Your Project Calculations

Project Name: Beehive11a-JB-RevA

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Beehive11a-JB-RevA&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/8_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=YGy4QJlCcZdgIbX88hBSYaoDmqoUTKvacduqjmqwaYWgKg7BsnA7L81fY3ijebLT

Array Specification

Product:	Beam
Unique ID:	4P-19.75-10TOP-HD-45-L-5Hx10W-6GH5
Duty Classification:	HD
Module Width:	41.10 in
Module Length:	87.20in
Number of Rows:	5
Number of Columns:	10
Total Number of Modules:	50
Desired Tilt Angle:	46
Front Edge Clearance:	6
Total Array Height at Tilt:	18.39 ft
Total Frame Length:	74.25 ft
Frame Weight:	4326 lbs
Array Dimensions N/S:	17.33 ft
Array Dimensions E/W:	73.50 ft
Rail Length:	208.00 in
Rail Spacing:	3.68 ft
Rail Check:	PASS (40% utilized)

Support Specifications

Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	12.23 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø72 in
Foundation Depth (below grade):	Pile 1: 7.00 ft Pile 2: 7.25 ft Pile 3: 7.25 ft Pile 4: 7.00 ft
Foundation Volume:	29.845 y^3
Foundation Result:	PASSED
Mount Twist:	0.613735 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sandy_gravel
Site Location:	Big Sky, MT, USA
Wind Speed:	105 mph
Snow Load:	80 psf
Design Uplift Pressure:	0.017379 ksf
Design Downforce Pressure:	-0.017379 ksf
Design Snow Pressure:	0.021113 ksf

Design Disclaimer

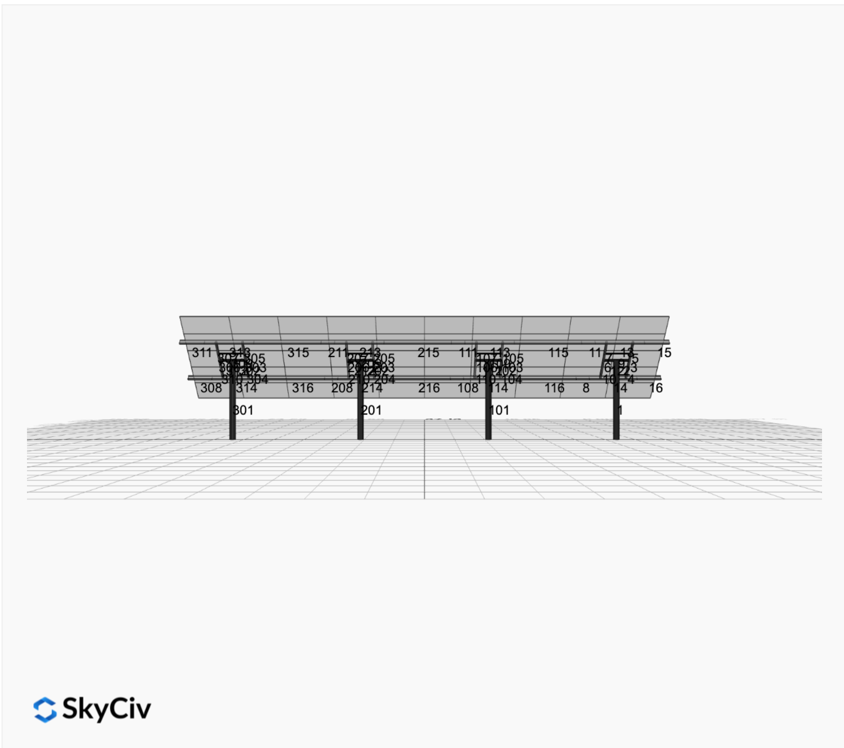
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

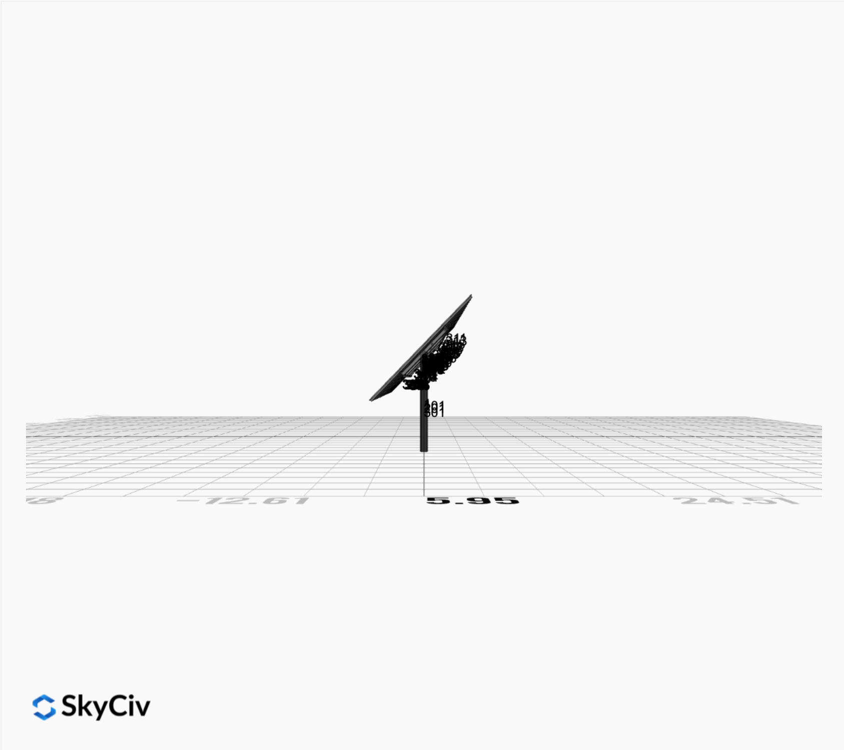
AutoDesigner Input

{"wind_speed_override":105,"snow_load_override":80,"direct_snow_load":false,"product_type":"Beam","project_id":"Beehive11a-JB-RevA","site_address":"Big Sky, MT, USA","module_width":41.1,"module_length":87.2,"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":46,"ground_clearance":6,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"10_40","soil_type":"sandy_gravel","customer_foundation_override":"48_Square","foundation_type":"Round","foundation_size":72,"check_rails":true}

Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent

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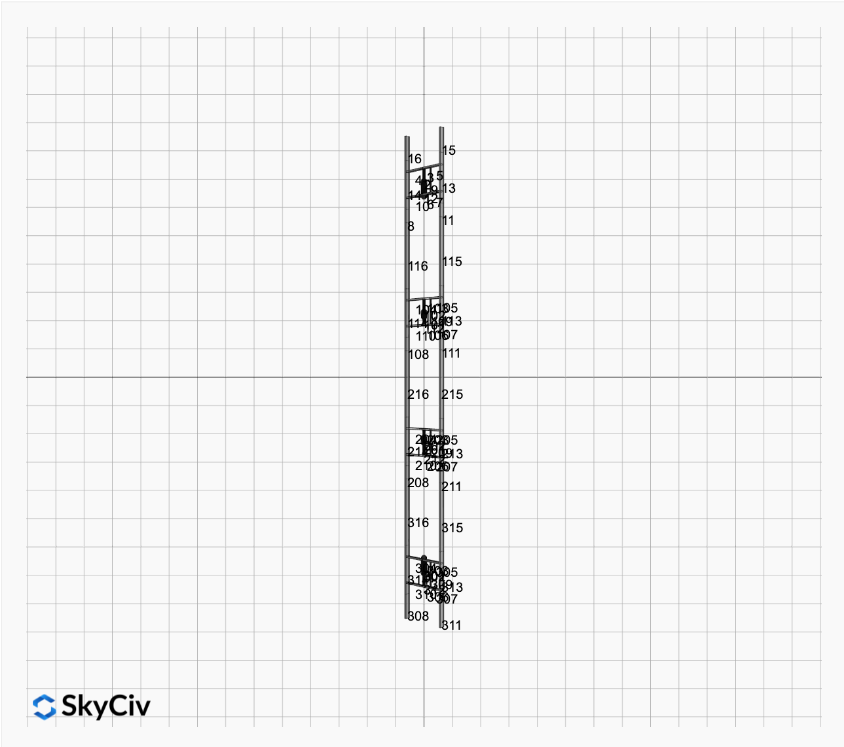
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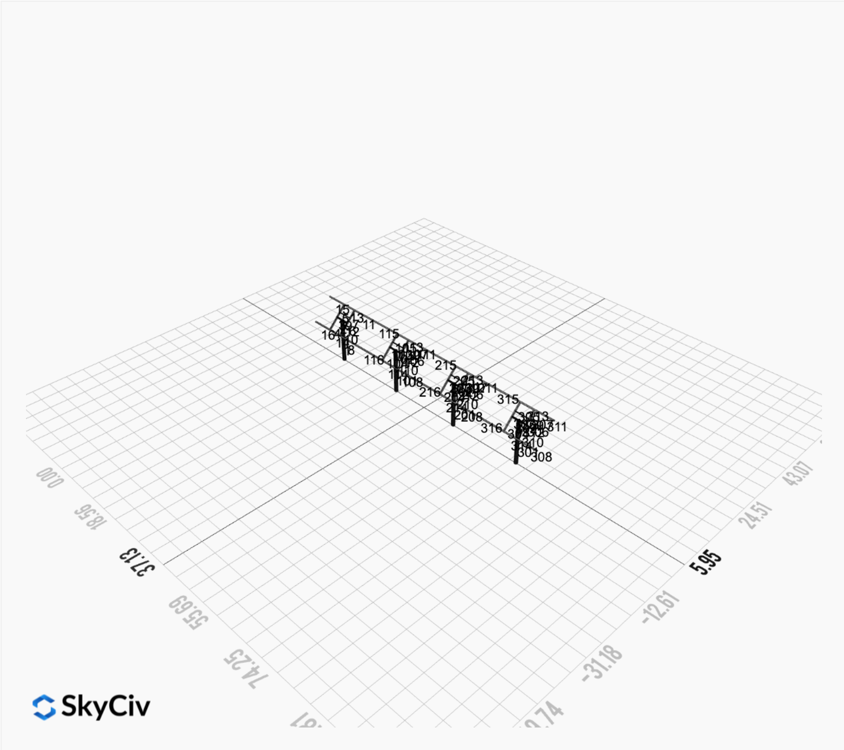
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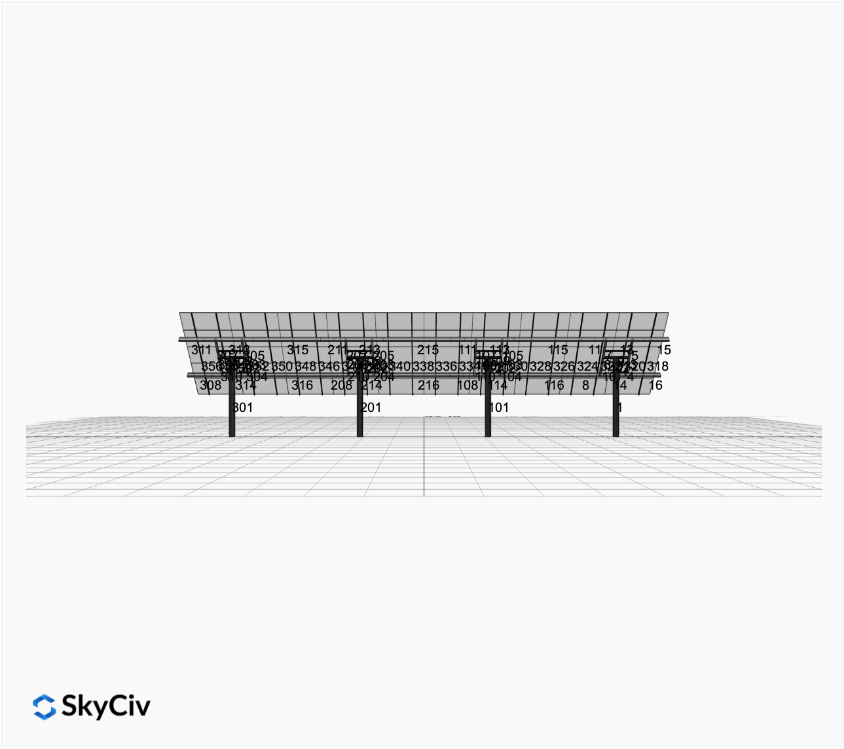
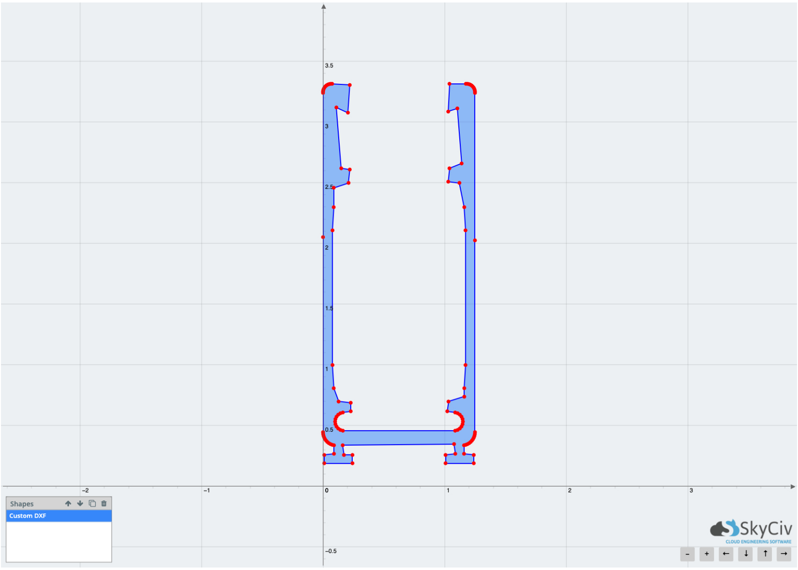
55.69
74.25
43.07
24.51
5.95
-12.61
-31.18
SkyCiv

