Project Details

Project Name: MTSOLAR_90EK4F5EGEDL 4x11 46deg Struts - V1Jb

Location: Embar, WY 82443, USA

Unique ID: 4P-19.75-8TOP-XD-12-L-4Hx11W-D34C

Dealer: ______________________________

Date: Tue May 06 2025

Number of Modules: 44

Number of Poles: 4

Date Sold:

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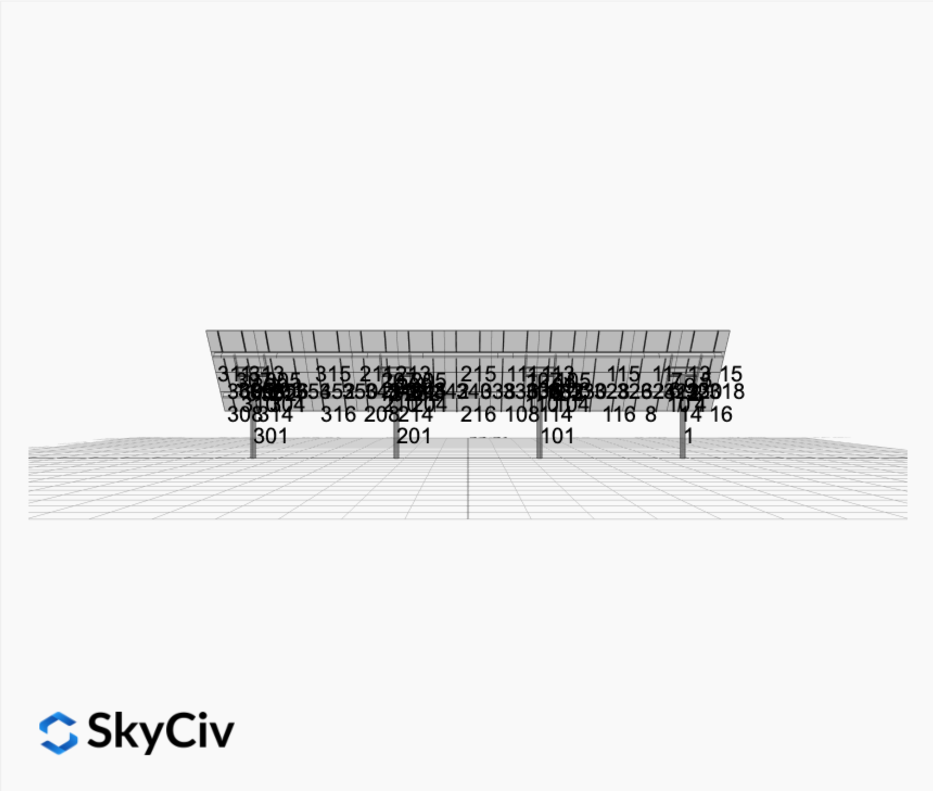


Array Dimensions N/S	15.05 ft
Array Dimensions E/W	69.81 ft
Winter Tilt Angle	46
Front Edge Clearance	6 ft

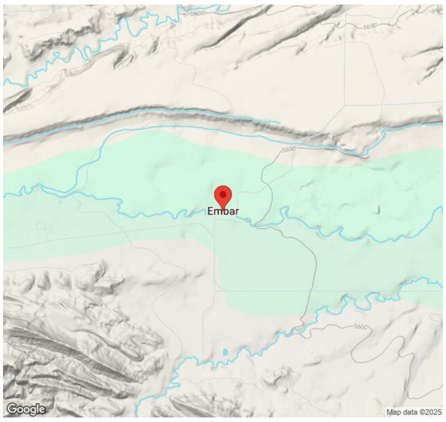
MT Solar Bill of Materials (4P-19.75-8TOP-XD-12-L-4Hx11W-D34C)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-12	12IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-HOOK-4PK	Hook Clamp	11

Rail Bill of Materials

Part	Qty
Rails (181in)	22
Rail Attachment	44
Module Mid Clamp	66
Module End Clamp	44
Ground Lug	11

Site Details:



Site Address: Embar, WY 82443, USA

Array Specification

Duty Classification:	XD
Module Width:	44.65 in
Module Length:	75.16in
Number of Rows:	4
Number of Columns:	11
Total Number of Modules:	44
Winter Tilt Angle:	46
Front Edge Clearance:	6
Total Array Height at Tilt:	16.83 ft
Total Frame Length:	68.75 ft
Module Info/Notes:	
Array Dimensions N/S:	15.05 ft
Array Dimensions E/W:	69.81 ft
Rail Length:	180.60 in
Rail Spacing:	3.17 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	11.41 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 8.75 ft Pile 2: No solution Pile 3: No solution Pile 4: 8.75 ft
Foundation Volume:	6.152 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Embar, WY 82443, USA
Wind Speed:	120 mph

Snow Load:	100 psf

Design Disclaimer

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

AutoDesigner Input

{"wind_speed_override":120,"snow_load_override":100,"direct_snow_load":false,"add_angle_brace":true,"product_type":"Beam","designer_name":"Luke","designer_email":"luke@cesolar.com","designer_phone":"","project_id":"MTSOLAR_90EK4F5EGEDL 4x11 46deg Struts - V1Jb","site_address":"Embar, WY 82443,
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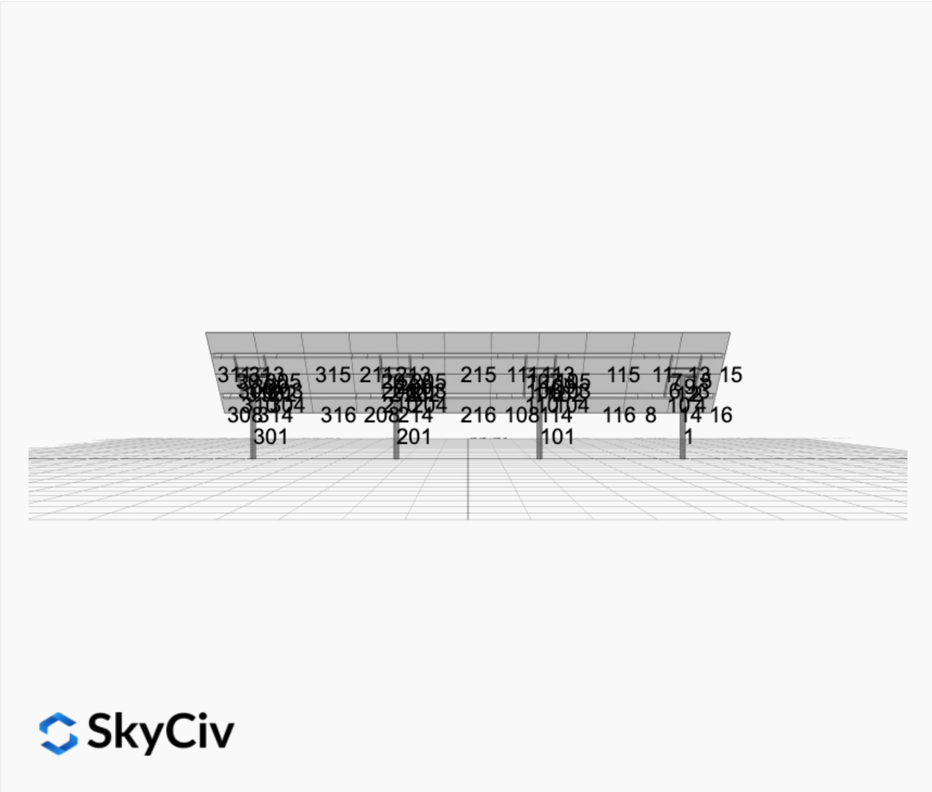
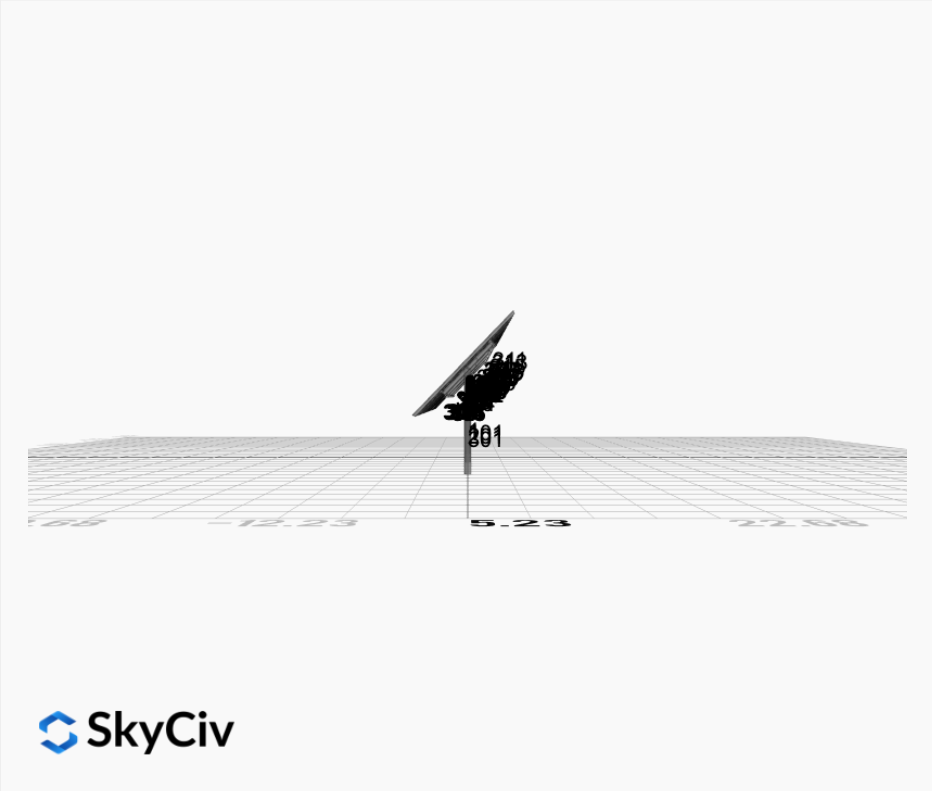
Design Notes:

