crystalline bedrock	12000.000	1200.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.657	15.880
V_x (kip)	-4.834	-8.066
V_z (kip)	0.205	0.328
M_x (kipft)	0.625	0.981
M_z (kipft)	55.950	94.309

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.834 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.76975 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(55.95\ \text{kipft}) + ((-4.834\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.9092\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.0369\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.205\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.032643\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.625\ \text{kipft}) + ((0.205\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.099522\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.08\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.0369\ \text{ft}), (1.08\ \text{ft})]$$

$$L_{e,req} = 4.037\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.037\ \text{ft})}{(4.25\ \text{ft})}$$

$$Ratio = 0.94988$$

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

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

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

$$q = \frac{(10.657 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.66606 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.66606 \text{ kip/ft}^2)}{(12000 \text{ psf})}$$

$$Ratio = 0.055505$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.25 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.76975 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9092 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.9092 \text{ kipft/ft}) \times (4.25 \text{ ft})) + \left(3 \times (-0.76975 \text{ kip/ft}) \times (4.25 \text{ ft})^2\right)}{(6 \times (8.9092 \text{ kipft/ft})) + (4 \times (-0.76975 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.903 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.9092 \text{ kipft/ft})) + (3 \times (-0.76975 \text{ kip/ft}) \times (4.25 \text{ ft}))]^2}{(4.25 \text{ ft})^2 \times [(3 \times (8.9092 \text{ kipft/ft})) + (2 \times (-0.76975 \text{ kip/ft}) \times (4.25 \text{ ft}))]}$$

$$p = 1.3717 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.9092 \text{ kipft/ft})) + ((-0.76975 \text{ kip/ft}) \times (4.25 \text{ ft}))]}{(4.25 \text{ ft})^2}$$

$$s = 4.8322 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (1200 \text{ psf/ft}) \times \frac{(2.903 \text{ ft})}{2}$$

$$p_a = 1.7418 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.3717\ \mathrm{kip/ft^2}\right)}{\left(1.7418\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.78753$$

Status: **PASS**
Ratio: **0.790**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (1200\ \mathrm{psf/ft}) \times (4.25\ \mathrm{ft})$$

$$p_s = 5.1\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(4.8322\ \mathrm{kip/ft^2}\right)}{\left(5.1\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9475$$

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

Considering z-direction:

$H_o = 0.032643\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.099522\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.099522\ \mathrm{kipft/ft}) \times (4.25\ \mathrm{ft})) + \left(3 \times (0.032643\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft})^2\right)}{(6 \times (0.099522\ \mathrm{kipft/ft})) + (4 \times (0.032643\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft}))}$$

$$a = 3.0039\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.099522\ \mathrm{kipft/ft})) + (3 \times (0.032643\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft}))]^{\ 2}}{(4.25\ \mathrm{ft})^2 \times [(3 \times (0.099522\ \mathrm{kipft/ft})) + (2 \times (0.032643\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft}))]}$$

$$p = 0.047796\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.099522\ \mathrm{kipft/ft})) + ((0.032643\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft}))]}{(4.25\ \mathrm{ft})^2}$$

$$s = 0.1122\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (1200\ \mathrm{psf/ft}) \times \frac{(3.0039\ \mathrm{ft})}{2}$$

$$p_a = 1.8024\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.047796\ \mathrm{kip/ft^2}\right)}{\left(1.8024\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.026519$$

Status: **PASS**
Ratio: **0.030**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (1200\ \mathrm{psf/ft}) \times (4.25\ \mathrm{ft})$$