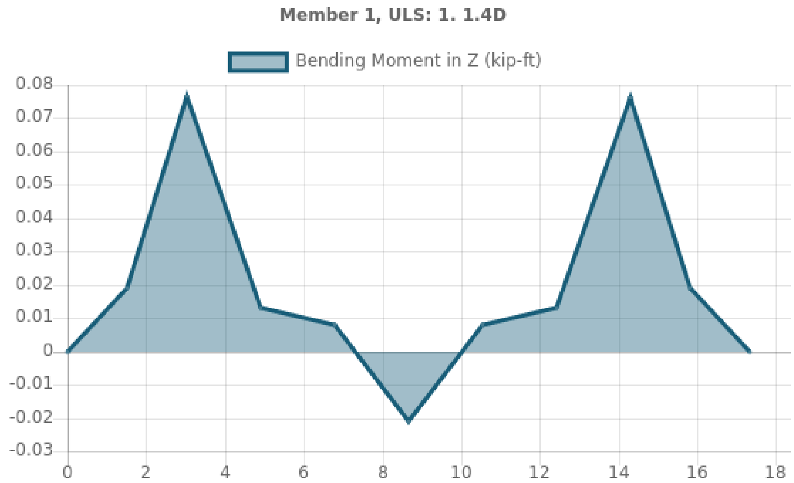

SkyCiv

Rail Design Check

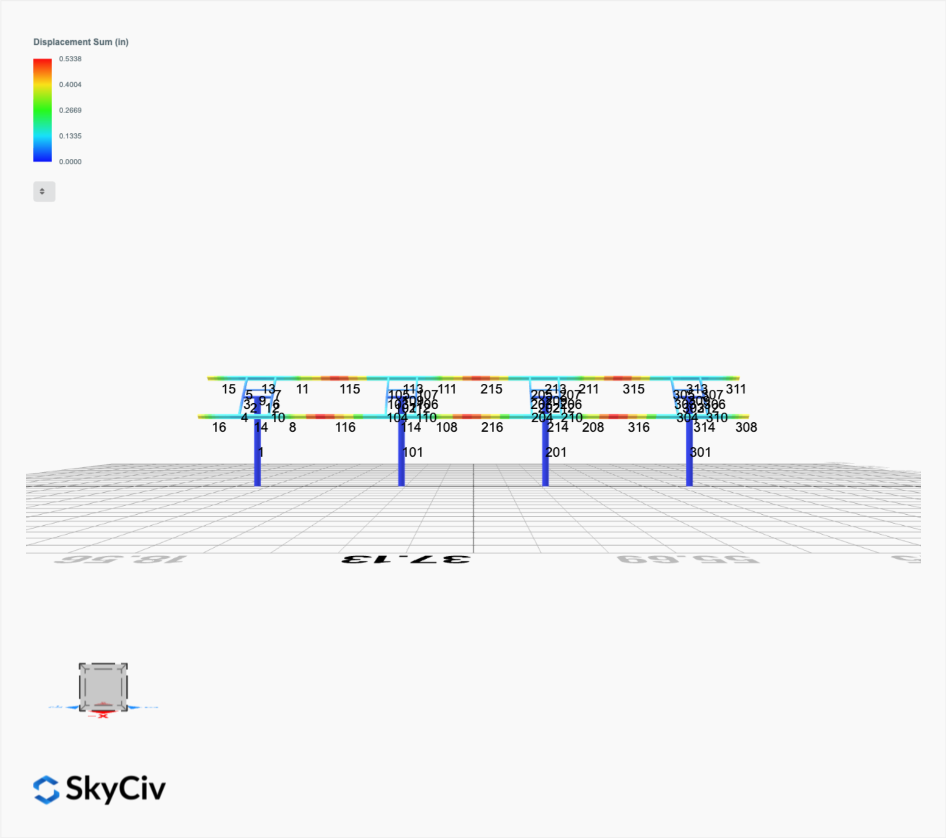
Rail Length: 17.333333333333332 ft
Additional Restraints Required: 4ft Spread Clamps
Tributary Width: 3.6750000000000003 ft
Material: Aluminium
Density: 169 lb/ft^3
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0539 kip/ft
Snow (Y): -0.0558 kip/ft
Wind uplift Case A: 0.0639 kip/ft
Wind downforce Case A: 0.0639 kip/ft
Dead (Panel load) (X): 0.0114 kip/ft
Dead (Panel load) (Y): -0.0118 kip/ft

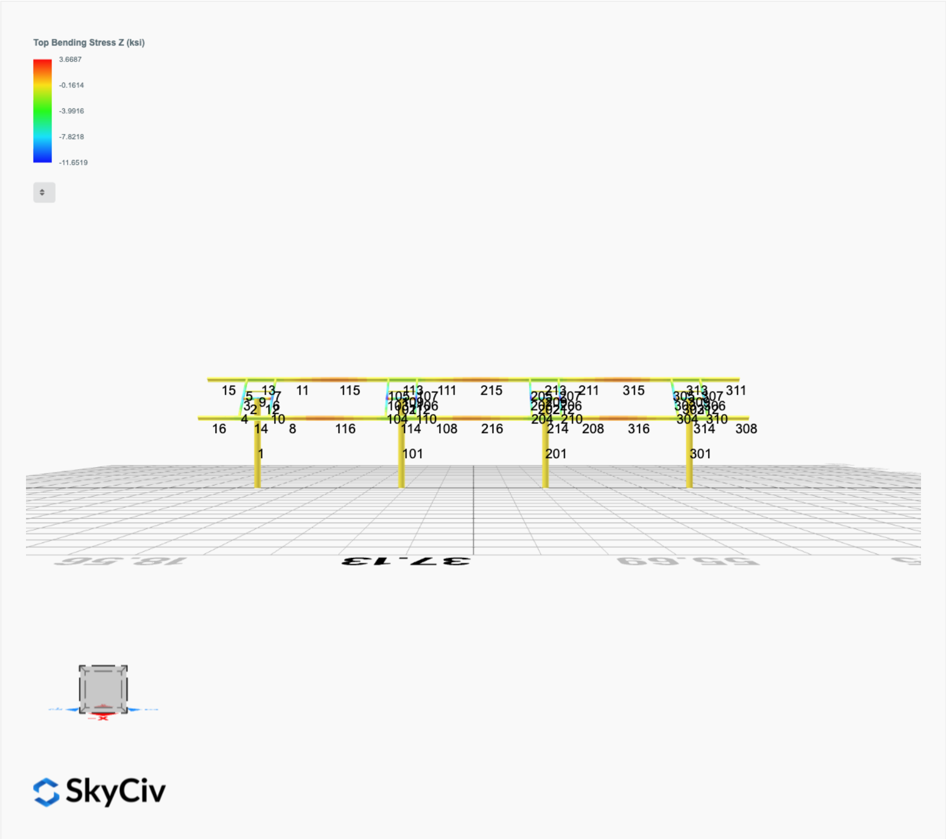


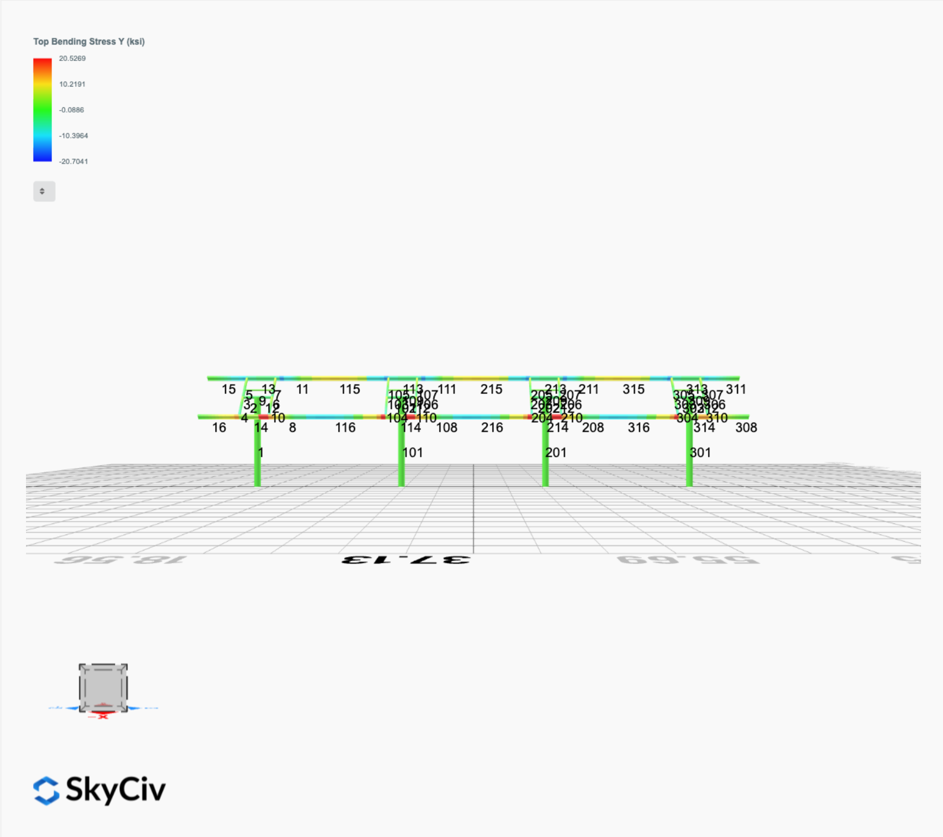
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	13.7368821	0.398	PASS
Material Yield	34.5	13.7368821	0.398	PASS
Material Strength	37	13.7368821	0.371	PASS