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

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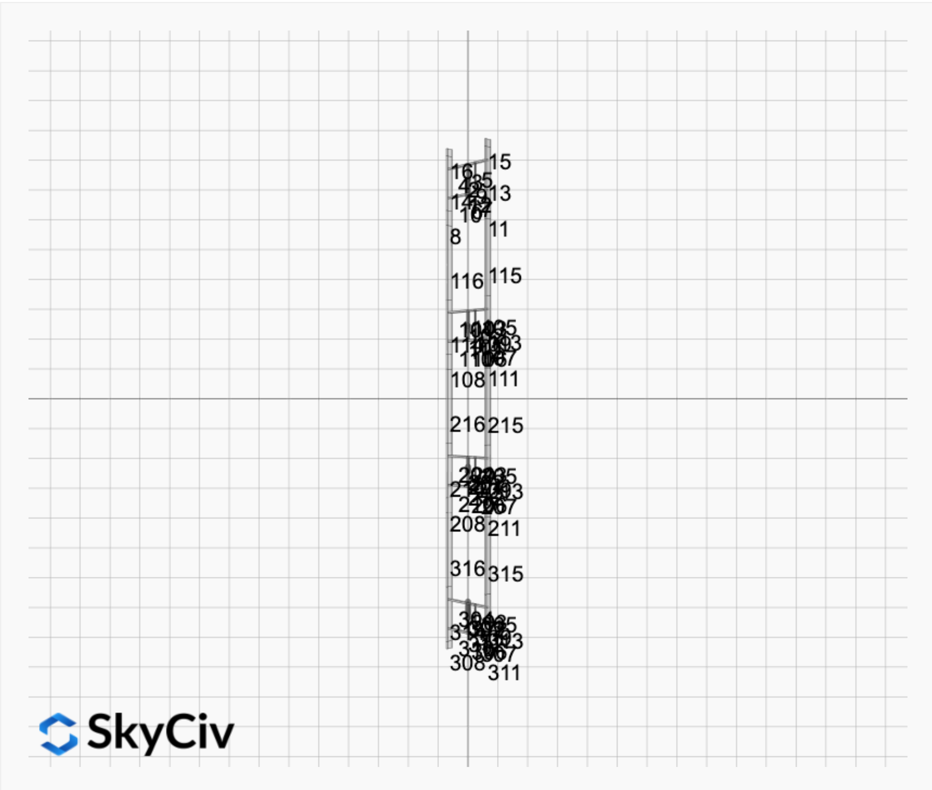
SkyCiv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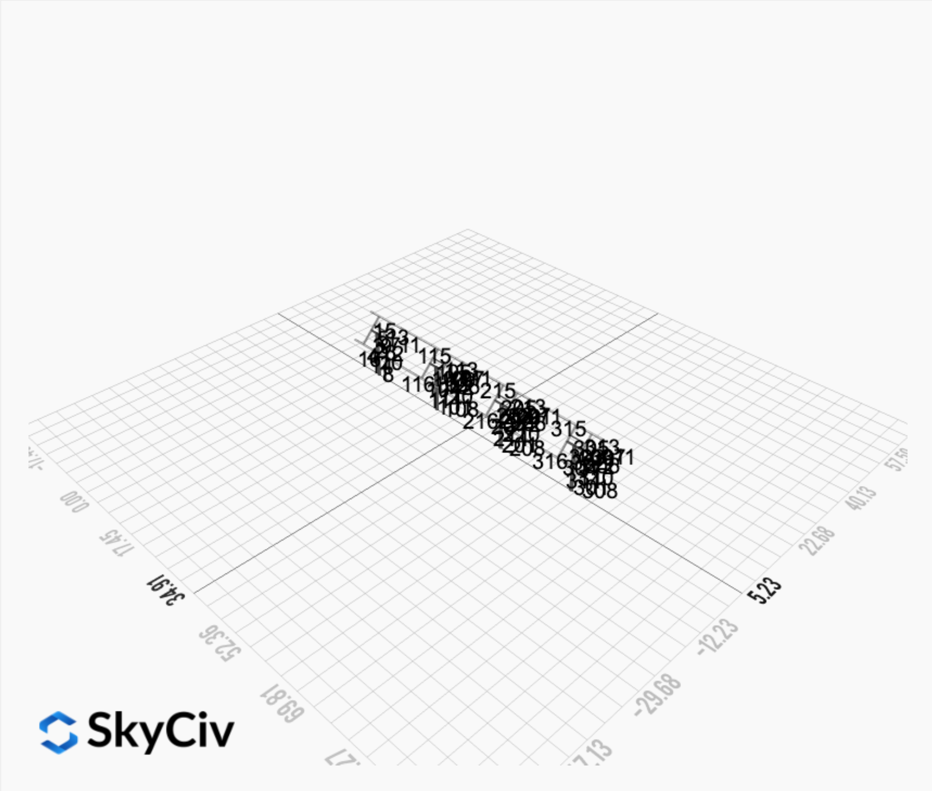
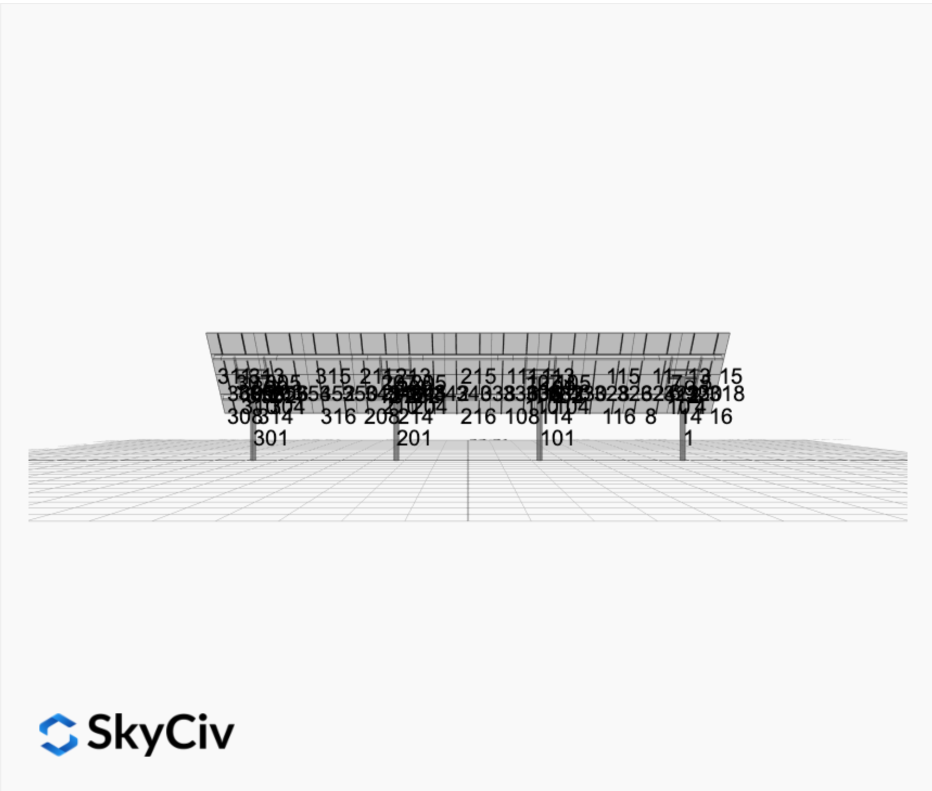
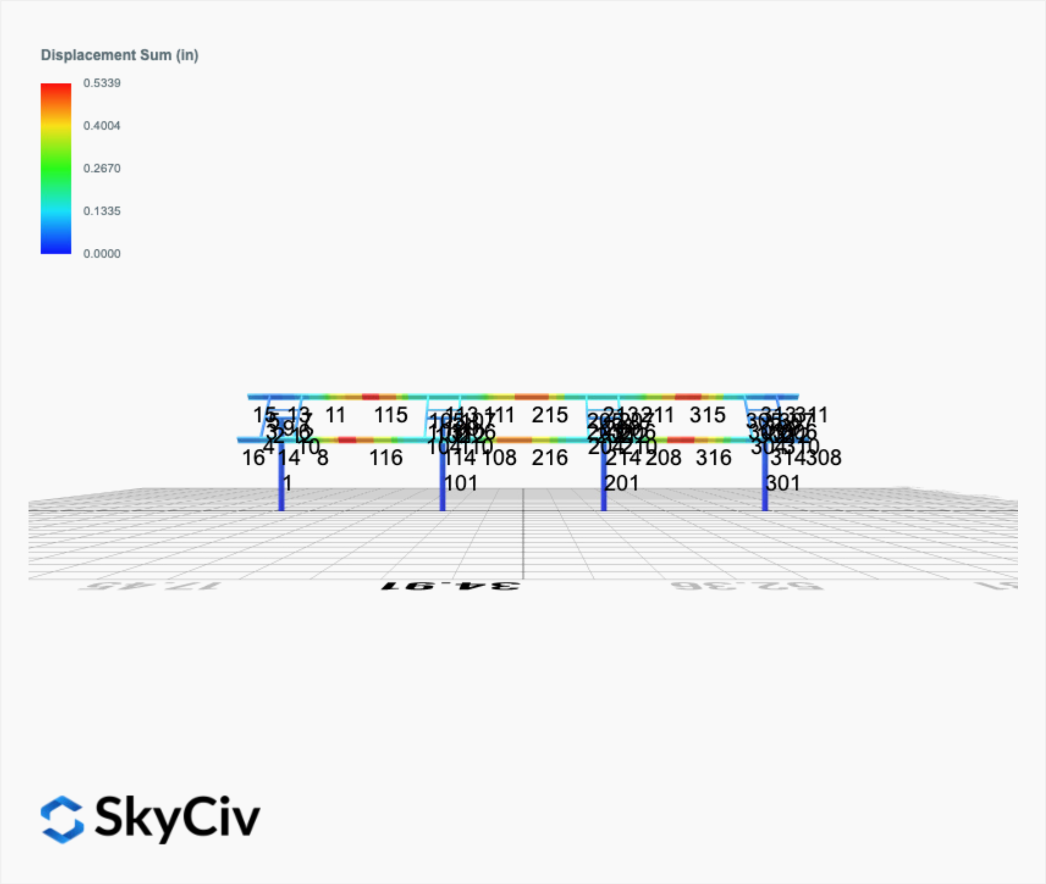
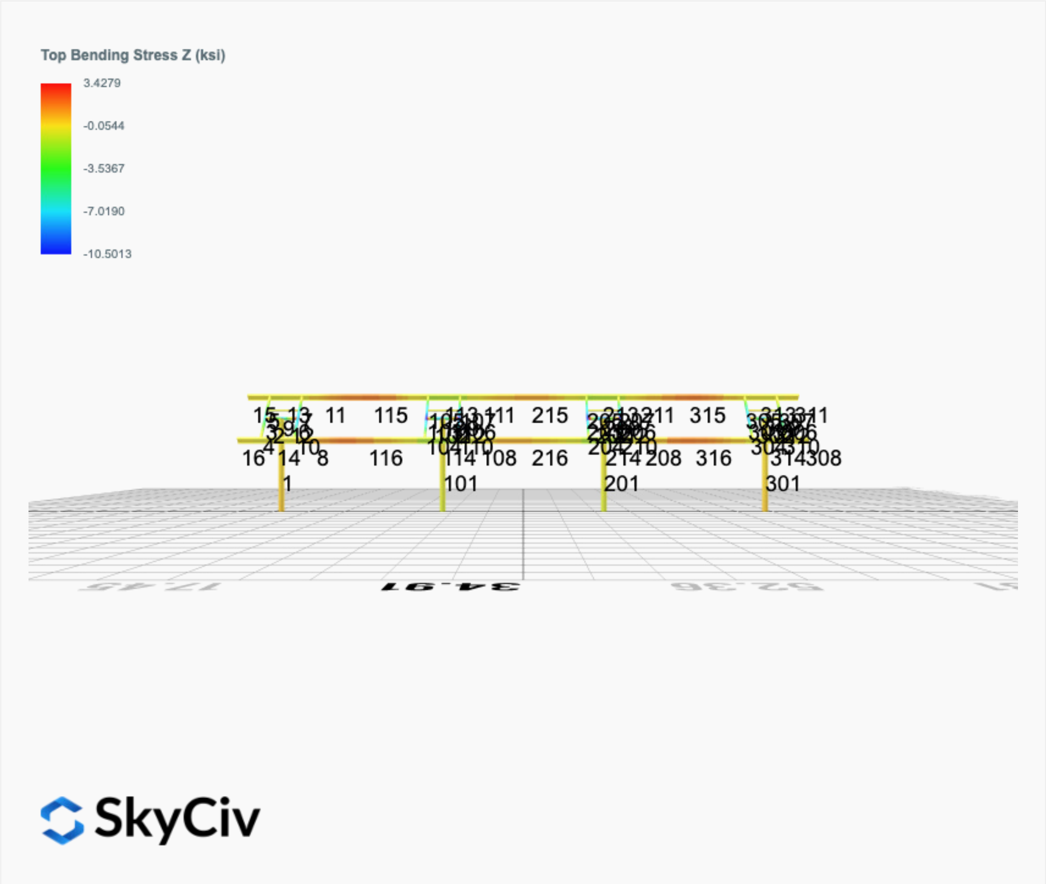
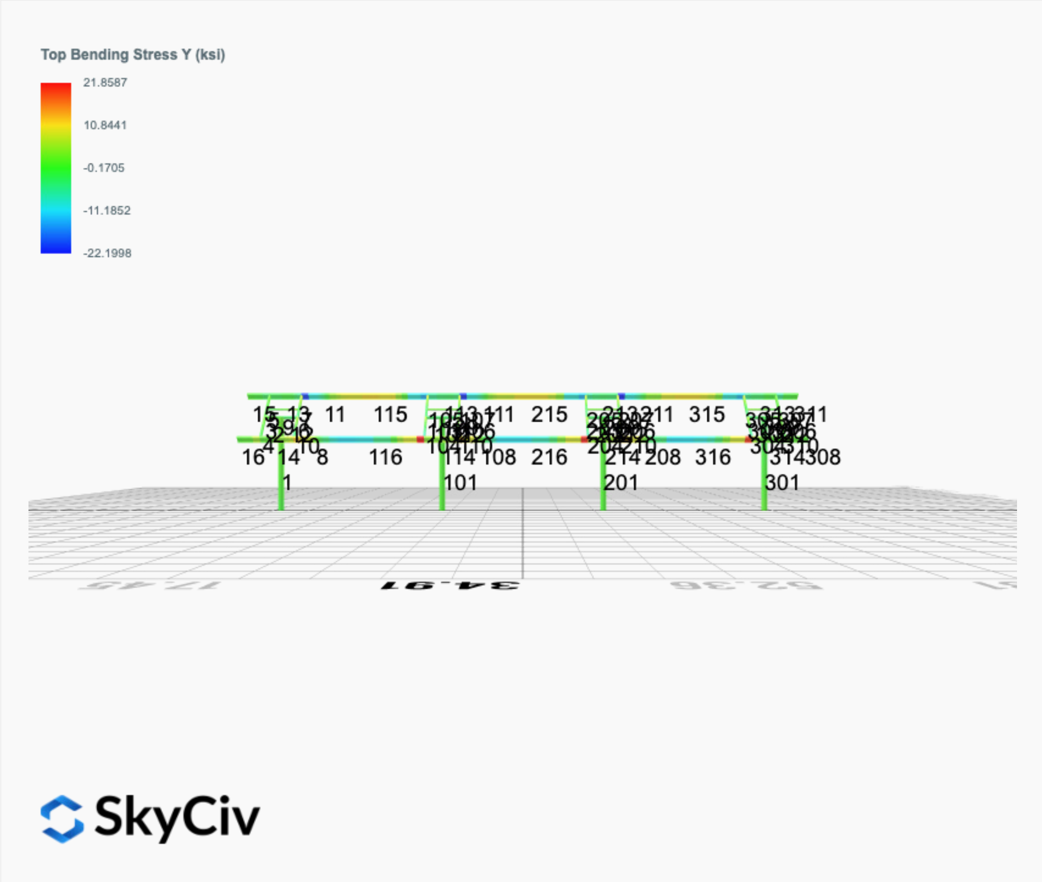




FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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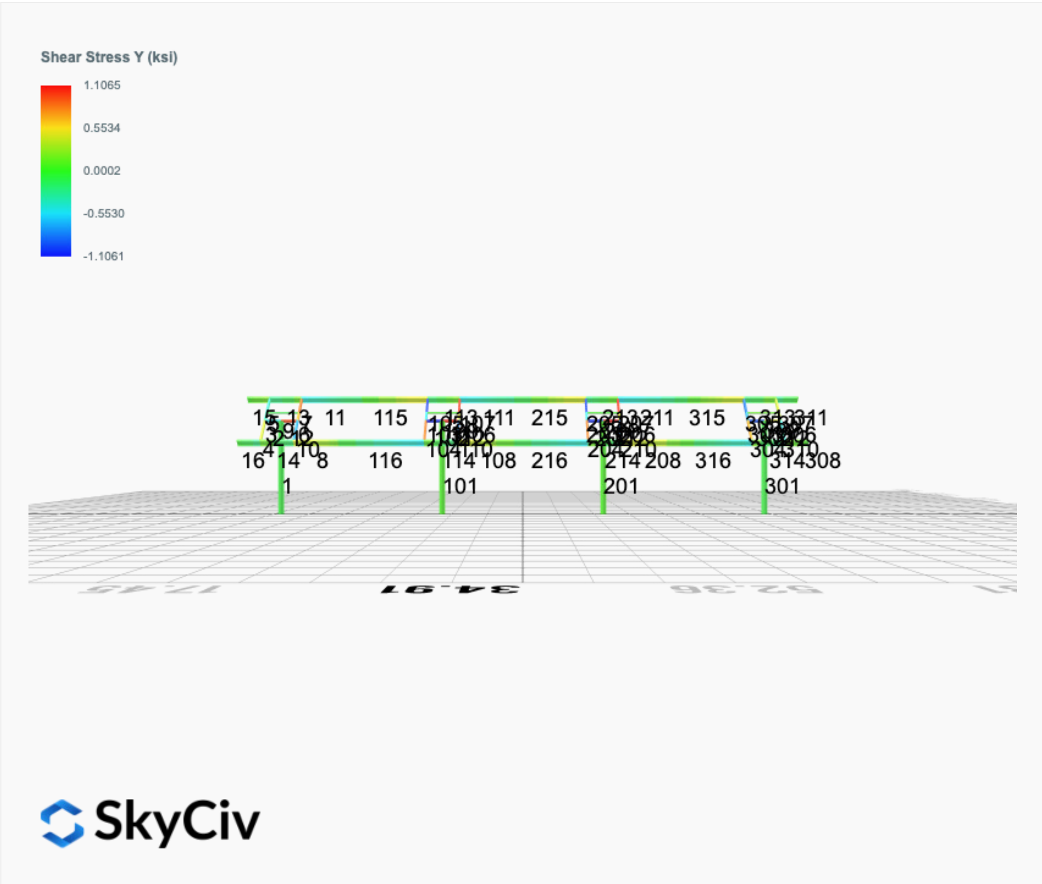
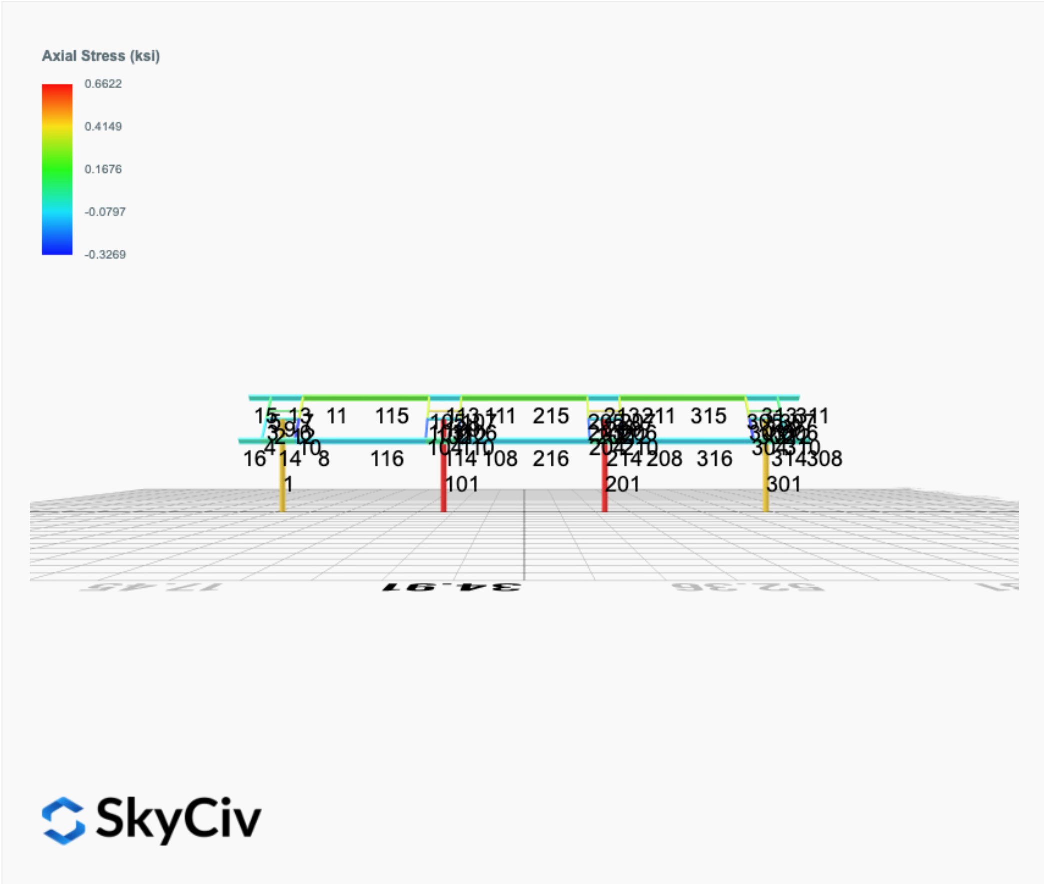
10.8441
-0.1705
-11.1852
-22.1998
SkyCiv