$$p_s = 5.1\ \mathrm{kip/ft^2}$$

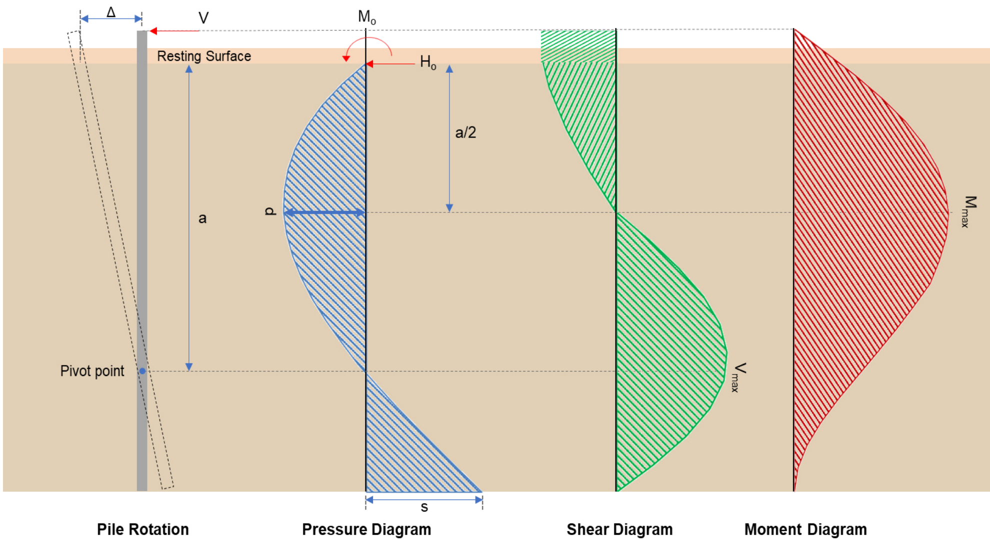
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.1122\ \mathrm{kip/ft^2})}{(5.1\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.022001$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-8.066\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.2844\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(94.309\ \mathrm{kipft}) + ((-8.066\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.017\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.017\ \mathrm{kipft/ft})}{(-1.2844\ \mathrm{kip/ft})}$$

$$E = 11.692\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.017\ \mathrm{kipft/ft}) \times (4.25\ \mathrm{ft})) + \left(3 \times (-1.2844\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{\quad}{(6 \times (15.017\ \mathrm{kipft/ft})) + (4 \times (-1.2844\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft}))}$$

$$a = 2.9024\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.2844\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.692\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.9024\ \mathrm{ft})}{(4.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.692\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.9024\ \mathrm{ft})}{(4.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 28.418\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.2844\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4.25\ \mathrm{ft})) \times \left[\left(\frac{(11.692\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + \frac{(2.9024\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (11.692\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.9024\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.692\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.9024\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 58.395\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.328\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.052229\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.981\ \mathrm{kipft}) + ((0.328\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.15621\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.15621\ \mathrm{kipft/ft})}{(0.052229\ \mathrm{kip/ft})}$$

$$E = 2.991\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.15621\ \mathrm{kipft/ft}) \times (4.25\ \mathrm{ft})) + \left(3 \times (0.052229\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft})^2\right)}{(6 \times (0.15621\ \mathrm{kipft/ft})) + (4 \times (0.052229\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft}))}$$

$$a = 3.0056\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.052229\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0056\ \mathrm{ft})}{(4.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0056\ \mathrm{ft})}{(4.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.39867\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.052229\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4.25\ \mathrm{ft})) \times \left[\left(\frac{(2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + \frac{(3.0056\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0056\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0056\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.7676\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.88\ \mathrm{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.068\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.068\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.88\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.005936$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15.88 \text{ kip} \rightarrow 15880 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(15880 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.6 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.6 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.6 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.6 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.47 \text{ kip}$$

Considering x-direction:

$V_{max} = 28.418 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(28.418\ \text{kip})}{(111.47\ \text{kip})}$$ $$Ratio = 0.25493$$	Status: **PASS** Ratio: **0.250**
	Considering z-direction: $V_{max} = 0.39867\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.39867\ \text{kip})}{(111.47\ \text{kip})}$$ $$Ratio = 0.0035764$$	Status: **PASS** Ratio: **0.000**
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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ 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:** $M_{max} = 58.395\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(58.395\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.23395$$	Status: **PASS** Ratio: **0.230**
	Considering z-direction: $M_{max} = 0.7676\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.7676\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.0030753$$	Status: **PASS** Ratio: **0.000**	

REFERENCES	CALCULATIONS	RESULTS

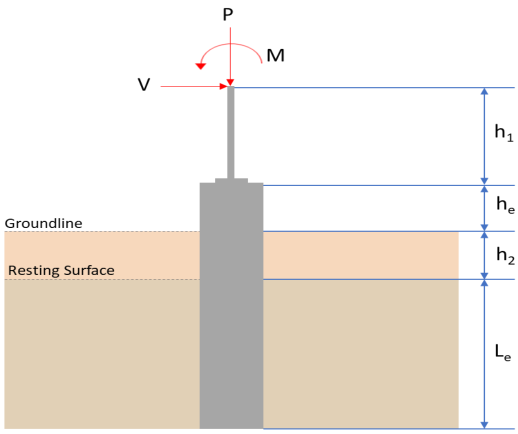
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - 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	Crystalline bedrock	12000.000	1200.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	10.657	15.880
V_x (kip)	-4.834	-8.066
V_z (kip)	-0.205	-0.328
M_x (kipft)	-0.626	-0.981
M_z (kipft)	55.950	94.310