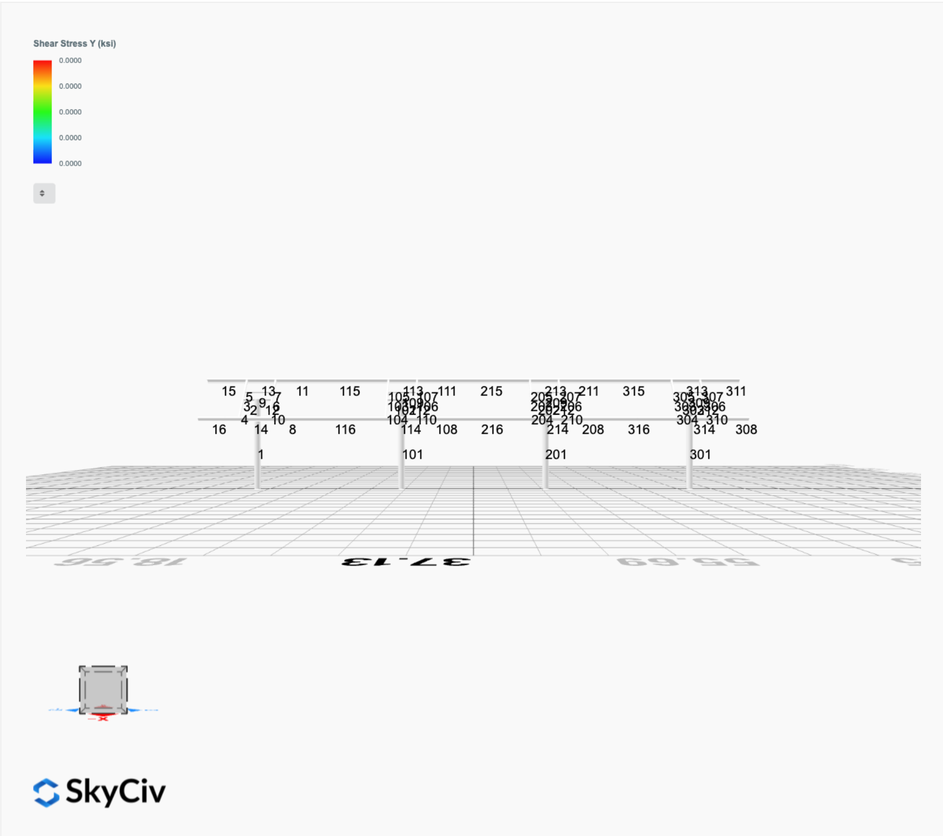


FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
20.5269
10.2191
-0.0886
-10.3964
-20.7041


Shear Stress Y (ksi)
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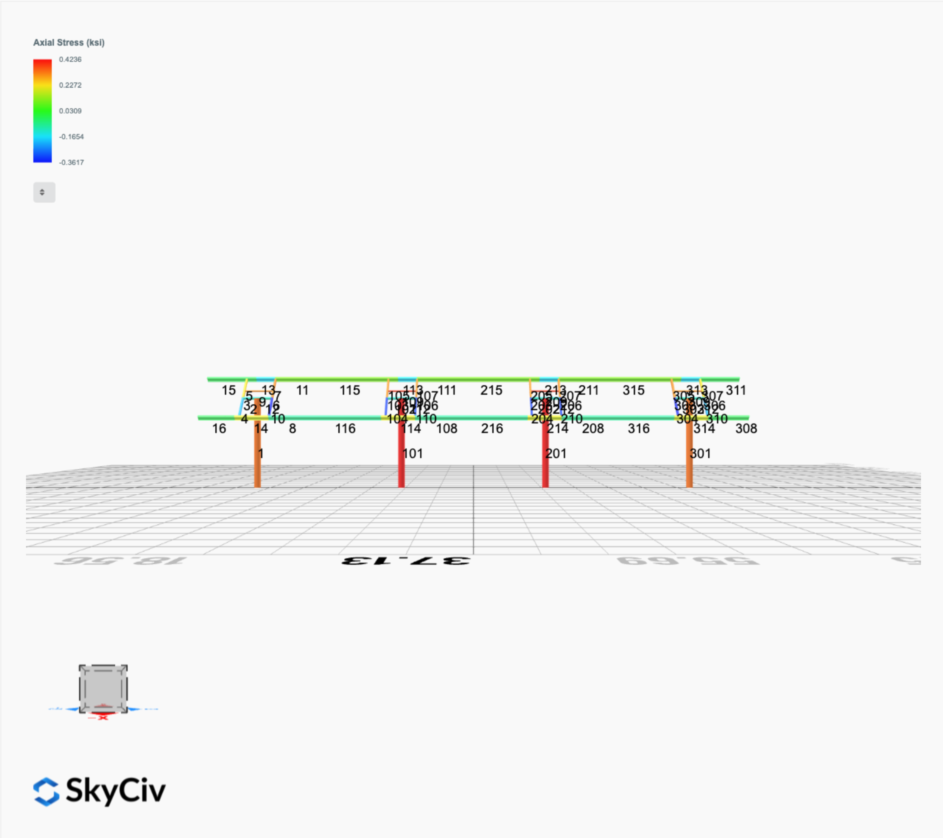
0.0000
0.0000
0.0000
0.0000



Axial Stress (ksi)
0.4236
0.2272
0.0309
-0.1654
-0.3617
15
11
115
111
215
211
315
311
16
14
8
116
114
108
216
214
208
316
314
308
1
101
201
301
37.13
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 2. D + L	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 3. D + (S or Lr or R)	0.0303	6.7756	0.1078	0.3656	-0.0199	-0.3141
ULS: 3. D + (S or Lr or R)	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0248	5.6771	0.0882	0.2992	-0.0162	-0.2547
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 5b. D + 0.7E	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0248	5.6771	0.0882	0.2992	-0.0162	-0.2547
ULS: 8. 0.6D + 0.7E	0.0050	1.4290	0.0177	0.0600	-0.0030	-0.0461
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.2229	4.5244	0.0845	0.2610	-0.3632	27.4267
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2390	0.2392	-0.0248	-0.0593	0.3497	-27.2709
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6486	7.2842	0.1294	0.4200	-0.2848	20.3729
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0248	5.6771	0.0882	0.2992	-0.0162	-0.2547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6978	4.0703	0.0475	0.1797	0.2499	-20.6503
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0248	5.6771	0.0882	0.2992	-0.0162	-0.2547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6651	3.9887	0.0708	0.2207	-0.2736	20.5508
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6814	0.7748	-0.0112	-0.0195	0.2610	-20.4724
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0083	2.3817	0.0296	0.0999	-0.0050	-0.0768
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2262	3.5718	0.0727	0.2210	-0.3612	27.4574
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0050	1.4290	0.0177	0.0600	-0.0030	-0.0461
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2357	-0.7135	-0.0366	-0.0993	0.3517	-27.2402
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0050	1.4290	0.0177	0.0600	-0.0030	-0.0461

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.6742
Shear X	-3.7394
Shear Z	0.2078
Moment X	0.6869
Moment Y (Twist)	0.6134
Moment Z	46.0511

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.2842
Shear X	-2.2390
Shear Z	0.1294
Moment X	0.4200
Moment Y (Twist)	0.3632
Moment Z	27.4574

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	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222
ULS: 2. D + L	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222
ULS: 3. D + (S or Lr or R)	-0.0303	7.6731	-0.0034	-0.0119	0.0179	0.4178
ULS: 3. D + (S or Lr or R)	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0248	6.4122	-0.0028	-0.0097	0.0146	0.3439
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222
ULS: 5b. D + 0.7E	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0248	6.4122	-0.0028	-0.0097	0.0146	0.3439
ULS: 8. 0.6D + 0.7E	-0.0050	1.5775	-0.0006	-0.0020	0.0030	0.0733
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.5552	5.1007	0.0051	0.0129	-0.0500	31.4266
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5391	0.1575	-0.0067	-0.0186	0.0576	-30.7954
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9350	8.2658	0.0017	0.0024	-0.0265	23.8221
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0248	6.4122	-0.0028	-0.0097	0.0146	0.3439
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8858	4.5583	-0.0071	-0.0212	0.0542	-22.8443
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0248	6.4122	-0.0028	-0.0097	0.0146	0.3439
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9185	4.4828	0.0036	0.0089	-0.0362	23.6005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9023	0.7754	-0.0052	-0.0148	0.0444	-23.0660
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0083	2.6292	-0.0009	-0.0033	0.0049	0.1222
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.5519	4.0490	0.0055	0.0142	-0.0519	31.3777
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0050	1.5775	-0.0006	-0.0020	0.0030	0.0733
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5424	-0.8942	-0.0063	-0.0173	0.0556	-30.8443
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0050	1.5775	-0.0006	-0.0020	0.0030	0.0733

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.2846
Shear X	-4.2652
Shear Z	-0.0122
Moment X	-0.0345
Moment Y (Twist)	0.1027
Moment Z	52.9924

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.2658
Shear X	-2.5552
Shear Z	-0.0071
Moment X	-0.0212
Moment Y (Twist)	0.0576
Moment Z	31.4266

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	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 2. D + L	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 3. D + (S or Lr or R)	-0.0303	7.6731	0.0034	0.0119	-0.0178	0.4178
ULS: 3. D + (S or Lr or R)	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0248	6.4122	0.0028	0.0097	-0.0145	0.3439
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 5b. D + 0.7E	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0248	6.4122	0.0028	0.0097	-0.0145	0.3439
ULS: 8. 0.6D + 0.7E	-0.0050	1.5775	0.0006	0.0020	-0.0029	0.0733
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.5552	5.1007	-0.0051	-0.0129	0.0500	31.4266
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5391	0.1575	0.0067	0.0186	-0.0576	-30.7954
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9350	8.2658	-0.0017	-0.0025	0.0266	23.8221
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0248	6.4122	0.0028	0.0097	-0.0145	0.3439
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8858	4.5583	0.0071	0.0212	-0.0541	-22.8443
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0248	6.4122	0.0028	0.0097	-0.0145	0.3439

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	-1.9185	4.4828	-0.0036	-0.0089	0.0363	23.6005
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9023	0.7754	0.0052	0.0148	-0.0444	-23.0660
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0083	2.6292	0.0009	0.0033	-0.0049	0.1222
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.5519	4.0490	-0.0055	-0.0142	0.0519	31.3777
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0050	1.5775	0.0006	0.0020	-0.0029	0.0733
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5424	-0.8942	0.0063	0.0173	-0.0556	-30.8443
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0050	1.5775	0.0006	0.0020	-0.0029	0.0733

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.2846
Shear X	-4.2652
Shear Z	0.0122
Moment X	0.0347
Moment Y (Twist)	0.1026
Moment Z	52.9924

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.2658
Shear X	-2.5552
Shear Z	0.0071
Moment X	0.0212
Moment Y (Twist)	0.0576
Moment Z	31.4266