Shear Stress Y (ksi)
1.1065
0.5534
0.0002
-0.5530
-1.1061
SkyCiv


Axial Stress (ksi)
0.6622
0.4149
0.1676
-0.0797
-0.3269
11
115
215
315
16
116
216
316
208
1
101
201
301
34.91

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	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 2. D + L	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 3. D + (S or Lr or R)	0.1376	5.8689	0.3139	1.0868	-0.3660	-1.4257
ULS: 3. D + (S or Lr or R)	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.1120	4.8880	0.2554	0.8840	-0.2977	-1.1567
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 5b. D + 0.7E	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.1120	4.8880	0.2554	0.8840	-0.2977	-1.1567
ULS: 8. 0.6D + 0.7E	0.0211	1.1672	0.0479	0.1655	-0.0557	-0.2098
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1215	3.9721	0.3207	1.0665	-1.0744	24.8749
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1873	-0.0783	-0.1556	-0.4964	0.8679	-24.9965
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5055	6.4081	0.4360	1.4770	-1.0339	17.7617
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.1120	4.8880	0.2554	0.8840	-0.2977	-1.1567
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.7261	3.3703	0.0788	0.3049	0.4229	-19.6418
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1120	4.8880	0.2554	0.8840	-0.2977	-1.1567
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5823	3.4654	0.2605	0.8688	-0.8290	18.5687
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6493	0.4276	-0.0968	-0.3034	0.6278	-18.8348
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0352	1.9453	0.0799	0.2758	-0.0928	-0.3497
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1356	3.1940	0.2888	0.9561	-1.0373	25.0147
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0211	1.1672	0.0479	0.1655	-0.0557	-0.2098
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1732	-0.8564	-0.1876	-0.6067	0.9050	-24.8567
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0211	1.1672	0.0479	0.1655	-0.0557	-0.2098

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.3036
Shear X	-3.6846
Shear Z	0.6788
Moment X	2.3224
Moment Y (Twist)	1.9044
Moment Z	42.6488

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.4081
Shear X	-2.1873
Shear Z	0.4360
Moment X	1.4770
Moment Y (Twist)	1.0744
Moment Z	25.0147

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	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 2. D + L	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 3. D + (S or Lr or R)	-0.1389	8.0701	-0.0082	-0.0343	0.0048	1.5424
ULS: 3. D + (S or Lr or R)	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1130	6.6797	-0.0067	-0.0279	0.0040	1.2573

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 5b. D + 0.7E	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1130	6.6797	-0.0067	-0.0279	0.0040	1.2573
ULS: 8. 0.6D + 0.7E	-0.0213	1.5050	-0.0013	-0.0054	0.0009	0.2411
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0219	5.4483	0.0346	0.1081	-0.1867	34.6288
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.9555	-0.4350	-0.0359	-0.1160	0.1766	-32.9186
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3528	8.8847	0.0209	0.0599	-0.1371	26.9275
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1130	6.6797	-0.0067	-0.0279	0.0040	1.2573
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1302	4.4722	-0.0320	-0.1082	0.1353	-23.7331
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.1130	6.6797	-0.0067	-0.0279	0.0040	1.2573
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.2753	4.7133	0.0254	0.0788	-0.1396	26.0721
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2077	0.3009	-0.0274	-0.0892	0.1328	-24.5885
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0355	2.5083	-0.0022	-0.0090	0.0015	0.4019
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0077	4.4450	0.0355	0.1117	-0.1873	34.4680
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0213	1.5050	-0.0013	-0.0054	0.0009	0.2411
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.9697	-1.4383	-0.0350	-0.1124	0.1760	-33.0794
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0213	1.5050	-0.0013	-0.0054	0.0009	0.2411

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	14.3563
Shear X	-5.0666
Shear Z	-0.0648
Moment X	-0.2111
Moment Y (Twist)	0.3252
Moment Z	59.1287

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	8.8847
Shear X	-3.0219
Shear Z	-0.0359
Moment X	-0.1160
Moment Y (Twist)	0.1873
Moment Z	34.6288

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	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931
ULS: 2. D + L	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931
ULS: 3. D + (S or Lr or R)	-0.1354	8.0672	0.0088	0.0284	0.0034	1.5078
ULS: 3. D + (S or Lr or R)	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1102	6.6772	0.0071	0.0232	0.0027	1.2291
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931
ULS: 5b. D + 0.7E	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1102	6.6772	0.0071	0.0232	0.0027	1.2291
ULS: 8. 0.6D + 0.7E	-0.0208	1.5045	0.0014	0.0045	0.0004	0.2358
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0179	5.4437	-0.0354	-0.1155	0.1869	34.5861
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.9532	-0.4319	0.0369	0.1202	-0.1727	-32.8951
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931

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	-2.3476	8.8794	-0.0211	-0.0690	0.1425	26.8739
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1102	6.6772	0.0071	0.0232	0.0027	1.2291
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1307	4.4727	0.0331	0.1077	-0.1273	-23.7370
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.1102	6.6772	0.0071	0.0232	0.0027	1.2291
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.2721	4.7097	-0.0260	-0.0847	0.1404	26.0378
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2062	0.3030	0.0283	0.0920	-0.1293	-24.5730
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0346	2.5075	0.0023	0.0075	0.0006	0.3931
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0040	4.4407	-0.0363	-0.1185	0.1867	34.4288
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0208	1.5045	0.0014	0.0045	0.0004	0.2358
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.9671	-1.4349	0.0360	0.1172	-0.1729	-33.0523
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0208	1.5045	0.0014	0.0045	0.0004	0.2358

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	14.3487
Shear X	-5.0591
Shear Z	0.0667
Moment X	0.2170
Moment Y (Twist)	0.3277
Moment Z	59.0474

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	8.8794
Shear X	-3.0179
Shear Z	0.0369
Moment X	0.1202
Moment Y (Twist)	0.1869
Moment Z	34.5861

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	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472
ULS: 2. D + L	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472
ULS: 3. D + (S or Lr or R)	0.1366	5.8693	-0.3144	-1.0962	0.3536	-1.4162
ULS: 3. D + (S or Lr or R)	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.1112	4.8884	-0.2558	-0.8917	0.2876	-1.1490
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472
ULS: 5b. D + 0.7E	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.1112	4.8884	-0.2558	-0.8917	0.2876	-1.1490
ULS: 8. 0.6D + 0.7E	0.0210	1.1673	-0.0480	-0.1669	0.0538	-0.2083
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1225	3.9733	-0.3199	-1.0687	1.0641	24.8842
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.1878	-0.0793	0.1546	0.4938	-0.8641	-25.0009
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5069	6.4093	-0.4358	-1.4846	1.0185	17.7746
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.1112	4.8884	-0.2558	-0.8917	0.2876	-1.1490
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.7259	3.3699	-0.0799	-0.3127	-0.4277	-19.6393
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1112	4.8884	-0.2558	-0.8917	0.2876	-1.1490
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5832	3.4663	-0.2599	-0.8711	0.8205	18.5764
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6496	0.4269	0.0959	0.3008	-0.6257	-18.8375
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0350	1.9454	-0.0800	-0.2782	0.0896	-0.3472

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1365	3.1951	-0.2879	-0.9574	1.0283	25.0231
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0210	1.1673	-0.0480	-0.1669	0.0538	-0.2083
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.1738	-0.8574	0.1866	0.6051	-0.9000	-24.8620
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0210	1.1673	-0.0480	-0.1669	0.0538	-0.2083