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.834\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.76975\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(55.95\ \mathrm{kipft}) + ((-4.834\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.9092\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 4.0369\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.205\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.032643\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.626\ \mathrm{kipft}) + ((-0.205\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.099682\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.91744\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.0369\ \mathrm{ft}), (0.91744\ \mathrm{ft})]$$

$$L_{e,req} = 4.037\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.25\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 4.25\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.037\ \mathrm{ft})}{(4.25\ \mathrm{ft})}$$

$$Ratio = 0.94988$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.657\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.66606\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.66606\ \text{kip/ft}^2\right)}{(12000\ \text{psf})}$$

$$Ratio = 0.055505$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.76975\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9092\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.9092\ \text{kipft/ft}) \times (4.25\ \text{ft})) + \left(3 \times (-0.76975\ \text{kip/ft}) \times (4.25\ \text{ft})^2\right)}{(6 \times (8.9092\ \text{kipft/ft})) + (4 \times (-0.76975\ \text{kip/ft}) \times (4.25\ \text{ft}))}$$

$$a = 2.903\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.9092\ \text{kipft/ft})) + (3 \times (-0.76975\ \text{kip/ft}) \times (4.25\ \text{ft}))]^{\ 2}}{(4.25\ \text{ft})^2 \times [(3 \times (8.9092\ \text{kipft/ft})) + (2 \times (-0.76975\ \text{kip/ft}) \times (4.25\ \text{ft}))]}$$

$$p = 1.3717\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.9092\ \text{kipft/ft})) + ((-0.76975\ \text{kip/ft}) \times (4.25\ \text{ft}))]}{(4.25\ \text{ft})^2}$$

$$s = 4.8322\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (1200\ \text{psf/ft}) \times \frac{(2.903\ \text{ft})}{2}$$

$$p_a = 1.7418\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(1.3717\ \mathrm{kip/ft^2}\right)}{\left(1.7418\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.78753$$	Status: **PASS** Ratio: **0.790**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = \left(1200\ \mathrm{psf/ft}\right) \times \left(4.25\ \mathrm{ft}\right)$$ $$p_s = 5.1\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(4.8322\ \mathrm{kip/ft^2}\right)}{\left(5.1\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.9475$$	Status: **PASS** Ratio: **0.950**
	Considering z-direction: $H_o = -0.032643\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.099682\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{\left(4\,M_o\,L_e\right) + \left(3\,H_o\,L_e^2\right)}{\left(6\,M_o\right) + \left(4\,H_o\,L_e\right)}$$ $$a = \frac{\left(4 \times \left(0.099682\ \mathrm{kipft/ft}\right) \times \left(4.25\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.032643\ \mathrm{kip/ft}\right) \times \left(4.25\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(0.099682\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.032643\ \mathrm{kip/ft}\right) \times \left(4.25\ \mathrm{ft}\right)\right)}$$ $$a = 3.0038\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,\left[\left(4\,M_o\right) + \left(3\,H_o\,L_e\right)\right]^2}{L_e^2\,\left[\left(3\,M_o\right) + \left(2\,H_o\,L_e\right)\right]}$$ $$p = \frac{0.75 \times \left[\left(4 \times \left(0.099682\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(-0.032643\ \mathrm{kip/ft}\right) \times \left(4.25\ \mathrm{ft}\right)\right)\right]^2}{\left(4.25\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(0.099682\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(-0.032643\ \mathrm{kip/ft}\right) \times \left(4.25\ \mathrm{ft}\right)\right)\right]}$$ $$p = 0.00058775\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,\left[\left(2\,M_o\right) + \left(H_o\,L_e\right)\right]}{L_e^2}$$ $$s = \frac{6 \times \left[\left(2 \times \left(0.099682\ \mathrm{kipft/ft}\right)\right) + \left(\left(-0.032643\ \mathrm{kip/ft}\right) \times \left(4.25\ \mathrm{ft}\right)\right)\right]}{\left(4.25\ \mathrm{ft}\right)^2}$$ $$s = 0.02014\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = \left(1200\ \mathrm{psf/ft}\right) \times \frac{\left(3.0038\ \mathrm{ft}\right)}{2}$$ $$p_a = 1.8023\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.00058775\ \mathrm{kip/ft^2}\right)}{\left(1.8023\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = 0.00032612$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (1200\ \mathrm{psf/ft}) \times (4.25\ \mathrm{ft})$$