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	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 2. D + L	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 3. D + (S or Lr or R)	0.0303	6.7756	-0.1078	-0.3658	0.0200	-0.3140
ULS: 3. D + (S or Lr or R)	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0248	5.6771	-0.0883	-0.2994	0.0162	-0.2547
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 5b. D + 0.7E	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0248	5.6771	-0.0883	-0.2994	0.0162	-0.2547
ULS: 8. 0.6D + 0.7E	0.0050	1.4290	-0.0177	-0.0600	0.0030	-0.0461
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.2229	4.5244	-0.0845	-0.2610	0.3632	27.4267
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2390	0.2392	0.0248	0.0593	-0.3497	-27.2709
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6486	7.2842	-0.1295	-0.4202	0.2848	20.3729
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0248	5.6771	-0.0883	-0.2994	0.0162	-0.2547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6978	4.0703	-0.0475	-0.1799	-0.2498	-20.6503
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0248	5.6771	-0.0883	-0.2994	0.0162	-0.2547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6651	3.9887	-0.0708	-0.2207	0.2737	20.5508
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6814	0.7748	0.0112	0.0195	-0.2610	-20.4724
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0083	2.3817	-0.0296	-0.1000	0.0050	-0.0768
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2262	3.5718	-0.0727	-0.2210	0.3612	27.4574
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0050	1.4290	-0.0177	-0.0600	0.0030	-0.0461
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2357	-0.7135	0.0366	0.0993	-0.3517	-27.2402
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0050	1.4290	-0.0177	-0.0600	0.0030	-0.0461

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	11.6742
Shear X	-3.7394
Shear Z	-0.2078
Moment X	-0.6875
Moment Y (Twist)	0.6137
Moment Z	46.0517

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

Result	Value (kip, kip-ft)
Axial	7.2842
Shear X	-2.2390
Shear Z	-0.1295
Moment X	-0.4202
Moment Y (Twist)	0.3632
Moment Z	27.4574

Project Details

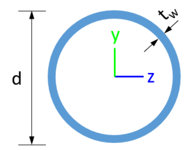
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Project Name:	Beehive11a-JB-RevA
Unit System:	imperial

Design Input Information

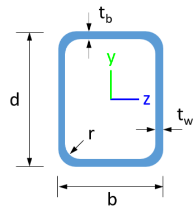
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

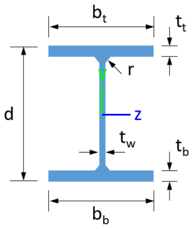
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
11	10in Pipe Sch 40	10.75	0.36					



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85

11	10in Pipe Sch 40	11.91	321.47	160.73	160.73	0.00	39.38	39.38
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	92.39	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	11	25.69	25.69	12.23	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
6	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
8	19	1.33	1.33	2.05	1.74,1.75,1.74,1.75,1.74,1.74,1.74,1.75,1.74,1.75,1.74,1.74,1.74,1.74,1.74,1.75,1.75,1.75,1.74,1.74,1.74,1.74,1.74,1.74,1.74,1.74	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
11	19	1.33	1.33	2.05	1.77,1.77,1.77,1.78,1.77,1.77,1.84,1.77,2.04,1.77,1.86,1.77,1.92,1.77,1.81,1.78,1.71,1.78,1.84,1.77,2.03,1.77,1.86,1.77,1.90,1.77	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.08,1.10,1.09,1.10,1.09,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.08,1.10,1.09,1.10,1.09,1.10	300	200	1
14	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.10,1.10,1.10,1.09,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.10,1.10,1.10,1.10,1.10	300	200	1
15	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	11	25.69	25.69	12.23	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	30	20	1

						0	0	
108	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.08,2.09,2.07,2.09,2.08,2.09,2.08,2.09,2.09,2.09,2.09,2.09,2.08,2.09,2.07,2.09,2.08,2.09,2.08,2.09	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
111	19	1.33	1.33	2.05	2.08,2.09,2.08,2.09,2.09,2.08,2.07,2.09,1.81,2.09,2.06,2.08,2.02,2.08,2.08,2.09,2.11,2.09,2.07,2.08,1.84,2.08,2.06,2.08,2.05,2.08	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1
113	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.07,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.05,1.04	300	200	1
114	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.05,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.05,1.04	300	200	1
115	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.12,1.15,1.14,1.15,1.13,1.15,1.15,1.15,1.17,1.15,1.14,1.15,1.12,1.15,1.14,1.15,1.13,1.15	300	200	1
116	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15	300	200	1
201	11	25.69	25.69	12.23	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
204	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
208	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.05,2.07,2.07,2.07,2.06,2.07,2.07,2.07,2.08,2.07,2.07,2.07,2.06,2.07,2.07,2.07,2.06,2.07	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
211	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.99,2.07,1.63,2.07,1.95,2.07,1.80,2.07,2.06,2.07,2.10,2.07,1.99,2.07,1.65,2.07,1.94,2.07,1.83,2.07	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.07,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.04,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.05,1.04	300	200	1
214	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.05,1.04,1.04,1.04,1.04,1.04,1.05,1.04,1.06,1.04,1.05,1.04,1.05,1.04	300	200	1
215	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.13,1.16,1.15,1.16,1.14,1.16,1.15,1.16,1.17,1.16,1.15,1.16,1.13,1.16,1.15,1.16,1.14,1.16	300	200	1
216	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.15,1.16,1.15,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.15,1.16,1.15,1.16	300	200	1
301	11	25.69	25.69	12.23	-	300	200	1

302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
305	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
308	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
311	19	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.08,1.10,1.09,1.10,1.09,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.08,1.10,1.09,1.10,1.09,1.10	300	200	1
314	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.10,1.10,1.10,1.09,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.10,1.10,1.10,1.10,1.10	300	200	1
315	19	6.63	6.63	10.20	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.15,1.13,1.13,1.13,1.14,1.13,1.13,1.13,1.12,1.13,1.13,1.13,1.15,1.13,1.13,1.13,1.14,1.13	300	200	1
316	19	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	535.87	320.22	147.68	147.68	160.76	160.76
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	126.01	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	24.75	6.12	40.24	43.62
14	133.20	104.94	24.98	6.12	40.24	43.62
15	133.20	52.83	32.87	6.12	40.24	43.62
16	133.20	52.83	32.87	6.12	40.24	43.62
101	535.87	320.22	147.68	147.68	160.76	160.76
102	198.33	196.72	21.95	21.95	59.50	59.50

103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	23.83	6.12	40.24	43.62
114	133.20	104.94	23.83	6.12	40.24	43.62
115	133.20	69.16	17.33	6.12	40.24	43.62
116	133.20	69.16	17.64	6.12	40.24	43.62
201	535.87	320.22	147.68	147.68	160.76	160.76
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	126.01	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	126.01	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	104.94	23.83	6.12	40.24	43.62
214	133.20	104.94	23.83	6.12	40.24	43.62
215	133.20	69.16	17.49	6.12	40.24	43.62
216	133.20	69.16	17.80	6.12	40.24	43.62
301	535.87	320.22	147.68	147.68	160.76	160.76
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	52.83	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	52.83	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	104.94	24.75	6.12	40.24	43.62
314	133.20	104.94	24.98	6.12	40.24	43.62
315	133.20	69.16	17.33	6.12	40.24	43.62
316	133.20	69.16	17.33	6.12	40.24	43.62

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.036	0.312	0.013	0.023	0.001	0.329	#13	0.420	Not Required	Pass
2	0.004	0.342	0.164	0.084	0.030	0.470	#21	0.035	Not Required	Pass
3	0.013	0.498	0.062	0.049	0.005	0.565	#21	0.045	Not Required	Pass

4	0.012	0.493	0.198	0.050	0.043	0.637	#21	0.080	Not Required	Pass
5	0.012	0.309	0.196	0.050	0.049	0.359	#21	0.074	Not Required	Pass
6	0.016	0.568	0.116	0.057	0.023	0.692	#21	0.045	Not Required	Pass
7	0.017	0.353	0.268	0.056	0.067	0.423	#21	0.074	Not Required	Pass
8	0.002	0.067	0.233	0.038	0.026	0.239	#23	0.095	Not Required	Pass
9	0.018	0.038	0.076	0.002	0.002	0.105	#21	0.204	Not Required	Pass
10	0.017	0.558	0.254	0.056	0.054	0.729	#21	0.080	Not Required	Pass
11	0.003	0.065	0.240	0.038	0.026	0.249	#21	0.095	Not Required	Pass
12	0.004	0.427	0.192	0.103	0.035	0.569	#21	0.035	Not Required	Pass
13	0.009	0.173	0.618	0.049	0.034	0.753	#21	0.286	Not Required	Pass
14	0.009	0.174	0.610	0.049	0.034	0.737	#21	0.190	Not Required	Pass
15	0.000	0.055	0.216	0.024	0.016	0.271	#21	Not Required	Not Required	Pass
16	0.000	0.055	0.216	0.024	0.016	0.271	#21	Not Required	Not Required	Pass
101	0.041	0.359	0.001	0.027	0.000	0.374	#13	0.420	Not Required	Pass
102	0.005	0.441	0.203	0.107	0.035	0.598	#21	0.035	Not Required	Pass
103	0.016	0.613	0.099	0.061	0.015	0.720	#21	0.045	Not Required	Pass
104	0.016	0.610	0.258	0.061	0.055	0.791	#21	0.080	Not Required	Pass
105	0.016	0.381	0.269	0.061	0.068	0.451	#21	0.074	Not Required	Pass
106	0.016	0.615	0.099	0.061	0.015	0.721	#21	0.045	Not Required	Pass
107	0.016	0.382	0.266	0.061	0.067	0.452	#21	0.074	Not Required	Pass
108	0.002	0.048	0.231	0.039	0.026	0.266	#21	0.095	Not Required	Pass
109	0.021	0.037	0.058	0.001	0.000	0.102	#21	0.204	Not Required	Pass
110	0.016	0.609	0.255	0.061	0.054	0.789	#21	0.080	Not Required	Pass
111	0.003	0.051	0.237	0.039	0.026	0.270	#21	0.095	Not Required	Pass
112	0.005	0.441	0.207	0.107	0.036	0.600	#21	0.035	Not Required	Pass
113	0.009	0.191	0.621	0.051	0.034	0.791	#21	0.286	Not Required	Pass
114	0.010	0.199	0.615	0.051	0.034	0.791	#21	0.286	Not Required	Pass
115	0.006	0.233	0.343	0.040	0.027	0.579	#21	0.473	Not Required	Pass
116	0.002	0.233	0.342	0.040	0.027	0.576	#21	0.473	Not Required	Pass
201	0.041	0.359	0.001	0.027	0.000	0.374	#13	0.420	Not Required	Pass
202	0.005	0.441	0.207	0.107	0.036	0.600	#21	0.035	Not Required	Pass
203	0.016	0.615	0.099	0.061	0.015	0.721	#21	0.045	Not Required	Pass
204	0.016	0.609	0.255	0.061	0.054	0.789	#21	0.080	Not Required	Pass
205	0.016	0.382	0.266	0.061	0.067	0.452	#21	0.074	Not Required	Pass
206	0.016	0.613	0.099	0.061	0.015	0.720	#21	0.045	Not Required	Pass
207	0.016	0.381	0.269	0.061	0.068	0.451	#21	0.074	Not Required	Pass
208	0.002	0.055	0.237	0.040	0.027	0.267	#21	0.095	Not Required	Pass
209	0.021	0.037	0.058	0.001	0.000	0.102	#21	0.204	Not Required	Pass
210	0.016	0.610	0.258	0.061	0.055	0.791	#21	0.080	Not Required	Pass
211	0.003	0.058	0.243	0.040	0.027	0.270	#21	0.095	Not Required	Pass
212	0.005	0.441	0.203	0.107	0.035	0.598	#21	0.035	Not Required	Pass
213	0.009	0.191	0.621	0.051	0.034	0.791	#21	0.286	Not Required	Pass
214	0.010	0.199	0.615	0.051	0.034	0.791	#21	0.286	Not Required	Pass
215	0.006	0.211	0.343	0.039	0.026	0.558	#21	0.473	Not Required	Pass
216	0.002	0.206	0.342	0.039	0.026	0.549	#21	0.473	Not Required	Pass
301	0.036	0.312	0.013	0.023	0.001	0.329	#13	0.420	Not Required	Pass
302	0.004	0.427	0.192	0.103	0.035	0.569	#21	0.035	Not Required	Pass
303	0.016	0.568	0.116	0.057	0.023	0.692	#21	0.045	Not Required	Pass
304	0.017	0.558	0.254	0.056	0.054	0.729	#21	0.080	Not Required	Pass
305	0.017	0.353	0.268	0.056	0.067	0.423	#21	0.074	Not Required	Pass
306	0.013	0.498	0.062	0.049	0.005	0.565	#21	0.045	Not Required	Pass
307	0.012	0.309	0.196	0.050	0.049	0.359	#21	0.074	Not Required	Pass
308	0.000	0.055	0.216	0.024	0.016	0.271	#21	Not Required	Not Required	Pass
309	0.018	0.038	0.076	0.002	0.002	0.105	#21	0.204	Not Required	Pass