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.3053
Shear X	-3.6852
Shear Z	-0.6787
Moment X	-2.3364
Moment Y (Twist)	1.8839
Moment Z	42.6544

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.4093
Shear X	-2.1878
Shear Z	-0.4358
Moment X	-1.4846
Moment Y (Twist)	1.0641
Moment Z	25.0231

Project Details

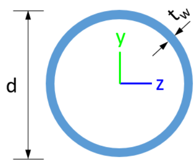
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

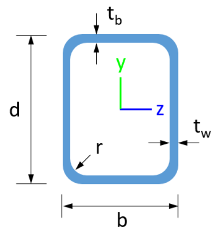
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

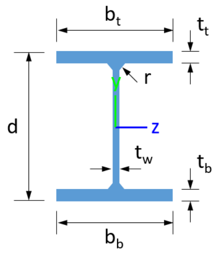
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
9	8in Pipe Sch 40	8.63	0.32					



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



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

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

3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	23.97	23.97	11.41	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.18,1.15,1.18,1.17,1.19,1.16,1.19,1.17,1.17,1.18,1.17,1.17,1.19,1.14,1.19,1.17,1.19,1.16,1.19	300	200	1
4	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.68,1.65,1.68,1.67,1.70,1.65,1.70,1.67,1.67,1.68,1.67,1.68,1.70,1.63,1.70,1.67,1.70,1.66,1.70	300	200	1
5	17	1.52	1.52	2.33	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
8	20	1.33	1.33	2.05	1.22,1.22,1.22,1.22,1.22,1.22,1.21,1.22,1.20,1.22,1.21,1.22,1.21,1.22,1.22,1.22,1.23,1.22,1.21,1.22,1.21,1.22,1.21,1.22,1.21,1.22	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
11	20	1.33	1.33	2.05	1.25,1.25,1.25,1.25,1.25,1.25,1.30,1.25,1.40,1.25,1.31,1.25,1.34,1.25,1.27,1.25,1.20,1.25,1.29,1.25,1.38,1.25,1.31,1.25,1.33,1.25	300	200	1
12	6	2.00	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.42,1.45,1.43,1.45,1.44,1.43,1.27,1.45,1.25,1.45,1.25,1.43,1.21,1.43,1.32,1.45,2.06,1.45,1.27,1.43,1.24,1.43,1.24,1.43,1.22,1.43	300	200	1
14	20	4.88	4.00	7.50	1.69,1.73,1.69,1.74,1.71,1.69,1.85,1.73,2.10,1.73,1.86,1.69,1.97,1.69,1.80,1.74,1.60,1.74,1.83,1.69,2.10,1.69,1.87,1.69,1.95,1.69	300	200	1
15	20	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.32,2.33,2.32	300	200	1
16	20	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.32,2.33,2.32	300	200	1
101	9	23.97	23.97	11.41	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19	300	200	1
104	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.66,1.67,1.68,1.66,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.66,1.66,1.67,1.66,1.67,1.68,1.65,1.68,1.66,1.68,1.66,1.68	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
108	20	1.33	1.33	2.05	2.12,2.12,2.12,2.12,2.12,2.12,2.08,2.12,1.87,2.12,2.08,2.12,2.06,2.12,2.10,2.12,2.33,2.12,2.08,2.12,1.94,2.12,2.08,2.12,2.07,2.12	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.67,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
111	20	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.52,2.07,1.25,2.07,1.47,2.07,1.36,2.07,1.74,2.07,2.10,2.07,1.53,2.07,1.27,2.07,1.46,2.07,1.38,2.07	300	200	1
112	6	2.00	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.07,1.07,1.07,1.08,1.07,1.07,1.11,1.07,2.79,1.07,1.13,1.07,1.18,1.07,1.09,1.08,1.05,1.08,1.11,1.07,2.18,1.07,1.13,1.07,1.16,1.07	300	200	1
114	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.12,1.07,1.09,1.07,1.10,1.07,1.07,1.07,1.05,1.07,1.08,1.07,1.11,1.07,1.09,1.07,1.09,1.07	300	200	1
115	20	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.12,1.16,1.06,1.16,1.11,1.16,1.09,1.16,1.14,1.16,1.22,1.16,1.12,1.16,1.07,1.16,1.11,1.16,1.09,1.16	300	200	1
116	20	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.15,1.18,1.16,1.18,1.16,1.18,1.17,1.18,1.19,1.18,1.17,1.18,1.15,1.18,1.16,1.18,1.16,1.18	300	200	1
201	9	23.97	23.97	11.41	-	300	200	1
202	6	2.00	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
204	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.66,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.66,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.66,1.68,1.66,1.68	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
208	20	1.33	1.33	2.05	1.86,1.86,1.86,1.87,1.86,1.86,1.72,1.86,1.55,1.86,1.70,1.86,1.64,1.86,1.79,1.87,2.07,1.87,1.72,1.86,1.57,1.86,1.69,1.86,1.65,1.86	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
211	20	1.33	1.33	2.05	1.64,1.64,1.64,1.63,1.64,1.64,1.36,1.64,1.17,1.64,1.33,1.64,1.25,1.64,1.47,1.63,2.14,1.63,1.36,1.64,1.19,1.64,1.32,1.64,1.27,1.64	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.07,1.07,1.07,1.08,1.07,1.07,1.12,1.07,2.91,1.07,1.13,1.07,1.18,1.07,1.09,1.08,1.05,1.08,1.11,1.07,2.26,1.07,1.13,1.07,1.17,1.07	300	200	1
214	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.12,1.07,1.09,1.07,1.10,1.07,1.08,1.07,1.05,1.07,1.08,1.07,1.11,1.07,1.09,1.07,1.10,1.07	300	200	1
215	20	10.20	10.20	10.20	1.13,1.13,1.13,1.13,1.13,1.13,1.10,1.13,1.07,1.13,1.09,1.13,1.08,1.13,1.11,1.13,1.21,1.13,1.10,1.13,1.07,1.13,1.09,1.13,1.08,1.13	300	200	1
216	20	10.20	10.20	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.15,1.12,1.15,1.13,1.15,1.13,1.15,1.14,1.15,1.16,1.15,1.13,1.15,1.12,1.15,1.13,1.15,1.13,1.15	300	200	1
301	9	23.97	23.97	11.41	-	300	200	1
302	6	2.00	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.18,1.15,1.18,1.17,1.19,1.16,1.19,1.17,1.17,1.18,1.17,1.17,1.19,1.14,1.19,1.17,1.19,1.16,1.19	300	200	1
307	17	1.52	1.52	2.33	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.67,1.67,1.69,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
308	20	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.32,2.33,2.32	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.68,1.65,1.68,1.67,1.70,1.65,1.70,1.67,1.67,1.68,1.67,1.68,1.70,1.63,1.70,1.67,1.70,1.66,1.70	300	200	1
311	20	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.32,2.33,2.32	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.44,1.46,1.44,1.46,1.45,1.44,1.27,1.46,1.24,1.46,1.25,1.44,1.22,1.44,1.32,1.46,2.08,1.46,1.27,1.44,1.24,1.44,1.25,1.44,1.22,1.44	300	200	1
314	20	4.88	4.00	7.50	1.70,1.74,1.70,1.76,1.72,1.70,1.87,1.74,2.13,1.74,1.88,1.70,1.99,1.70,1.81,1.76,1.61,1.76,1.85,1.70,2.13,1.70,1.89,1.70,1.97,1.70	300	200	1

315	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.12,1.08,1.08,1.08,1.10,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.12,1.08,1.08,1.08,1.09,1.08	300	200	1
316	20	10.20	10.20	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08	300	200	1

Member Design Capacity

Member ID	Φ_tP_n (kip)	Φ_cP_n (kip)	Φ_bM_{zn} (k-ft)	Φ_bM_{yn} (k-ft)	Φ_vV_{yn} (kip)	Φ_vV_{zn} (kip)
1	377.97	187.54	83.29	83.29	113.39	113.39
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	246.00	27.16	27.16	75.30	75.30
13	159.30	97.43	37.02	6.46	56.26	44.91
14	159.30	97.43	46.90	6.46	56.26	44.91
15	159.30	137.23	46.90	6.46	56.26	44.91
16	159.30	137.23	46.90	6.46	56.26	44.91
101	377.97	187.54	83.29	83.29	113.39	113.39
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	246.00	27.16	27.16	75.30	75.30
113	159.30	97.43	32.07	6.46	56.26	44.91
114	159.30	97.43	32.14	6.46	56.26	44.91
115	159.30	32.87	20.44	6.46	56.26	44.91
116	159.30	32.87	22.16	6.46	56.26	44.91
201	377.97	187.54	83.29	83.29	113.39	113.39
202	251.01	246.00	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30