$$p_s = 5.1\ \mathrm{kip/ft^2}$$

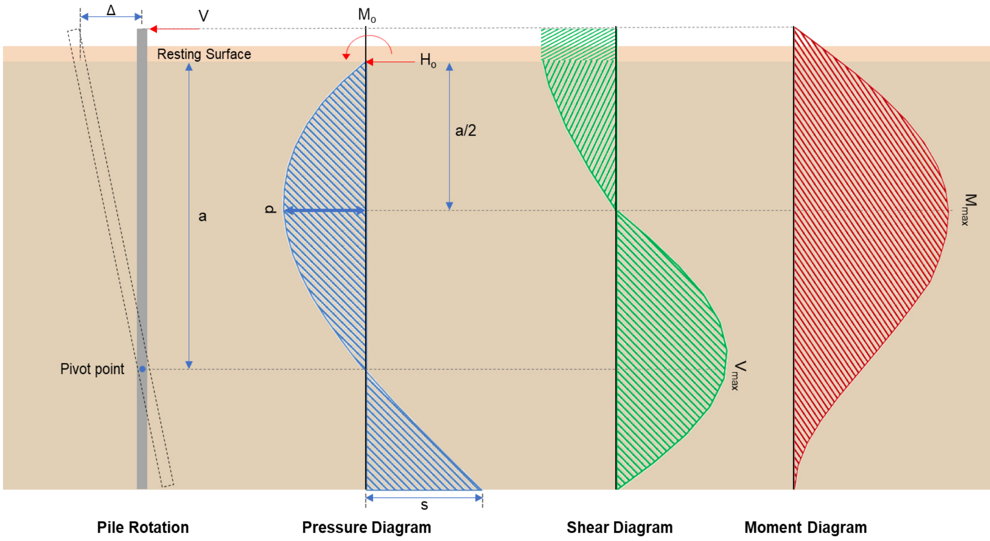
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.02014\ \mathrm{kip/ft^2}\right)}{\left(5.1\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.003949$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-8.066\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.2844\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(94.31\ \mathrm{kipft}) + ((-8.066\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.018\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.018\ \mathrm{kipft/ft})}{(-1.2844\ \mathrm{kip/ft})}$$

$$E = 11.692\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.018\ \mathrm{kipft/ft}) \times (4.25\ \mathrm{ft})) + \left(3 \times (-1.2844\ \mathrm{kip/ft}) \times (4.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (15.018 \text{ kipft/ft})) + (4 \times (-1.2844 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 2.9024 \text{ ft}$$

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

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

$$V_{max} = ((-1.2844 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.692 \text{ ft})}{(4.25 \text{ ft})} + 3\right) \times \left(\frac{(2.9024 \text{ ft})}{(4.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.692 \text{ ft})}{(4.25 \text{ ft})} + 2\right) \times \left(\frac{(2.9024 \text{ ft})}{(4.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 28.418 \text{ kip}$$

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

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

$$M_{max} = ((-1.2844 \text{ kip/ft}) \times (48 \text{ in}) \times (4.25 \text{ ft})) \times \left[\left(\frac{(11.692 \text{ ft})}{(4.25 \text{ ft})} + \frac{(2.9024 \text{ ft})}{2 \times (4.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.692 \text{ ft})}{(4.25 \text{ ft})} + 3\right) \times \left(\frac{(2.9024 \text{ ft})}{2 \times (4.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.692 \text{ ft})}{(4.25 \text{ ft})} + 2\right) \times \left(\frac{(2.9024 \text{ ft})}{2 \times (4.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 58.395 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.328 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.052229 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.981 \text{ kipft}) + ((-0.328 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.15621 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.15621 \text{ kipft/ft})}{(-0.052229 \text{ kip/ft})}$$

$$E = 2.991 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.15621 \text{ kipft/ft}) \times (4.25 \text{ ft})) + \left(3 \times (-0.052229 \text{ kip/ft}) \times (4.25 \text{ ft})^2\right)}{(6 \times (0.15621 \text{ kipft/ft})) + (4 \times (-0.052229 \text{ kip/ft}) \times (4.25 \text{ ft}))}$$

$$a = 3.0056 \text{ ft}$$

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

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

$$V_{max} = ((-0.052229\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0056\ \mathrm{ft})}{(4.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0056\ \mathrm{ft})}{(4.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.39867\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.052229\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (4.25\ \mathrm{ft})) \times \left[\left(\frac{(2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + \frac{(3.0056\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0056\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.991\ \mathrm{ft})}{(4.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0056\ \mathrm{ft})}{2 \times (4.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.7676\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(15.88\ \mathrm{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.068\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.068\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.88\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.005936$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15.88 \text{ kip} \rightarrow 15880 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(15880 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.6 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.6 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.6 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.6 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.47 \text{ kip}$$