309	0.018	0.058	0.070	0.002	0.002	0.105	#21	0.204	Not Required	Pass
310	0.012	0.493	0.198	0.050	0.043	0.637	#21	0.080	Not Required	Pass
311	0.000	0.055	0.216	0.024	0.016	0.271	#21	Not Required	Not Required	Pass
312	0.004	0.342	0.164	0.084	0.030	0.470	#21	0.035	Not Required	Pass
313	0.009	0.173	0.618	0.049	0.034	0.753	#21	0.190	Not Required	Pass
314	0.009	0.174	0.610	0.049	0.034	0.737	#21	0.286	Not Required	Pass
315	0.006	0.236	0.343	0.038	0.026	0.582	#21	0.473	Not Required	Pass
316	0.002	0.238	0.342	0.038	0.026	0.580	#21	0.473	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

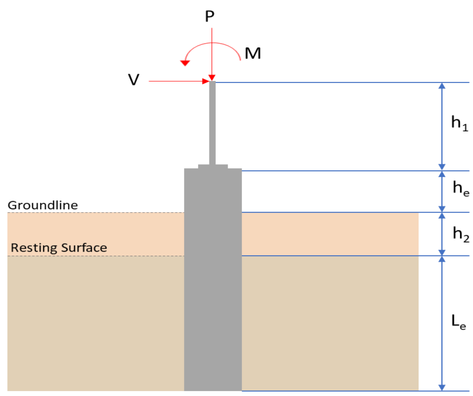
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round

$D = 72\ \mathrm{in}$ - Pile diameter

$L = 7\ \mathrm{ft}$ - 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	Sandy gravel and/or gravel	3000.000	200.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.284	11.674
V_x (kip)	-2.239	-3.739
V_z (kip)	0.129	0.208
M_x (kipft)	0.420	0.687
M_z (kipft)	27.457	46.051

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,

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

$$H_o = \frac{(-2.239\ \mathrm{kip})}{(72\ \mathrm{in})}$$

$$H_o = -0.37317\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.457\ \text{kipft}) + ((-2.239\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 4.5762\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.4021\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.129\ \text{kip})}{(72\ \text{in})}$$

$$H_o = 0.0215\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.42\ \text{kipft}) + ((0.129\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 0.07\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 2.1441\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.4021\ \text{ft}), (2.1441\ \text{ft})]$$

$$L_{e,req} = 6.402\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.402\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.91457$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(72\ \text{in})}{2}\right)^2$$

$$A = 28.274\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(7.284\ \text{kip})}{(28.274\ \text{ft}^2)}$$

$$q = 0.25762\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.25762\ \mathrm{kip/ft^2})}{(3000\ \mathrm{psf})}$$

$$Ratio = 0.085873$$

Status: **PASS**
Ratio: **0.090**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7\ \mathrm{ft})}{(72\ \mathrm{in})}$$

$$L/D = 1.1667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.37317\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.5762\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5762\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.37317\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (4.5762\ \mathrm{kipft/ft})) + (4 \times (-0.37317\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.8275\ \mathrm{ft}$$

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

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (4.5762\ \mathrm{kipft/ft})) + (3 \times (-0.37317\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^2}{(7\ \mathrm{ft})^2 \times [(3 \times (4.5762\ \mathrm{kipft/ft})) + (2 \times (-0.37317\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = 0.30978\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (4.5762\ \mathrm{kipft/ft})) + ((-0.37317\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = 1.258\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(4.8275\ \mathrm{ft})}{2}$$

$$p_a = 0.48275\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.30978\ \mathrm{kip/ft^2})}{(0.48275\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.64171$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (200\text{ psf/ft}) \times (7\text{ ft})$$

$$p_s = 1.4\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.258\text{ kip/ft}^2\right)}{\left(1.4\text{ kip/ft}^2\right)}$$

$$Ratio = 0.89856$$

Status: PASS
Ratio: 0.900

Considering z-direction:

$H_o = 0.0215\text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.07\text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.07\text{ kipft/ft}) \times (7\text{ ft})) + \left(3 \times (0.0215\text{ kip/ft}) \times (7\text{ ft})^2\right)}{(6 \times (0.07\text{ kipft/ft})) + (4 \times (0.0215\text{ kip/ft}) \times (7\text{ ft}))}$$

$$a = 5.0103\text{ ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.07\text{ kipft/ft})) + (3 \times (0.0215\text{ kip/ft}) \times (7\text{ ft}))]^{\,2}}{(7\text{ ft})^2 \times [(3 \times (0.07\text{ kipft/ft})) + (2 \times (0.0215\text{ kip/ft}) \times (7\text{ ft}))]}$$

$$p = 0.025174\text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.07\text{ kipft/ft})) + ((0.0215\text{ kip/ft}) \times (7\text{ ft}))]}{(7\text{ ft})^2}$$

$$s = 0.055877\text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (200\text{ psf/ft}) \times \frac{(5.0103\text{ ft})}{2}$$

$$p_a = 0.50103\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.025174\text{ kip/ft}^2\right)}{\left(0.50103\text{ kip/ft}^2\right)}$$

$$Ratio = 0.050245$$

Status: PASS
Ratio: 0.050

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (200\text{ psf/ft}) \times (7\text{ ft})$$

$$p_s = 1.4\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

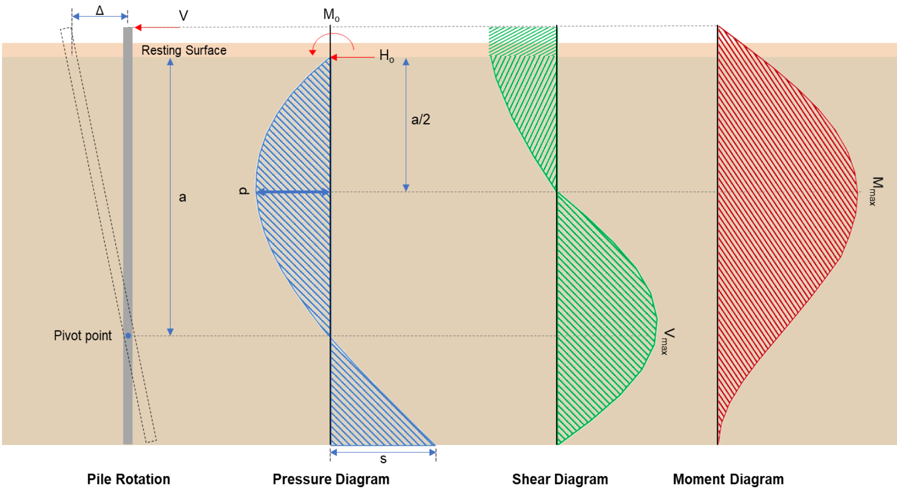
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{(0.055877\ \text{kip/ft}^2)}{(1.4\ \text{kip/ft}^2)}$$

$$Ratio = 0.039912$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.739\ \text{kip})}{(72\ \text{in})}$$

$$H_o = -0.62317\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(46.051\ \text{kipft}) + ((-3.739\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 7.6752\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.6752\ \text{kipft/ft})}{(-0.62317\ \text{kip/ft})}$$

$$E = 12.316\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.6752\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-0.62317\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (7.6752\ \text{kipft/ft})) + (4 \times (-0.62317\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.827\ \text{ft}$$

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

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

$$V_{max} = ((-0.62317\ \text{kip/ft}) \times (72\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.316\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.827\ \text{ft})}{(7\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.316\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.827\ \text{ft})}{(7\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.107 \text{ kip}$$

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

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

$$M_{max} = ((-0.62317 \text{ kip/ft}) \times (72 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(12.316 \text{ ft})}{(7 \text{ ft})} + \frac{(4.827 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (12.316 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.827 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.316 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.827 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 47 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.208 \text{ kip})}{(72 \text{ in})}$$

$$H_o = 0.034667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.687 \text{ kipft}) + ((0.208 \text{ kip}) \times (0 \text{ ft}))}{(72 \text{ in})}$$

$$M_o = 0.1145 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.1145 \text{ kipft/ft})}{(0.034667 \text{ kip/ft})}$$

$$E = 3.3029 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.1145 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (0.034667 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.1145 \text{ kipft/ft})) + (4 \times (0.034667 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0082 \text{ ft}$$

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

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

$$V_{max} = ((0.034667 \text{ kip/ft}) \times (72 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3029 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(5.0082 \text{ ft})}{(7 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.3029 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(5.0082 \text{ ft})}{(7 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.31237 \text{ kip}$$

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

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

$$M_{max} = ((0.034667 \text{ kip/ft}) \times (72 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.3029 \text{ ft})}{(7 \text{ ft})} + \frac{(5.0082 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.3029 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(5.0082 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.3029 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(5.0082 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.96353 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 4071.5 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.674 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(4071.5 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(4071.5 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -149.13 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-149.13 \text{ in}^2\right), \left(0.0018 \times \left(4071.5 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 7.3287 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(7.3287 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 24$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (24) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 7.3631 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(7.3287 \text{ in}^2\right)}{\left(7.3631 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

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 center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (72 \text{ in})\right]$$

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

Summary:

Main reinforcement: **24 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(4071.5\ \mathrm{in}^2\right) - \left(7.3631\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(7.3631\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 5015.6\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.674\ \mathrm{kip})}{(5015.6\ \mathrm{kip})}$$

$$Ratio = 0.0023275$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 72\ \mathrm{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (72\ \mathrm{in})$$

$$d = 57.6\ \mathrm{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(57.6\ \mathrm{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.54393$$

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

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

$$V_{c,max} = 5 \times (0.54393) \times \sqrt{(2500\ \mathrm{psi})} \times (72\ \mathrm{in}) \times (57.6\ \mathrm{in})$$

$$V_{c,max} = 563.94\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 11.674\ \mathrm{kip} \rightarrow 11674\ \mathrm{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.54393) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(11674\ \mathrm{lbf})}{6 \times \left(4071.5\ \mathrm{in}^2\right)}\right] \times (72\ \mathrm{in}) \times (57.6\ \mathrm{in})$$

$$V_{c,a} = 227.56\ \mathrm{kip}$$

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

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

$$V_{c,b} = \left[2 \times (0.54393) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (72\ \mathrm{in}) \times (57.6\ \mathrm{in})$$

$$V_{c,b} = 743.98\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(563.94\ \mathrm{kip}), (227.56\ \mathrm{kip}), (743.98\ \mathrm{kip})\right]$$

$$V_c = 227.56 \text{ kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (72 \text{ in}) \times (57.6 \text{ in})$$

$$V_{s,a} = 1658.9 \text{ kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (57.6 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 76.341 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(1658.9 \text{ kip}), (76.341 \text{ kip})\right]$$

$$V_s = 76.341 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((227.56 \text{ kip}) + (76.341 \text{ kip}))$$

$$\phi V_n = 197.54 \text{ kip}$$

Considering x-direction:

$V_{max} = 14.107 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.107 \text{ kip})}{(197.54 \text{ kip})}$$

$$Ratio = 0.071417$$

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

Considering z-direction:

$V_{max} = 0.31237 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.31237 \text{ kip})}{(197.54 \text{ kip})}$$

$$Ratio = 0.0015813$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (72 \text{ in})^3}{32}$$

$$S_m = 36644 \text{ in}^3$$

	$S_m = 36644\ \text{in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 36643.536in^3$$ $$\phi M_{n,1} = 496.215kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(36644\ \text{in}^3\right)$$ $$\phi M_{n,2} = 4217.8\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(496.21\ \text{kipft}), (4217.8\ \text{kipft})]$$ $$\phi M_n = 496.21\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 47\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(47\ \text{kipft})}{(496.21\ \text{kipft})}$$ $$Ratio = 0.094715$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $M_{max} = 0.96353\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.96353\ \text{kipft})}{(496.21\ \text{kipft})}$$ $$Ratio = 0.0019418$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

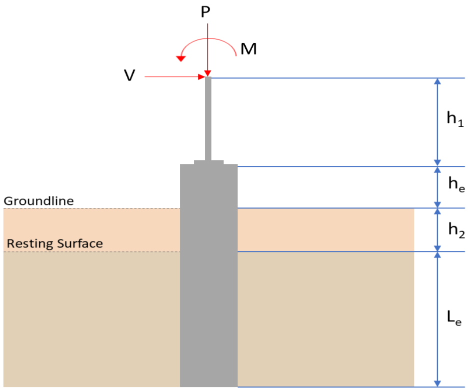
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 72\ \mathrm{in}$ - Pile diameter
$L = 7\ \mathrm{ft}$ - 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	Sandy gravel and/or gravel	3000.000	200.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.284	11.674
V_x (kip)	-2.239	-3.739
V_z (kip)	-0.129	-0.208
M_x (kipft)	-0.420	-0.688
M_z (kipft)	27.457	46.052

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,

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

$$H_o = \frac{(-2.239\ \mathrm{kip})}{(72\ \mathrm{in})}$$

$$H_o = -0.37317\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.457\ \text{kipft}) + ((-2.239\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 4.5762\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.4021\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.129\ \text{kip})}{(72\ \text{in})}$$

$$H_o = -0.0215\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.42\ \text{kipft}) + ((-0.129\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 0.07\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.6075\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.4021\ \text{ft}), (1.6075\ \text{ft})]$$

$$L_{e,req} = 6.402\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.402\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.91457$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(72\ \text{in})}{2}\right)^2$$

$$A = 28.274\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(7.284\ \text{kip})}{(28.274\ \text{ft}^2)}$$

$$q = 0.25762 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.25762 \text{ kip/ft}^2)}{(3000 \text{ psf})}$$

$$Ratio = 0.085873$$

Status: **PASS**
Ratio: **0.090**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(72 \text{ in})}$$

$$L/D = 1.1667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.37317 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 4.5762 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5762 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.37317 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (4.5762 \text{ kipft/ft})) + (4 \times (-0.37317 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8275 \text{ ft}$$

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

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (4.5762 \text{ kipft/ft})) + (3 \times (-0.37317 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (4.5762 \text{ kipft/ft})) + (2 \times (-0.37317 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.30978 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (4.5762 \text{ kipft/ft})) + ((-0.37317 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.258 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (200 \text{ psf/ft}) \times \frac{(4.8275 \text{ ft})}{2}$$

$$p_a = 0.48275 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.30978 \text{ kip/ft}^2)}{(0.48275 \text{ kip/ft}^2)}$$

$$Ratio = 0.64171$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.4\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.258\ \mathrm{kip/ft^2})}{(1.4\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.89856$$

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

Considering z-direction:

$H_o = -0.0215\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.07\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.07\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.0215\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (0.07\ \mathrm{kipft/ft})) + (4 \times (-0.0215\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 5.0103\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.07\ \mathrm{kipft/ft})) + (3 \times (-0.0215\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^{\ 2}}{(7\ \mathrm{ft})^2 \times [(3 \times (0.07\ \mathrm{kipft/ft})) + (2 \times (-0.0215\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = -0.0077703\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.07\ \mathrm{kipft/ft})) + ((-0.0215\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = -0.0020196\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(5.0103\ \mathrm{ft})}{2}$$

$$p_a = 0.50103\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.0077703\ \mathrm{kip/ft^2})}{(0.50103\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.015509$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.4\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

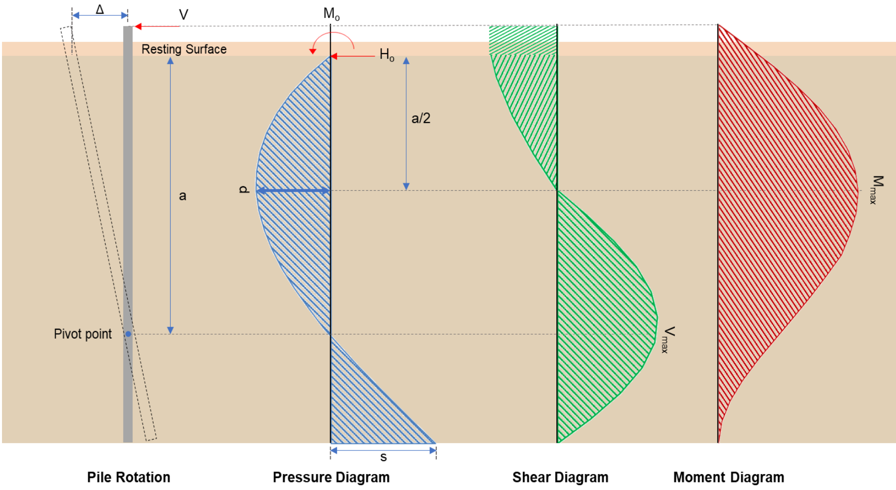
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(-0.0020196\ \mathrm{kip/ft^2}\right)}{\left(1.4\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0014426$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.739\ \mathrm{kip})}{(72\ \mathrm{in})}$$

$$H_o = -0.62317\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(46.052\ \mathrm{kipft}) + ((-3.739\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(72\ \mathrm{in})}$$

$$M_o = 7.6753\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.6753\ \mathrm{kipft/ft})}{(-0.62317\ \mathrm{kip/ft})}$$

$$E = 12.317\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.6753\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.62317\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (7.6753\ \mathrm{kipft/ft})) + (4 \times (-0.62317\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.827\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.62317\ \mathrm{kip/ft}) \times (72\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.317\ \mathrm{ft})}{(7\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.827\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.317\ \mathrm{ft})}{(7\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.827\ \mathrm{ft})}{(7\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.108 \text{ kip}$$

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

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

$$M_{max} = ((-0.62317 \text{ kip/ft}) \times (72 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(12.317 \text{ ft})}{(7 \text{ ft})} + \frac{(4.827 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.317 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.827 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.317 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.827 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 47 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.208 \text{ kip})}{(72 \text{ in})}$$

$$H_o = -0.034667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.688 \text{ kipft}) + ((-0.208 \text{ kip}) \times (0 \text{ ft}))}{(72 \text{ in})}$$

$$M_o = 0.11467 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.11467 \text{ kipft/ft})}{(-0.034667 \text{ kip/ft})}$$

$$E = 3.3077 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.11467 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.034667 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.11467 \text{ kipft/ft})) + (4 \times (-0.034667 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.008 \text{ ft}$$

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

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

$$V_{max} = ((-0.034667 \text{ kip/ft}) \times (72 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3077 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.008 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.3077 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.008 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.31262 \text{ kip}$$

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

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

$$M_{max} = ((-0.034667 \text{ kip/ft}) \times (72 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.3077 \text{ ft})}{(7 \text{ ft})} + \frac{(5.008 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.3077 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.008 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.3077 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.008 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.9644 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 4071.5 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.674 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (4071.5 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (4071.5 \text{ in}^2))\right]$$

$$A_{st,required} = -149.13 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-149.13 \text{ in}^2), (0.0018 \times (4071.5 \text{ in}^2))\right]$$

$$A_{min} = 7.3287 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(7.3287 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 24$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (24) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 7.3631 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.3287 \text{ in}^2)}{(7.3631 \text{ in}^2)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

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 center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (72 \text{ in})\right]$$

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

Summary:

Main reinforcement: **24 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(4071.5\ \text{in}^2\right) - \left(7.3631\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(7.3631\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 5015.6\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.674\ \text{kip})}{(5015.6\ \text{kip})}$$

$$Ratio = 0.0023275$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 72\ \text{in}$ - Effective width,
22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (72\ \text{in})$$

$$d = 57.6\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(57.6\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.54393$$

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

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

$$V_{c,max} = 5 \times (0.54393) \times \sqrt{(2500\ \text{psi})} \times (72\ \text{in}) \times (57.6\ \text{in})$$

$$V_{c,max} = 563.94\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 11.674\ \text{kip} \rightarrow 11674\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.54393) \times \sqrt{(2500\ \text{psi})} + \frac{(11674\ \text{lbf})}{6 \times \left(4071.5\ \text{in}^2\right)}\right] \times (72\ \text{in}) \times (57.6\ \text{in})$$

$$V_{c,a} = 227.56\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.54393) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (72\ \text{in}) \times (57.6\ \text{in})$$

$$V_{c,b} = 743.98\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(563.94\ \text{kip}), (227.56\ \text{kip}), (743.98\ \text{kip})\right]$$

$$V_c = 227.56\ \mathrm{kip}$$

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

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \mathrm{psi})} \times (72\ \mathrm{in}) \times (57.6\ \mathrm{in})$$

$$V_{s,a} = 1658.9\ \mathrm{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \mathrm{in}^2\right) \times (60\ \mathrm{ksi}) \times (57.6\ \mathrm{in})}{(10\ \mathrm{in})}$$

$$V_{s,b} = 76.341\ \mathrm{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(1658.9\ \mathrm{kip}), (76.341\ \mathrm{kip})\right]$$

$$V_s = 76.341\ \mathrm{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((227.56\ \mathrm{kip}) + (76.341\ \mathrm{kip}))$$

$$\phi V_n = 197.54\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 14.108\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.108\ \mathrm{kip})}{(197.54\ \mathrm{kip})}$$

$$Ratio = 0.071418$$

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

Considering z-direction:

$V_{max} = 0.31262\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.31262\ \mathrm{kip})}{(197.54\ \mathrm{kip})}$$

$$Ratio = 0.0015826$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (72\ \mathrm{in})^3}{32}$$

$$S_m = 36644\ \mathrm{in}^3$$

	$$S_m = 36644 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 36643.536in^3$$ $$\phi M_{n,1} = 496.215kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi \, 0.85 \, f_{ck}' \, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(36644 \text{ in}^3\right)$$ $$\phi M_{n,2} = 4217.8 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(496.21 \text{ kipft}), (4217.8 \text{ kipft})]$$ $$\phi M_n = 496.21 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 47$ kipft - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(47 \text{ kipft})}{(496.21 \text{ kipft})}$$ $$Ratio = 0.094717$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $M_{max} = 0.9644$ kipft - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.9644 \text{ kipft})}{(496.21 \text{ kipft})}$$ $$Ratio = 0.0019435$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