212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	32.06	6.46	56.26	44.91
214	159.30	97.43	32.14	6.46	56.26	44.91
215	159.30	32.87	20.54	6.46	56.26	44.91
216	159.30	32.87	21.49	6.46	56.26	44.91
301	377.97	187.54	83.29	83.29	113.39	113.39
302	251.01	246.00	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	137.23	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	137.23	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	37.16	6.46	56.26	44.91
314	159.30	97.43	46.90	6.46	56.26	44.91
315	159.30	75.13	20.86	6.46	56.26	44.91
316	159.30	32.87	20.73	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.055	0.512	0.065	0.032	0.006	0.547	#13	0.490	Not Required	Pass
2	0.002	0.173	0.093	0.044	0.020	0.237	#21	0.054	Not Required	Pass
3	0.006	0.288	0.030	0.028	0.007	0.300	#21	0.046	Not Required	Pass
4	0.005	0.287	0.070	0.029	0.017	0.359	#21	0.082	Not Required	Pass
5	0.006	0.179	0.035	0.029	0.010	0.189	#21	0.076	Not Required	Pass
6	0.014	0.466	0.138	0.047	0.040	0.611	#21	0.046	Not Required	Pass
7	0.014	0.289	0.229	0.046	0.056	0.337	#21	0.076	Not Required	Pass
8	0.007	0.104	0.240	0.026	0.027	0.262	#23	0.102	Not Required	Pass
9	0.007	0.045	0.094	0.004	0.006	0.105	#23	0.206	Not Required	Pass
10	0.015	0.436	0.214	0.044	0.047	0.554	#21	0.082	Not Required	Pass
11	0.010	0.098	0.252	0.028	0.027	0.278	#23	0.102	Not Required	Pass
12	0.001	0.373	0.163	0.087	0.033	0.487	#21	0.083	Not Required	Pass
13	0.014	0.052	0.636	0.037	0.035	0.645	#23	0.306	Not Required	Pass
14	0.007	0.052	0.619	0.035	0.035	0.628	#23	0.204	Not Required	Pass
15	0.000	0.003	0.015	0.005	0.004	0.018	#21	Not Required	Not Required	Pass
16	0.000	0.003	0.015	0.005	0.004	0.018	#21	Not Required	Not Required	Pass
101	0.077	0.710	0.006	0.045	0.001	0.741	#13	0.490	Not Required	Pass
102	0.005	0.385	0.184	0.093	0.032	0.528	#21	0.036	Not Required	Pass
103	0.014	0.528	0.083	0.052	0.011	0.618	#21	0.046	Not Required	Pass
104	0.014	0.544	0.233	0.054	0.050	0.705	#21	0.082	Not Required	Pass
105	0.014	0.328	0.243	0.052	0.062	0.391	#21	0.076	Not Required	Pass
106	0.013	0.544	0.083	0.054	0.012	0.629	#21	0.046	Not Required	Pass
107	0.013	0.338	0.232	0.053	0.060	0.401	#21	0.076	Not Required	Pass
108	0.007	0.035	0.235	0.030	0.027	0.264	#21	0.102	Not Required	Pass
109	0.022	0.037	0.049	0.001	0.000	0.092	#21	0.206	Not Required	Pass
110	0.013	0.542	0.220	0.054	0.048	0.694	#21	0.082	Not Required	Pass

111	0.010	0.062	0.245	0.030	0.027	0.270	#23	0.102	Not Required	Pass
112	0.004	0.392	0.196	0.093	0.035	0.541	#21	0.055	Not Required	Pass
113	0.014	0.129	0.659	0.041	0.036	0.761	#21	0.306	Not Required	Pass
114	0.009	0.166	0.647	0.044	0.036	0.784	#21	0.306	Not Required	Pass
115	0.041	0.295	0.344	0.033	0.028	0.659	#21	0.780	Not Required	Pass
116	0.010	0.277	0.338	0.035	0.028	0.617	#21	0.780	Not Required	Pass
201	0.077	0.709	0.007	0.045	0.001	0.740	#13	0.490	Not Required	Pass
202	0.004	0.392	0.195	0.093	0.035	0.541	#21	0.055	Not Required	Pass
203	0.013	0.544	0.083	0.054	0.012	0.629	#21	0.046	Not Required	Pass
204	0.013	0.541	0.220	0.054	0.048	0.693	#21	0.082	Not Required	Pass
205	0.013	0.338	0.232	0.053	0.060	0.401	#21	0.076	Not Required	Pass
206	0.014	0.527	0.083	0.052	0.011	0.617	#21	0.046	Not Required	Pass
207	0.014	0.327	0.243	0.052	0.062	0.390	#21	0.076	Not Required	Pass
208	0.007	0.061	0.262	0.035	0.028	0.275	#21	0.102	Not Required	Pass
209	0.022	0.037	0.049	0.001	0.000	0.092	#21	0.206	Not Required	Pass
210	0.014	0.543	0.232	0.054	0.050	0.704	#21	0.082	Not Required	Pass
211	0.010	0.083	0.272	0.033	0.028	0.287	#21	0.102	Not Required	Pass
212	0.005	0.385	0.183	0.093	0.032	0.528	#21	0.036	Not Required	Pass
213	0.014	0.128	0.660	0.041	0.036	0.761	#21	0.306	Not Required	Pass
214	0.009	0.165	0.647	0.043	0.036	0.783	#21	0.306	Not Required	Pass
215	0.042	0.234	0.329	0.030	0.027	0.566	#21	0.780	Not Required	Pass
216	0.014	0.172	0.322	0.030	0.027	0.496	#21	0.780	Not Required	Pass
301	0.055	0.512	0.065	0.032	0.006	0.547	#13	0.490	Not Required	Pass
302	0.001	0.373	0.163	0.087	0.033	0.486	#21	0.083	Not Required	Pass
303	0.014	0.465	0.138	0.047	0.040	0.610	#21	0.046	Not Required	Pass
304	0.015	0.436	0.214	0.043	0.047	0.554	#21	0.082	Not Required	Pass
305	0.014	0.289	0.228	0.046	0.056	0.337	#21	0.076	Not Required	Pass
306	0.006	0.289	0.030	0.028	0.007	0.301	#21	0.046	Not Required	Pass
307	0.006	0.179	0.035	0.029	0.010	0.190	#21	0.076	Not Required	Pass
308	0.000	0.003	0.015	0.005	0.004	0.018	#21	Not Required	Not Required	Pass
309	0.007	0.045	0.093	0.004	0.006	0.105	#23	0.206	Not Required	Pass
310	0.005	0.288	0.070	0.029	0.017	0.360	#21	0.122	Not Required	Pass
311	0.000	0.003	0.015	0.005	0.004	0.018	#21	Not Required	Not Required	Pass
312	0.002	0.174	0.094	0.044	0.020	0.238	#21	0.054	Not Required	Pass
313	0.014	0.051	0.636	0.037	0.035	0.645	#23	0.204	Not Required	Pass
314	0.007	0.053	0.619	0.035	0.035	0.628	#23	0.306	Not Required	Pass
315	0.018	0.309	0.338	0.028	0.027	0.656	#21	0.507	Not Required	Pass
316	0.010	0.303	0.332	0.026	0.027	0.636	#21	0.780	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

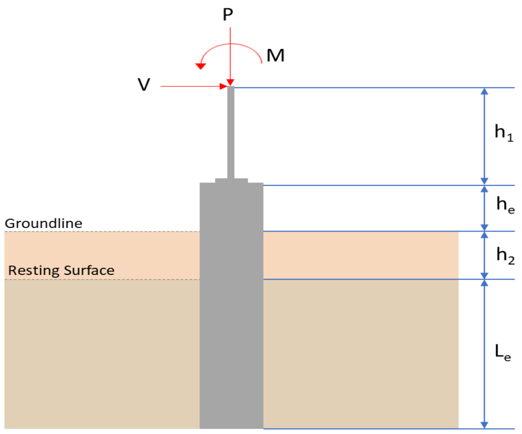
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 3\ \mathrm{ft}$ - 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	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.885	14.356
V_x (kip)	-3.022	-5.067
V_z (kip)	-0.036	-0.065
M_x (kipft)	-0.116	-0.211
M_z (kipft)	34.629	59.129

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,

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

$$H_o = \frac{(-3.022\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.0073\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(34.629\ \text{kipft}) + ((-3.022\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 11.543\ \text{kipft/ft}$$

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:
$L_{e,x} = 8.5933\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.036\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.012\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.116\ \text{kipft}) + ((-0.036\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.038667\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.4726\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.5933\ \text{ft}), (1.4726\ \text{ft})]$$

$$L_{e,req} = 8.593\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (3\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 3\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.593\ \text{ft})}{(3\ \text{ft})}$$

$$Ratio = 2.8643$$

Status: **FAIL**
Ratio: **2.860**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(8.885\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 1.257\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.257\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.62849$$

Status: **PASS**
Ratio: **0.630**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(3\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 1$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.0073\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 11.543\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.543\ \mathrm{kipft/ft}) \times (3\ \mathrm{ft})) + \left(3 \times (-1.0073\ \mathrm{kip/ft}) \times (3\ \mathrm{ft})^2\right)}{(6 \times (11.543\ \mathrm{kipft/ft})) + (4 \times (-1.0073\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))}$$

$$a = 2.0372\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (11.543\ \mathrm{kipft/ft})) + (3 \times (-1.0073\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]^{\ 2}}{(3\ \mathrm{ft})^2 \times [(3 \times (11.543\ \mathrm{kipft/ft})) + (2 \times (-1.0073\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]}$$

$$p = 6.3045\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (11.543\ \mathrm{kipft/ft})) + ((-1.0073\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]}{(3\ \mathrm{ft})^2}$$

$$s = 21.011\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.0372\ \mathrm{ft})}{2}$$

$$p_a = 0.15279\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(6.3045\ \mathrm{kip/ft^2}\right)}{\left(0.15279\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 41.264$$

Status: **FAIL**
Ratio: **41.260**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (3\ \mathrm{ft})$$

$$p_s = 0.45\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(21.011\ \mathrm{kip/ft^2}\right)}{\left(0.45\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 46.692$$

Status: **FAIL**
Ratio: **46.690**

Considering z-direction:

$H_o = -0.012\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.038667\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.038667\ \mathrm{kipft/ft}) \times (3\ \mathrm{ft})) + \left(3 \times (-0.012\ \mathrm{kip/ft}) \times (3\ \mathrm{ft})^2\right)}{(6 \times (0.038667\ \mathrm{kipft/ft})) + (4 \times (-0.012\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))}$$

$$a = 2.0957\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.038667\ \mathrm{kipft/ft})) + (3 \times (-0.012\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]^{\ 2}}{(3\ \mathrm{ft})^2 \times [(3 \times (0.038667\ \mathrm{kipft/ft})) + (2 \times (-0.012\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]}$$

$$p = 0.0064783\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.038667\ \mathrm{kipft/ft})) + ((-0.012\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]}{(3\ \mathrm{ft})^2}$$

$$s = 0.043285\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.0957\ \mathrm{ft})}{2}$$

$$p_a = 0.15718\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0064783\ \mathrm{kip/ft^2}\right)}{\left(0.15718\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.041216$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (3\ \mathrm{ft})$$

$$p_s = 0.45\ \mathrm{kip/ft^2}$$

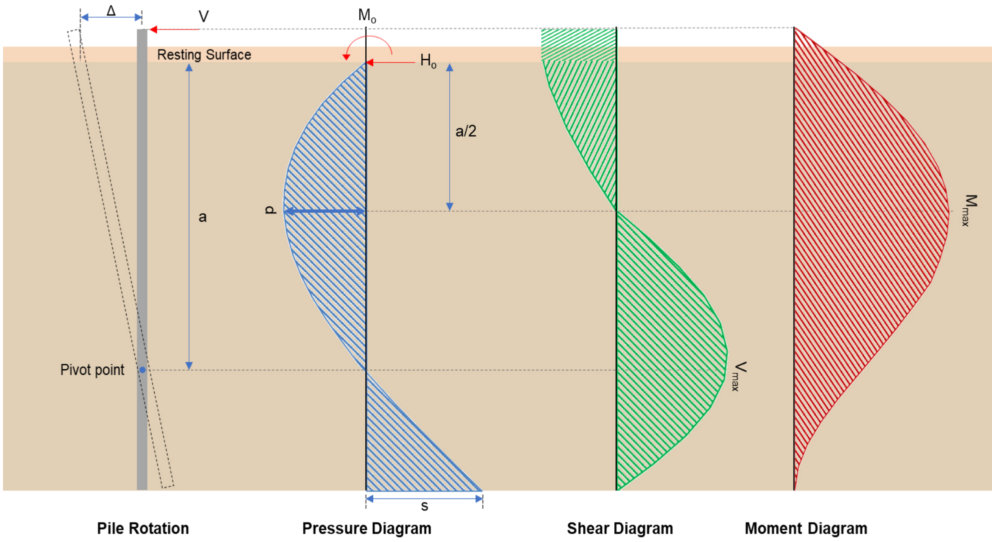
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.043285\ \mathrm{kip/ft^2})}{(0.45\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.096189$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.067\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.689\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(59.129\ \mathrm{kipft}) + ((-5.067\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 19.71\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(19.71\ \mathrm{kipft/ft})}{(-1.689\ \mathrm{kip/ft})}$$

$$E = 11.669\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (19.71\ \text{kipft/ft}) \times (3\ \text{ft})) + \left(3 \times (-1.689\ \text{kip/ft}) \times (3\ \text{ft})^2\right)}{(6 \times (19.71\ \text{kipft/ft})) + (4 \times (-1.689\ \text{kip/ft}) \times (3\ \text{ft}))}$$

$$a = 2.0366\ \text{ft}$$

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

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

$$V_{max} = ((-1.689\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.669\ \text{ft})}{(3\ \text{ft})} + 3\right) \times \left(\frac{(2.0366\ \text{ft})}{(3\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.669\ \text{ft})}{(3\ \text{ft})} + 2\right) \times \left(\frac{(2.0366\ \text{ft})}{(3\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 38.271\ \text{kip}$$

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

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

$$M_{max} = ((-1.689\ \text{kip/ft}) \times (36\ \text{in}) \times (3\ \text{ft})) \times \left[\left(\frac{(11.669\ \text{ft})}{(3\ \text{ft})} + \frac{(2.0366\ \text{ft})}{2 \times (3\ \text{ft})}\right) - \left[\left(\frac{4 \times (11.669\ \text{ft})}{(3\ \text{ft})} + 3\right) \times \left(\frac{(2.0366\ \text{ft})}{2 \times (3\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.669\ \text{ft})}{(3\ \text{ft})} + 2\right) \times \left(\frac{(2.0366\ \text{ft})}{2 \times (3\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 56.014\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.065\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.021667\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.211\ \text{kipft}) + ((-0.065\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.070333\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.070333\ \text{kipft/ft})}{(-0.021667\ \text{kip/ft})}$$

$$E = 3.2462\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.070333\ \text{kipft/ft}) \times (3\ \text{ft})) + \left(3 \times (-0.021667\ \text{kip/ft}) \times (3\ \text{ft})^2\right)}{(6 \times (0.070333\ \text{kipft/ft})) + (4 \times (-0.021667\ \text{kip/ft}) \times (3\ \text{ft}))}$$

$$a = 2.0953\ \text{ft}$$

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

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

$$V_{max} = ((-0.021667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.2462 \text{ ft})}{(3 \text{ ft})} + 3\right) \times \left(\frac{(2.0953 \text{ ft})}{(3 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.2462 \text{ ft})}{(3 \text{ ft})} + 2\right) \times \left(\frac{(2.0953 \text{ ft})}{(3 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.16736 \text{ kip}$$

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

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

$$M_{max} = ((-0.021667 \text{ kip/ft}) \times (36 \text{ in}) \times (3 \text{ ft})) \times \left[\left(\frac{(3.2462 \text{ ft})}{(3 \text{ ft})} + \frac{(2.0953 \text{ ft})}{2 \times (3 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.2462 \text{ ft})}{(3 \text{ ft})} + 3\right) \times \left(\frac{(2.0953 \text{ ft})}{2 \times (3 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.2462 \text{ ft})}{(3 \text{ ft})} + 2\right) \times \left(\frac{(2.0953 \text{ ft})}{2 \times (3 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.23345 \text{ kipft}$$

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,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(14.356 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -36.924 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.924 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$(1.8322 \text{ in}^2)$$

$$Ratio = \frac{}{(1.8408 \text{ in}^2)}$$

$$Ratio = 0.99533$$

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,

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

$$s_{ties} = Min\left[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})\right]$$

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

Summary:

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5 \text{ ksi}) \times \left[\left(1017.9 \text{ in}^2\right) - \left(1.8408 \text{ in}^2\right)\right]\right) + \left((60 \text{ ksi}) \times \left(1.8408 \text{ in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9 \text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(14.356 \text{ kip})}{(1253.9 \text{ kip})}$$

$$Ratio = 0.011449$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36 \text{ in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 14.356\ \text{kip} \rightarrow 14356\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(14356\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.875\ \text{kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (76.875\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.875\ \text{kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.875\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.78\ \text{kip}$$

Considering x-direction:

$V_{max} = 38.271\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(38.271\ \mathrm{kip})}{(74.78\ \mathrm{kip})}$$ $$Ratio = 0.51179$$	Status: **PASS** Ratio: **0.510**
	Considering z-direction: $V_{max} = 0.16736\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.16736\ \mathrm{kip})}{(74.78\ \mathrm{kip})}$$ $$Ratio = 0.0022381$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36\ \mathrm{in})^3}{32}$$ $$S_m = 4580.4\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 4580.442 in^3$$ $$\phi M_{n,1} = 62.027 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 56.014\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(56.014\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.90306$$	Status: **PASS** Ratio: **0.900**
	Considering z-direction: $M_{max} = 0.23345\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{}$$	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(0.23345 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0037638$$	Status: **PASS** Ratio: **0.000**	

REFERENCES	CALCULATIONS	RESULTS

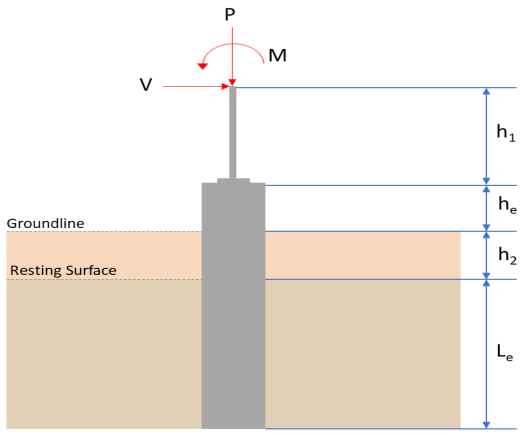
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 3 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.879	14.349
V_x (kip)	-3.018	-5.059
V_z (kip)	0.037	0.067
M_x (kipft)	0.120	0.217
M_z (kipft)	34.586	59.047

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,

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

$$H_o = \frac{(-3.018 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.006 \text{ kip/ft}$$

M_o - Moment per length of pile,

SkyCiv

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

$$M_o = \frac{(34.586\text{ kipft}) + ((-3.018\text{ kip}) \times (0\text{ ft}))}{(36\text{ in})}$$

$$M_o = 11.529\text{ kipft/ft}$$

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:
$L_{e,x} = 8.591\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.037\text{ kip})}{(36\text{ in})}$$

$$H_o = 0.012333\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.12\text{ kipft}) + ((0.037\text{ kip}) \times (0\text{ ft}))}{(36\text{ in})}$$

$$M_o = 0.04\text{ kipft/ft}$$

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:
$L_{e,z} = 1.938\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.591\text{ ft}), (1.938\text{ ft})]$$

$$L_{e,req} = 8.591\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (3\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 3\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.591\text{ ft})}{(3\text{ ft})}$$

$$Ratio = 2.8637$$

Status: **FAIL**
Ratio: **2.860**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

$$A = \pi \times \left(\frac{(36\text{ in})}{2}\right)^2$$

$$A = 7.0686\text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(8.879 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.2561 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.2561 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.62806$$

Status: **PASS**
Ratio: **0.630**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(3 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 1$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.006 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 11.529 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.529 \text{ kipft/ft}) \times (3 \text{ ft})) + \left(3 \times (-1.006 \text{ kip/ft}) \times (3 \text{ ft})^2\right)}{(6 \times (11.529 \text{ kipft/ft})) + (4 \times (-1.006 \text{ kip/ft}) \times (3 \text{ ft}))}$$

$$a = 2.0371 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (11.529 \text{ kipft/ft})) + (3 \times (-1.006 \text{ kip/ft}) \times (3 \text{ ft}))]^{\,2}}{(3 \text{ ft})^2 \times [(3 \times (11.529 \text{ kipft/ft})) + (2 \times (-1.006 \text{ kip/ft}) \times (3 \text{ ft}))]}$$

$$p = 6.2968 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (11.529 \text{ kipft/ft})) + ((-1.006 \text{ kip/ft}) \times (3 \text{ ft}))]}{(3 \text{ ft})^2}$$

$$s = 20.986 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.0371 \text{ ft})}{2}$$

$$p_a = 0.15279 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(6.2968\ \mathrm{kip/ft^2}\right)}{\left(0.15279\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 41.213$$