Considering x-direction:

$V_{max} = 28.418 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(28.418 \text{ kip})}{(111.47 \text{ kip})}$$ $$Ratio = 0.25493$$	Status: **PASS** Ratio: **0.250**
	Considering z-direction: $V_{max} = 0.39867 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.39867 \text{ kip})}{(111.47 \text{ kip})}$$ $$Ratio = 0.0035764$$	Status: **PASS** Ratio: **0.000**
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:** $M_{max} = 58.395 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(58.395 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.23396$$	Status: **PASS** Ratio: **0.230**
	Considering z-direction: $M_{max} = 0.7676 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

		$$Ratio = \frac{(0.7676 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0030753$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

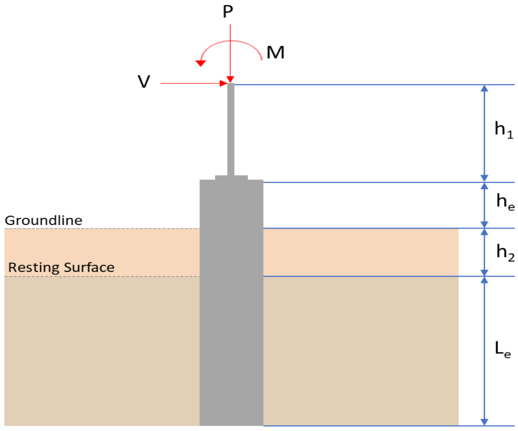
SkyCiv Foundation Design

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
$L = 4.5\ \text{ft}$ - 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	Crystalline bedrock	12000.000	1200.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.157	18.145
V_x (kip)	-5.513	-9.195
V_z (kip)	0.026	0.043
M_x (kipft)	0.072	0.122
M_z (kipft)	63.549	107.466

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,

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

$$H_o = \frac{(-5.513\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.87787\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(63.549\ \text{kipft}) + ((-5.513\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 10.119\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.1908\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.072\ \text{kipft}) + ((0.026\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.011465\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.50702\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.1908\ \text{ft}), (0.50702\ \text{ft})]$$

$$L_{e,req} = 4.191\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.191\ \text{ft})}{(4.5\ \text{ft})}$$

$$Ratio = 0.93133$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(12.157\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.75981\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.75981\ \mathrm{kip/ft}^2)}{(12000\ \mathrm{psf})}$$

$$Ratio = 0.063318$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.87787\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 10.119\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.119\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (10.119\ \mathrm{kipft/ft})) + (4 \times (-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0774\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.119\ \mathrm{kipft/ft})) + (3 \times (-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^{\ 2}}{(4.5\ \mathrm{ft})^2 \times [(3 \times (10.119\ \mathrm{kipft/ft})) + (2 \times (-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 1.3515\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (10.119\ \mathrm{kipft/ft})) + ((-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 4.8261\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (1200\ \mathrm{psf/ft}) \times \frac{(3.0774\ \mathrm{ft})}{2}$$

$$p_a = 1.8465\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(1.3515\ \mathrm{kip/ft^2}\right)}{\left(1.8465\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.73192$$	Status: **PASS** Ratio: **0.730**	
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (1200\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$ $$p_s = 5.4\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(4.8261\ \mathrm{kip/ft^2}\right)}{\left(5.4\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.89372$$	Status: **PASS** Ratio: **0.890**	

Considering z-direction:

$H_o = 0.0041401\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011465\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011465\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (0.011465\ \mathrm{kipft/ft})) + (4 \times (0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.195\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.011465\ \mathrm{kipft/ft})) + (3 \times (0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^2}{(4.5\ \mathrm{ft})^2 \times [(3 \times (0.011465\ \mathrm{kipft/ft})) + (2 \times (0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 0.0053514\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.011465\ \mathrm{kipft/ft})) + ((0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.012314\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (1200\ \mathrm{psf/ft}) \times \frac{(3.195\ \mathrm{ft})}{2}$$

$$p_a = 1.917\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0053514\ \mathrm{kip/ft^2}\right)}{\left(1.917\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0027915$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (1200\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 5.4\ \mathrm{kip/ft^2}$$