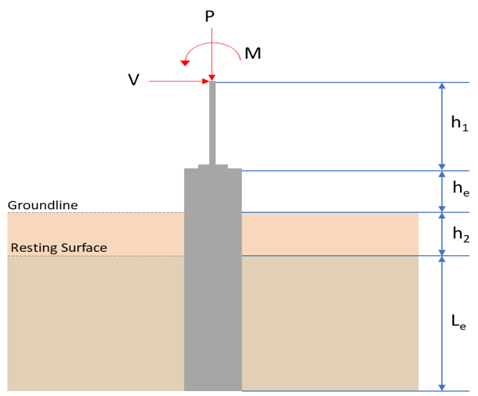
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 72\ \text{in}$ - Pile diameter
$L = 7.25\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sandy gravel and/or gravel	3000.000	200.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.266	13.285
V_x (kip)	-2.555	-4.265
V_z (kip)	-0.007	-0.012
M_x (kipft)	-0.021	-0.035
M_z (kipft)	31.427	52.992

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,

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

$$H_o = \frac{(-2.555\ \text{kip})}{(72\ \text{in})}$$

$$H_o = -0.42583\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.427\ \text{kipft}) + ((-2.555\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 5.2378\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.6462\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.007\ \text{kip})}{(72\ \text{in})}$$

$$H_o = -0.0011667\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.021\ \text{kipft}) + ((-0.007\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 0.0035\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.6511\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.6462\ \text{ft}), (0.6511\ \text{ft})]$$

$$L_{e,req} = 6.646\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.646\ \text{ft})}{(7.25\ \text{ft})}$$

$$Ratio = 0.91669$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(72\ \text{in})}{2}\right)^2$$

$$A = 28.274\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(8.266\ \text{kip})}{(28.274\ \text{ft}^2)}$$

$$q = 0.29235\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.29235\ \mathrm{kip/ft^2}\right)}{(3000\ \mathrm{psf})}$$

$$Ratio = 0.09745$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25\ \mathrm{ft})}{(72\ \mathrm{in})}$$

$$L/D = 1.2083$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.42583\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.2378\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.2378\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (5.2378\ \mathrm{kipft/ft})) + (4 \times (-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.0038\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (5.2378\ \mathrm{kipft/ft})) + (3 \times (-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (5.2378\ \mathrm{kipft/ft})) + (2 \times (-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.32104\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (5.2378\ \mathrm{kipft/ft})) + ((-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 1.3248\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(5.0038\ \mathrm{ft})}{2}$$

$$p_a = 0.50038\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.32104\ \mathrm{kip/ft^2}\right)}{\left(0.50038\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.6416$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.45\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.3248\ \mathrm{kip/ft^2}\right)}{\left(1.45\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91366$$

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

Considering z-direction:

$H_o = -0.0011667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0035\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0035\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.0035\ \mathrm{kipft/ft})) + (4 \times (-0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.2061\ \mathrm{ft}$$

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

$$p = \frac{1.178\, \left[(4\, M_o) + (3\, H_o\, L_e)\right]^2}{L_e^2\, \left[(3\, M_o) + (2\, H_o\, L_e)\right]}$$

$$p = \frac{1.178 \times \left[(4 \times (0.0035\ \mathrm{kipft/ft})) + (3 \times (-0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))\right]^2}{(7.25\ \mathrm{ft})^2 \times \left[(3 \times (0.0035\ \mathrm{kipft/ft})) + (2 \times (-0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))\right]}$$

$$p = -0.00045192\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, \left[(2\, M_o) + (H_o\, L_e)\right]}{L_e^2}$$

$$s = \frac{9.425 \times \left[(2 \times (0.0035\ \mathrm{kipft/ft})) + ((-0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))\right]}{(7.25\ \mathrm{ft})^2}$$

$$s = -0.00026149\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(5.2061\ \mathrm{ft})}{2}$$

$$p_a = 0.52061\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00045192\ \mathrm{kip/ft^2}\right)}{\left(0.52061\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00086806$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.45\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

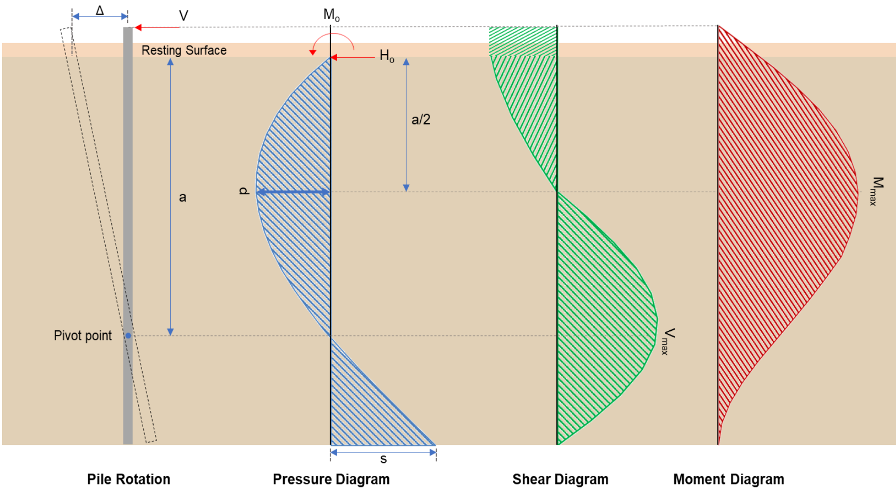
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(-0.00026149\ \text{kip/ft}^2\right)}{\left(1.45\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.00018034$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.265\ \text{kip})}{(72\ \text{in})}$$

$$H_o = -0.71083\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(52.992\ \text{kipft}) + ((-4.265\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 8.832\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.832\ \text{kipft/ft})}{(-0.71083\ \text{kip/ft})}$$

$$E = 12.425\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.832\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (-0.71083\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (8.832\ \text{kipft/ft})) + (4 \times (-0.71083\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 5.0025\ \text{ft}$$

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

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

$$V_{max} = ((-0.71083\ \text{kip/ft}) \times (72\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.425\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(5.0025\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.425\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(5.0025\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.747 \text{ kip}$$

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

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

$$M_{max} = ((-0.71083 \text{ kip/ft}) \times (72 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(12.425 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.0025 \text{ ft})}{2 \times (7.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.425 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left(\frac{(5.0025 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.425 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left(\frac{(5.0025 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 54.275 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.012 \text{ kip})}{(72 \text{ in})}$$

$$H_o = -0.002 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.035 \text{ kipft}) + ((-0.012 \text{ kip}) \times (0 \text{ ft}))}{(72 \text{ in})}$$

$$M_o = 0.0058333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0058333 \text{ kipft/ft})}{(-0.002 \text{ kip/ft})}$$

$$E = 2.9167 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0058333 \text{ kipft/ft}) \times (7.25 \text{ ft})) + \left(3 \times (-0.002 \text{ kip/ft}) \times (7.25 \text{ ft})^2\right)}{(6 \times (0.0058333 \text{ kipft/ft})) + (4 \times (-0.002 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.2101 \text{ ft}$$

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

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

$$V_{max} = ((-0.002 \text{ kip/ft}) \times (72 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.9167 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left(\frac{(5.2101 \text{ ft})}{(7.25 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.9167 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left(\frac{(5.2101 \text{ ft})}{(7.25 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.016565 \text{ kip}$$

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

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

$$M_{max} = ((-0.002 \text{ kip/ft}) \times (72 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(2.9167 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.2101 \text{ ft})}{2 \times (7.25 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.9167 \text{ ft})}{(7.25 \text{ ft})} + 3 \right) \times \left(\frac{(5.2101 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.9167 \text{ ft})}{(7.25 \text{ ft})} + 2 \right) \times \left(\frac{(5.2101 \text{ ft})}{2 \times (7.25 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.052308 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 4071.5 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.285 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (4071.5 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (4071.5 \text{ in}^2))\right]$$

$$A_{st,required} = -149.08 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-149.08 \text{ in}^2), (0.0018 \times (4071.5 \text{ in}^2))\right]$$

$$A_{min} = 7.3287 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(7.3287 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 24$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (24) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 7.3631 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.3287 \text{ in}^2)}{(7.3631 \text{ in}^2)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

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 center-to-center spacing of ties,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (72 \text{ in})\right]$$

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

Summary:

Main reinforcement: **24 - #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 $$\phi P_N = \phi\, 0.85\, \left[\left(0.85\, f'_{ck}\, [A_g - A_{st}]\right) + (f_{yk}\, A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(4071.5\ \text{in}^2\right) - \left(7.3631\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(7.3631\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 5015.6\ \text{kip}$$	
	$Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.285\ \text{kip})}{(5015.6\ \text{kip})}$$ $$Ratio = 0.0026487$$	Status: **PASS** Ratio: **0.000**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 72\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (72\ \text{in})$$ $$d = 57.6\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(57.6\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.54393$$ 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 $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.54393) \times \sqrt{(2500\ \text{psi})} \times (72\ \text{in}) \times (57.6\ \text{in})$$ $$V_{c,max} = 563.94\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 13.285\ \text{kip} \rightarrow 13285\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.54393) \times \sqrt{(2500\ \text{psi})} + \frac{(13285\ \text{lbf})}{6 \times (4071.5\ \text{in}^2)}\right] \times (72\ \text{in}) \times (57.6\ \text{in})$$ $$V_{c,a} = 227.83\ \text{kip}$$ 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) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.54393) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (72\ \text{in}) \times (57.6\ \text{in})$$ $$V_{c,b} = 743.98\ \text{kip}$$	
	V_c - Governing shear strength of concrete $$V_c = Min\,[V_{c,max}, V_{c,a}, V_{c,b}]$$ $$V_c = Min\,[(563.94\ \text{kip}), (227.83\ \text{kip}), (743.98\ \text{kip})]$$	

$$V_c = 227.83\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (72\ \text{in}) \times (57.6\ \text{in})$$

$$V_{s,a} = 1658.9\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (57.6\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 76.341\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(1658.9\ \text{kip}), (76.341\ \text{kip})\right]$$

$$V_s = 76.341\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((227.83\ \text{kip}) + (76.341\ \text{kip}))$$

$$\phi V_n = 197.71\ \text{kip}$$

Considering x-direction:

$V_{max} = 15.747\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.747\ \text{kip})}{(197.71\ \text{kip})}$$

$$Ratio = 0.079644$$

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

Considering z-direction:

$V_{max} = 0.016565\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.016565\ \text{kip})}{(197.71\ \text{kip})}$$

$$Ratio = 0.000083781$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\ D^3}{32}$$

$$S_m = \frac{\pi \times (72\ \text{in})^3}{32}$$

$$S_m = 36644\ \text{in}^3$$

	$S_m = 36644 \text{ in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 36643.536in^3$$ $$\phi M_{n,1} = 496.215kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(36644 \text{ in}^3\right)$$ $$\phi M_{n,2} = 4217.8 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(496.21 \text{ kipft}), (4217.8 \text{ kipft})]$$ $$\phi M_n = 496.21 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 54.275 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(54.275 \text{ kipft})}{(496.21 \text{ kipft})}$$ $$Ratio = 0.10938$$	Status: **PASS** Ratio: **0.110**
	Considering z-direction: $M_{max} = 0.052308 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.052308 \text{ kipft})}{(496.21 \text{ kipft})}$$ $$Ratio = 0.00010541$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

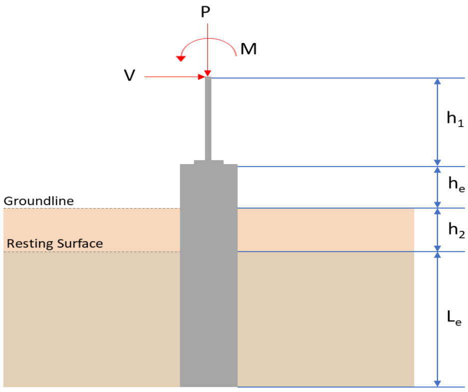
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 72\ \mathrm{in}$ - Pile diameter
$L = 7.25\ \mathrm{ft}$ - 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) $(\mathrm{psf/ft})$
1	Sandy gravel and/or gravel	3000.000	200.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.266	13.285
V_x (kip)	-2.555	-4.265
V_z (kip)	0.007	0.012
M_x (kipft)	0.021	0.035
M_z (kipft)	31.427	52.992

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,

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

$$H_o = \frac{(-2.555\ \mathrm{kip})}{(72\ \mathrm{in})}$$

$$H_o = -0.42583\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(31.427 \text{ kipft}) + ((-2.555 \text{ kip}) \times (0 \text{ ft}))}{(72 \text{ in})}$$

$$M_o = 5.2378 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.6462 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.007 \text{ kip})}{(72 \text{ in})}$$

$$H_o = 0.0011667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.021 \text{ kipft}) + ((0.007 \text{ kip}) \times (0 \text{ ft}))}{(72 \text{ in})}$$

$$M_o = 0.0035 \text{ kipft/ft}$$

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:
$L_{e,z} = 0.73082 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.6462 \text{ ft}), (0.73082 \text{ ft})]$$

$$L_{e,req} = 6.646 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.25 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.646 \text{ ft})}{(7.25 \text{ ft})}$$

$$Ratio = 0.91669$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(72 \text{ in})}{2}\right)^2$$

$$A = 28.274 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(8.266 \text{ kip})}{(28.274 \text{ ft}^2)}$$

$$q = 0.29235\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.29235\ \mathrm{kip/ft^2})}{(3000\ \mathrm{psf})}$$

$$Ratio = 0.09745$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25\ \mathrm{ft})}{(72\ \mathrm{in})}$$

$$L/D = 1.2083$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.42583\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.2378\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.2378\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (5.2378\ \mathrm{kipft/ft})) + (4 \times (-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.0038\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (5.2378\ \mathrm{kipft/ft})) + (3 \times (-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (5.2378\ \mathrm{kipft/ft})) + (2 \times (-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.32104\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (5.2378\ \mathrm{kipft/ft})) + ((-0.42583\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 1.3248\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(5.0038\ \mathrm{ft})}{2}$$

$$p_a = 0.50038\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.32104\ \mathrm{kip/ft^2})}{(0.50038\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.6416$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.45\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.3248\ \mathrm{kip/ft^2}\right)}{\left(1.45\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91366$$

Status: PASS
Ratio: 0.910

Considering z-direction:

$H_o = 0.0011667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0035\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0035\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.0035\ \mathrm{kipft/ft})) + (4 \times (0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.2061\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.0035\ \mathrm{kipft/ft})) + (3 \times (0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^{\,2}}{(7.25\ \mathrm{ft})^2 \times [(3 \times (0.0035\ \mathrm{kipft/ft})) + (2 \times (0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.0012673\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.0035\ \mathrm{kipft/ft})) + ((0.0011667\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 0.0027718\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (200\ \mathrm{psf/ft}) \times \frac{(5.2061\ \mathrm{ft})}{2}$$

$$p_a = 0.52061\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0012673\ \mathrm{kip/ft^2}\right)}{\left(0.52061\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0024343$$

Status: PASS
Ratio: 0.000

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (200\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.45\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

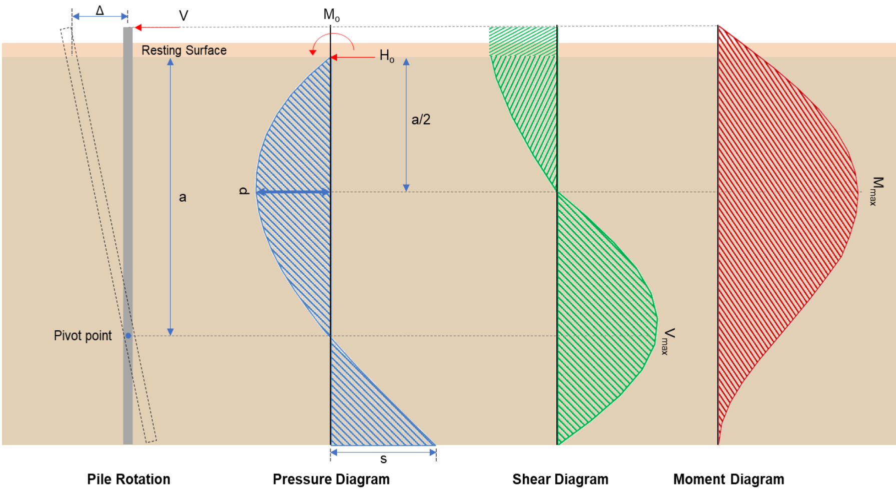
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{(0.0027718\ \text{kip}/\text{ft}^2)}{(1.45\ \text{kip}/\text{ft}^2)}$$

$$Ratio = 0.0019116$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.265\ \text{kip})}{(72\ \text{in})}$$

$$H_o = -0.71083\ \text{kip}/\text{ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(52.992\ \text{kipft}) + ((-4.265\ \text{kip}) \times (0\ \text{ft}))}{(72\ \text{in})}$$

$$M_o = 8.832\ \text{kipft}/\text{ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.832\ \text{kipft}/\text{ft})}{(-0.71083\ \text{kip}/\text{ft})}$$

$$E = 12.425\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.832\ \text{kipft}/\text{ft}) \times (7.25\ \text{ft})) + \left(3 \times (-0.71083\ \text{kip}/\text{ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (8.832\ \text{kipft}/\text{ft})) + (4 \times (-0.71083\ \text{kip}/\text{ft}) \times (7.25\ \text{ft}))}$$

$$a = 5.0025\ \text{ft}$$

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

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

$$V_{max} = ((-0.71083\ \text{kip}/\text{ft}) \times (72\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.425\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(5.0025\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.425\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(5.0025\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.747 \text{ kip}$$

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

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

$$M_{max} = ((-0.71083 \text{ kip/ft}) \times (72 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(12.425 \text{ ft})}{(7.25 \text{ ft})}+\frac{(5.0025 \text{ ft})}{2\times(7.25 \text{ ft})}\right) - \left[\left(\frac{4\times(12.425 \text{ ft})}{(7.25 \text{ ft})}+3\right)\times\left(\frac{(5.0025 \text{ ft})}{2\times(7.25 \text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(12.425 \text{ ft})}{(7.25 \text{ ft})}+2\right)\times\left(\frac{(5.0025 \text{ ft})}{2\times(7.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 54.275 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.012 \text{ kip})}{(72 \text{ in})}$$

$$H_o = 0.002 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.035 \text{ kipft}) + ((0.012 \text{ kip}) \times (0 \text{ ft}))}{(72 \text{ in})}$$

$$M_o = 0.0058333 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0058333 \text{ kipft/ft})}{(0.002 \text{ kip/ft})}$$

$$E = 2.9167 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0058333 \text{ kipft/ft}) \times (7.25 \text{ ft})) + \left(3 \times (0.002 \text{ kip/ft}) \times (7.25 \text{ ft})^2\right)}{(6 \times (0.0058333 \text{ kipft/ft})) + (4 \times (0.002 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.2101 \text{ ft}$$

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

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

$$V_{max} = ((0.002 \text{ kip/ft}) \times (72 \text{ in})) \times \left[1 - \left[3\times\left(\frac{4\times(2.9167 \text{ ft})}{(7.25 \text{ ft})}+3\right)\times\left(\frac{(5.2101 \text{ ft})}{(7.25 \text{ ft})}\right)^2\right] + \left[4\times\left(\frac{3\times(2.9167 \text{ ft})}{(7.25 \text{ ft})}+2\right)\times\left(\frac{(5.2101 \text{ ft})}{(7.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.016565 \text{ kip}$$

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

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

$$M_{max} = ((0.002 \text{ kip/ft}) \times (72 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(2.9167 \text{ ft})}{(7.25 \text{ ft})}+\frac{(5.2101 \text{ ft})}{2\times(7.25 \text{ ft})}\right) - \left[\left(\frac{4\times(2.9167 \text{ ft})}{(7.25 \text{ ft})}+3\right)\times\left(\frac{(5.2101 \text{ ft})}{2\times(7.25 \text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(2.9167 \text{ ft})}{(7.25 \text{ ft})}+2\right)\times\left(\frac{(5.2101 \text{ ft})}{2\times(7.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.052308 \text{ kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 4071.5 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.285 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(4071.5 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(4071.5 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -149.08 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-149.08 \text{ in}^2\right), \left(0.0018 \times \left(4071.5 \text{ in}^2\right)\right)\right]$$

$$A_{min} = 7.3287 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(7.3287 \text{ in}^2\right)}{\left(0.3068 \text{ in}^2\right)}$$

$$n_{rebar} = 24$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (24) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 7.3631 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(7.3287 \text{ in}^2\right)}{\left(7.3631 \text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (72 \text{ in})\right]$$

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

Summary:

	Main reinforcement: **24 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(4071.5\ \mathrm{in}^2\right) - \left(7.3631\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(7.3631\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 5015.6\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.285\ \mathrm{kip})}{(5015.6\ \mathrm{kip})}$$

$$Ratio = 0.0026487$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 72\ \mathrm{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (72\ \mathrm{in})$$

$$d = 57.6\ \mathrm{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(57.6\ \mathrm{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.54393$$

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

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

$$V_{c,max} = 5 \times (0.54393) \times \sqrt{(2500\ \mathrm{psi})} \times (72\ \mathrm{in}) \times (57.6\ \mathrm{in})$$

$$V_{c,max} = 563.94\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 13.285\ \mathrm{kip} \rightarrow 13285\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.54393) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(13285\ \mathrm{lbf})}{6 \times \left(4071.5\ \mathrm{in}^2\right)}\right] \times (72\ \mathrm{in}) \times (57.6\ \mathrm{in})$$

$$V_{c,a} = 227.83\ \mathrm{kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.54393) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (72\ \mathrm{in}) \times (57.6\ \mathrm{in})$$

$$V_{c,b} = 743.98\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(563.94\ \mathrm{kip}), (227.83\ \mathrm{kip}), (743.98\ \mathrm{kip})\right]$$

$$V_c = 227.83\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (72\ \text{in}) \times (57.6\ \text{in})$$

$$V_{s,a} = 1658.9\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (57.6\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 76.341\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(1658.9\ \text{kip}), (76.341\ \text{kip})\right]$$

$$V_s = 76.341\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((227.83\ \text{kip}) + (76.341\ \text{kip}))$$

$$\phi V_n = 197.71\ \text{kip}$$

Considering x-direction:

$V_{max} = 15.747\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.747\ \text{kip})}{(197.71\ \text{kip})}$$

$$Ratio = 0.079644$$

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

Considering z-direction:

$V_{max} = 0.016565\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.016565\ \text{kip})}{(197.71\ \text{kip})}$$

$$Ratio = 0.000083781$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (72\ \text{in})^3}{32}$$

$$S_m = 36644\ \text{in}^3$$

$$S_m = 36644 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),
Allowable flexural strength:
M_n shall be the lesser of:
$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 36643.536in^3$$

$$\phi M_{n,1} = 496.215kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(36644 \text{ in}^3\right)$$

$$\phi M_{n,2} = 4217.8 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(496.21 \text{ kipft}), (4217.8 \text{ kipft})]$$

$$\phi M_n = 496.21 \text{ kipft}$$

Considering x-direction:

$M_{max} = 54.275 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(54.275 \text{ kipft})}{(496.21 \text{ kipft})}$$

$$Ratio = 0.10938$$

Status: **PASS**
Ratio: **0.110**

Considering z-direction:

$M_{max} = 0.052308 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.052308 \text{ kipft})}{(496.21 \text{ kipft})}$$

$$Ratio = 0.00010541$$

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