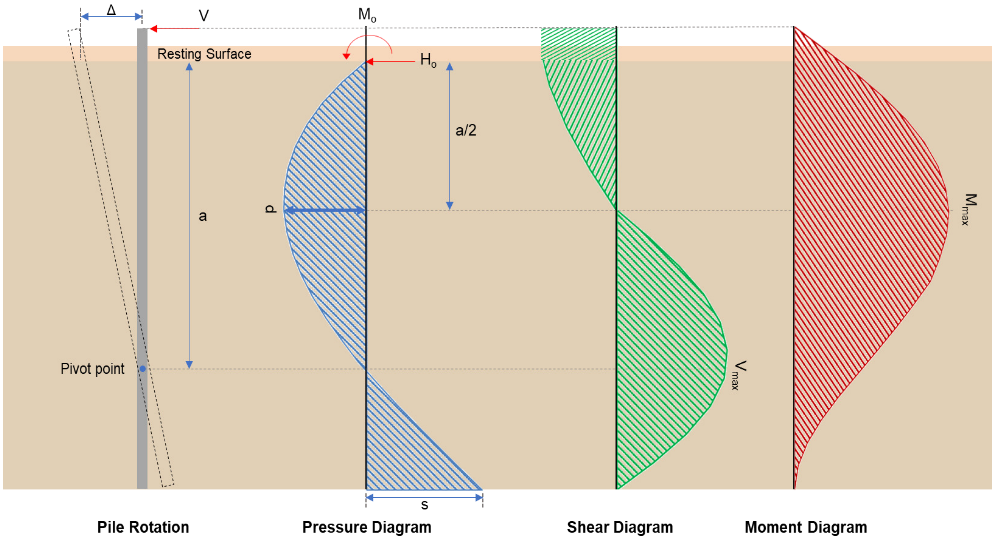
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.012314\ \mathrm{kip/ft^2})}{(5.4\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0022804$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-9.195\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.4642\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(107.47\ \mathrm{kipft}) + ((-9.195\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 17.112\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(17.112\ \mathrm{kipft/ft})}{(-1.4642\ \mathrm{kip/ft})}$$

$$E = 11.687\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (17.112\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-1.4642\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (17.112 \text{ kipft/ft})) + (4 \times (-1.4642 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0766 \text{ ft}$$

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

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

$$V_{max} = ((-1.4642 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.687 \text{ ft})}{(4.5 \text{ ft})} + 3\right) \times \left(\frac{(3.0766 \text{ ft})}{(4.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.687 \text{ ft})}{(4.5 \text{ ft})} + 2\right) \times \left(\frac{(3.0766 \text{ ft})}{(4.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 30.796 \text{ kip}$$

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

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

$$M_{max} = ((-1.4642 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(11.687 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0766 \text{ ft})}{2 \times (4.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.687 \text{ ft})}{(4.5 \text{ ft})} + 3\right) \times \left(\frac{(3.0766 \text{ ft})}{2 \times (4.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.687 \text{ ft})}{(4.5 \text{ ft})} + 2\right) \times \left(\frac{(3.0766 \text{ ft})}{2 \times (4.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 66.887 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.122 \text{ kipft}) + ((0.043 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.019427 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.019427 \text{ kipft/ft})}{(0.0068471 \text{ kip/ft})}$$

$$E = 2.8372 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.019427 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (0.0068471 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (0.019427 \text{ kipft/ft})) + (4 \times (0.0068471 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.1927 \text{ ft}$$

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

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

$$V_{max} = ((0.0068471\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.8372\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.1927\ \text{ft})}{(4.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.8372\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.1927\ \text{ft})}{(4.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.048742\ \text{kip}$$

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

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

$$M_{max} = ((0.0068471\ \text{kip/ft}) \times (48\ \text{in}) \times (4.5\ \text{ft})) \times \left[\left(\frac{(2.8372\ \text{ft})}{(4.5\ \text{ft})} + \frac{(3.1927\ \text{ft})}{2 \times (4.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.8372\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.1927\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.8372\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.1927\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.098642\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.145\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -83.993\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-83.993\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.145\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0067827$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.145 \text{ kip} \rightarrow 18145 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18145 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.9 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.9 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.9 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.9 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.67 \text{ kip}$$

Considering x-direction:

$V_{max} = 30.796 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(30.796\ \mathrm{kip})}{(111.67\ \mathrm{kip})}$$ $$Ratio = 0.27578$$	Status: **PASS** Ratio: **0.280**
	Considering z-direction: $V_{max} = 0.048742\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.048742\ \mathrm{kip})}{(111.67\ \mathrm{kip})}$$ $$Ratio = 0.00043649$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\ D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 66.887\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(66.887\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.26798$$	Status: **PASS** Ratio: **0.270**
	Considering z-direction: $M_{max} = 0.098642\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.098642 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0003952$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

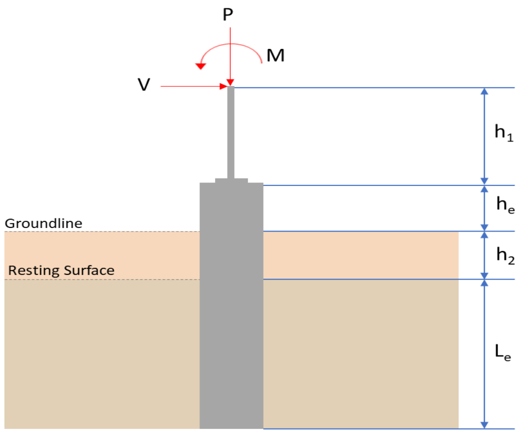
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) $(\mathrm{psf/ft})$
1	Crystalline bedrock	12000.000	1200.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	12.157	18.145
V_x (kip)	-5.513	-9.195
V_z (kip)	-0.026	-0.043
M_x (kipft)	-0.072	-0.123
M_z (kipft)	63.549	107.466

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.513\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.87787\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(63.549\text{ kipft}) + ((-5.513\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 10.119\text{ kipft/ft}$$

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:
$L_{e,x} = 4.1908\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.072\text{ kipft}) + ((-0.026\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.011465\text{ kipft/ft}$$

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:
$L_{e,z} = 0.46444\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.1908\text{ ft}), (0.46444\text{ ft})]$$

$$L_{e,req} = 4.191\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 4.5\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.191\text{ ft})}{(4.5\text{ ft})}$$

$$Ratio = 0.93133$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(12.157\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.75981\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.75981\ \mathrm{kip/ft}^2\right)}{(12000\ \mathrm{psf})}$$

$$Ratio = 0.063318$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.87787\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 10.119\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.119\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (10.119\ \mathrm{kipft/ft})) + (4 \times (-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0774\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (10.119\ \mathrm{kipft/ft})) + (3 \times (-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^2}{(4.5\ \mathrm{ft})^2 \times [(3 \times (10.119\ \mathrm{kipft/ft})) + (2 \times (-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 1.3515\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (10.119\ \mathrm{kipft/ft})) + ((-0.87787\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 4.8261\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (1200\ \mathrm{psf/ft}) \times \frac{(3.0774\ \mathrm{ft})}{2}$$

$$p_a = 1.8465\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.3515\ \mathrm{kip/ft^2}\right)}{\left(1.8465\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.73192$$

Status: **PASS**
Ratio: **0.730**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (1200\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 5.4\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(4.8261\ \mathrm{kip/ft^2}\right)}{\left(5.4\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.89372$$

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

Considering z-direction:

$H_o = -0.0041401\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011465\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011465\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (0.011465\ \mathrm{kipft/ft})) + (4 \times (-0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.195\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.011465\ \mathrm{kipft/ft})) + (3 \times (-0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^2}{(4.5\ \mathrm{ft})^2 \times [(3 \times (0.011465\ \mathrm{kipft/ft})) + (2 \times (-0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = -0.0013004\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.011465\ \mathrm{kipft/ft})) + ((-0.0041401\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.0012739\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (1200\ \mathrm{psf/ft}) \times \frac{(3.195\ \mathrm{ft})}{2}$$

$$p_a = 1.917\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0013004\ \mathrm{kip/ft^2}\right)}{\left(1.917\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00067836$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (1200\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 5.4\ \mathrm{kip/ft^2}$$

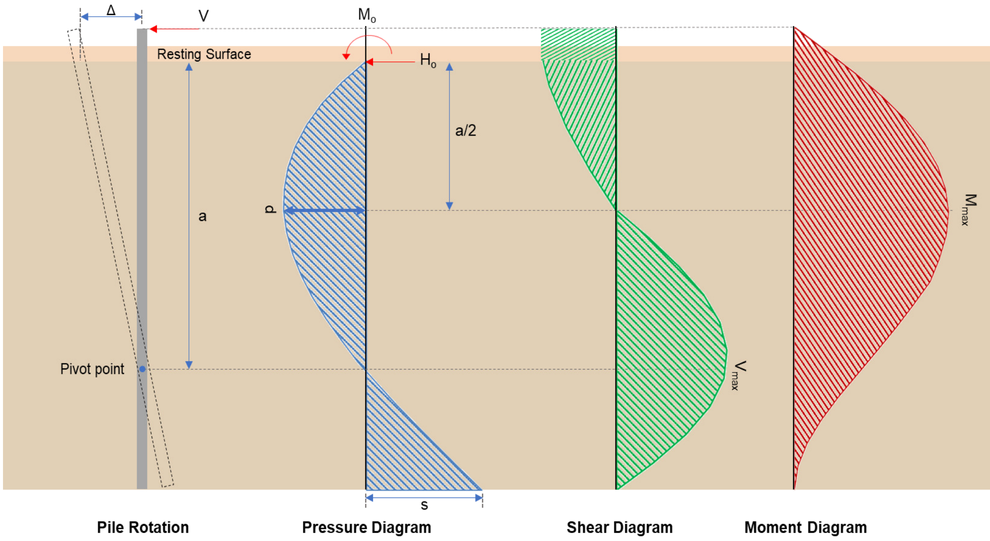
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0012739\ \mathrm{kip/ft^2}\right)}{\left(5.4\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0002359$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-9.195\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.4642\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(107.47\ \mathrm{kipft}) + ((-9.195\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 17.112\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(17.112\ \mathrm{kipft/ft})}{(-1.4642\ \mathrm{kip/ft})}$$

$$E = 11.687\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (17.112\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-1.4642\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{\quad}{(6 \times (17.112 \text{ kipft/ft})) + (4 \times (-1.4642 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0766 \text{ ft}$$

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

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

$$V_{max} = ((-1.4642 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.687 \text{ ft})}{(4.5 \text{ ft})} + 3\right) \times \left(\frac{(3.0766 \text{ ft})}{(4.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.687 \text{ ft})}{(4.5 \text{ ft})} + 2\right) \times \left(\frac{(3.0766 \text{ ft})}{(4.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 30.796 \text{ kip}$$

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

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

$$M_{max} = ((-1.4642 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(11.687 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0766 \text{ ft})}{2 \times (4.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.687 \text{ ft})}{(4.5 \text{ ft})} + 3\right) \times \left(\frac{(3.0766 \text{ ft})}{2 \times (4.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.687 \text{ ft})}{(4.5 \text{ ft})} + 2\right) \times \left(\frac{(3.0766 \text{ ft})}{2 \times (4.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 66.887 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

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

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

E - Distance from lateral load to resisting surface,

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

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

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

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.019586 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (-0.0068471 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (0.019586 \text{ kipft/ft})) + (4 \times (-0.0068471 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.192 \text{ ft}$$

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

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

$$V_{max} = ((-0.0068471\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.8605\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.192\ \text{ft})}{(4.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.8605\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.192\ \text{ft})}{(4.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.048991\ \text{kip}$$

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

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

$$M_{max} = ((-0.0068471\ \text{kip/ft}) \times (48\ \text{in}) \times (4.5\ \text{ft})) \times \left[\left(\frac{(2.8605\ \text{ft})}{(4.5\ \text{ft})} + \frac{(3.192\ \text{ft})}{2 \times (4.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.8605\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.192\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.8605\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.192\ \text{ft})}{2 \times (4.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.0992\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.145\ \text{kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(2304\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(2304\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -83.993\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-83.993\ \text{in}^2\right), \left(0.0018 \times \left(2304\ \text{in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.145\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0067827$$

Status: PASS
Ratio: 0.010

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 18.145 \text{ kip} \rightarrow 18145 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(18145 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.9 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.9 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.9 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((120.9 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.67 \text{ kip}$$

Considering x-direction:

$V_{max} = 30.796 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(30.796\ \mathrm{kip})}{(111.67\ \mathrm{kip})}$$ $$Ratio = 0.27578$$	Status: **PASS** Ratio: **0.280**
	Considering z-direction: $V_{max} = 0.048991\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.048991\ \mathrm{kip})}{(111.67\ \mathrm{kip})}$$ $$Ratio = 0.00043871$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 66.887\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(66.887\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.26798$$	Status: **PASS** Ratio: **0.270**
	Considering z-direction: $M_{max} = 0.0992\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.0992\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.00039743$$	Status: **PASS** Ratio: **0.000**