Status: **FAIL**
Ratio: **41.210**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (3\ \mathrm{ft})$$

$$p_s = 0.45\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(20.986\ \mathrm{kip/ft^2}\right)}{\left(0.45\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 46.635$$

Status: **FAIL**
Ratio: **46.630**

Considering z-direction:

$H_o = 0.012333\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.04\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.04\ \mathrm{kipft/ft}) \times (3\ \mathrm{ft})) + \left(3 \times (0.012333\ \mathrm{kip/ft}) \times (3\ \mathrm{ft})^2\right)}{(6 \times (0.04\ \mathrm{kipft/ft})) + (4 \times (0.012333\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))}$$

$$a = 2.0954\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.04\ \mathrm{kipft/ft})) + (3 \times (0.012333\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]^{\,2}}{(3\ \mathrm{ft})^2 \times [(3 \times (0.04\ \mathrm{kipft/ft})) + (2 \times (0.012333\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]}$$

$$p = 0.04955\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.04\ \mathrm{kipft/ft})) + ((0.012333\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))]}{(3\ \mathrm{ft})^2}$$

$$s = 0.12252\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.0954\ \mathrm{ft})}{2}$$

$$p_a = 0.15715\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.04955\ \mathrm{kip/ft^2}\right)}{\left(0.15715\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.3153$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (3\ \mathrm{ft})$$

$$p_s = 0.45\ \mathrm{kip/ft^2}$$

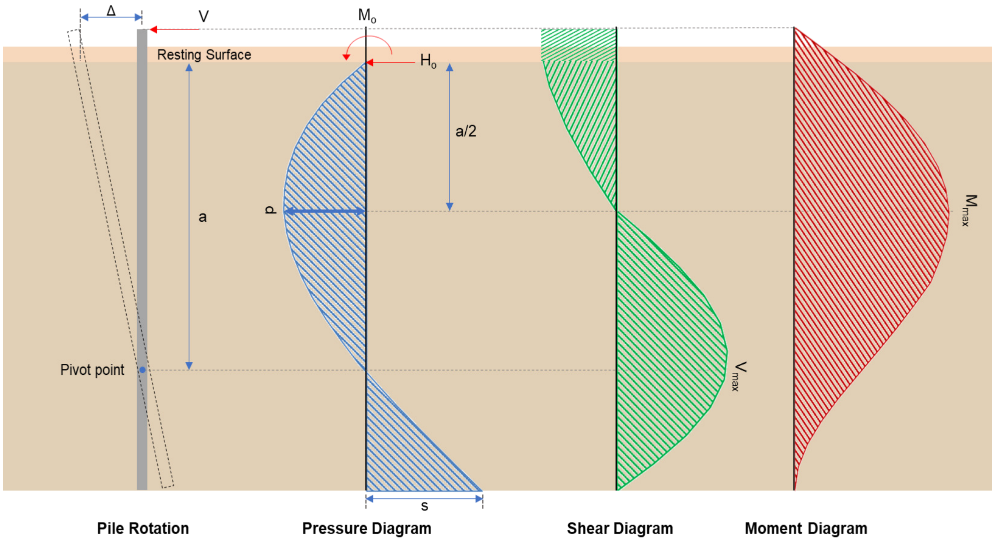
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.12252\ \mathrm{kip/ft^2}\right)}{\left(0.45\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.27228$$

Status: **PASS**
Ratio: **0.270**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.059\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.6863\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(59.047\ \mathrm{kipft}) + ((-5.059\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 19.682\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(19.682\ \mathrm{kipft/ft})}{(-1.6863\ \mathrm{kip/ft})}$$

$$E = 11.672\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (19.682\ \mathrm{kipft/ft}) \times (3\ \mathrm{ft})) + \left(3 \times (-1.6863\ \mathrm{kip/ft}) \times (3\ \mathrm{ft})^2\right)}{(6 \times (19.682\ \mathrm{kipft/ft})) + (4 \times (-1.6863\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))}$$

$$a = 2.0366\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.6863\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.672\ \mathrm{ft})}{(3\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.0366\ \mathrm{ft})}{(3\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.672\ \mathrm{ft})}{(3\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.0366\ \mathrm{ft})}{(3\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 38.217\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.6863\ \mathrm{kip/ft}) \times (36\ \mathrm{in}) \times (3\ \mathrm{ft})) \times \left[\left(\frac{(11.672\ \mathrm{ft})}{(3\ \mathrm{ft})} + \frac{(2.0366\ \mathrm{ft})}{2 \times (3\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (11.672\ \mathrm{ft})}{(3\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.0366\ \mathrm{ft})}{2 \times (3\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.672\ \mathrm{ft})}{(3\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.0366\ \mathrm{ft})}{2 \times (3\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 55.936\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.067\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = 0.022333\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.217\ \mathrm{kipft}) + ((0.067\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 0.072333\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.072333\ \mathrm{kipft/ft})}{(0.022333\ \mathrm{kip/ft})}$$

$$E = 3.2388\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.072333\ \mathrm{kipft/ft}) \times (3\ \mathrm{ft})) + \left(3 \times (0.022333\ \mathrm{kip/ft}) \times (3\ \mathrm{ft})^2\right)}{(6 \times (0.072333\ \mathrm{kipft/ft})) + (4 \times (0.022333\ \mathrm{kip/ft}) \times (3\ \mathrm{ft}))}$$

$$a = 2.0954\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.022333\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.2388\ \text{ft})}{(3\ \text{ft})} + 3\right) \times \left(\frac{(2.0954\ \text{ft})}{(3\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.2388\ \text{ft})}{(3\ \text{ft})} + 2\right) \times \left(\frac{(2.0954\ \text{ft})}{(3\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.17222\ \text{kip}$$

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

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

$$M_{max} = ((0.022333\ \text{kip/ft}) \times (36\ \text{in}) \times (3\ \text{ft})) \times \left[\left(\frac{(3.2388\ \text{ft})}{(3\ \text{ft})} + \frac{(2.0954\ \text{ft})}{2 \times (3\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.2388\ \text{ft})}{(3\ \text{ft})} + 3\right) \times \left(\frac{(2.0954\ \text{ft})}{2 \times (3\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.2388\ \text{ft})}{(3\ \text{ft})} + 2\right) \times \left(\frac{(2.0954\ \text{ft})}{2 \times (3\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.2402\ \text{kipft}$$

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,
$A_g = 1017.9\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(14.349\ \text{kip})}{(0.65) \times (0.85)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(1017.9\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(1017.9\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -36.925\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-36.925\ \text{in}^2\right), \left(0.0018 \times \left(1017.9\ \text{in}^2\right)\right)\right]$$

$$A_{min} = 1.8322\ \text{in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322\ \text{in}^2\right)}{\left(0.3068\ \text{in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625\ \text{in})^2}{4}$$

$$A_{st} = 1.8408\ \text{in}^2$$

$Ratio$ - Capacity

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

$$\left(1.8322\ \text{in}^2\right)$$

	$$Ratio = \frac{}{(1.8408\ \text{in}^2)}$$ $$Ratio = 0.99533$$	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 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum center-to-center spacing of ties, $$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), D\right]$$ $$s_{ties} = Min\left[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), (36\ \text{in})\right]$$ $$s_{ties} = 10\ \text{in}$$ **Summary:** Main reinforcement: **6 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.85\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 1253.9\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(14.349\ \text{kip})}{(1253.9\ \text{kip})}$$ $$Ratio = 0.011443$$	Status: **PASS** Ratio: **0.010**
22.5.2.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 36\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (36\ \text{in})$$ $$d = 28.8\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ 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 $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$	

$$V_{c,max} = 186.09 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 14.349 \text{ kip} \rightarrow 14349 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(14349 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.874 \text{ kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi}))\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.874 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.874 \text{ kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.874 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.779 \text{ kip}$$

Considering x-direction:

$V_{max} = 38.217 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(38.217\ \text{kip})}{(74.779\ \text{kip})}$$ $$Ratio = 0.51107$$	Status: **PASS** Ratio: **0.510**
	Considering z-direction: $V_{max} = 0.17222\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.17222\ \text{kip})}{(74.779\ \text{kip})}$$ $$Ratio = 0.0023031$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$ $$S_m = 4580.4\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$ $$\phi M_n = 62.027\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 55.936\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(55.936\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.9018$$	Status: **PASS** Ratio: **0.900**
	Considering z-direction: $M_{max} = 0.2402\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{}$$	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(0.2402 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0038726$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

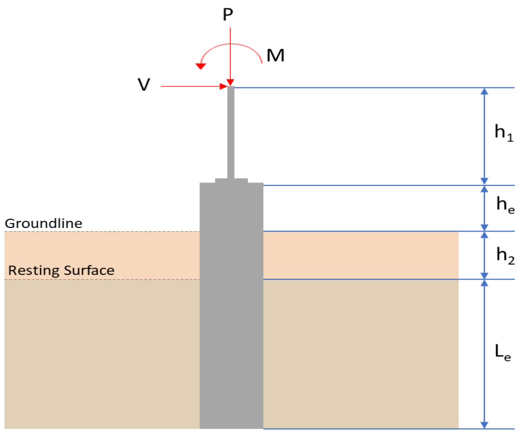
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 8.75\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.408	10.304
V_x (kip)	-2.187	-3.685
V_z (kip)	0.436	0.679
M_x (kipft)	1.477	2.322
M_z (kipft)	25.015	42.649

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,

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

$$H_o = \frac{(-2.187\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.729\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(25.015\ \text{kipft}) + ((-2.187\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 8.3383\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.9464\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.436\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.14533\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.477\ \text{kipft}) + ((0.436\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.49233\ \text{kipft/ft}$$

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:
$L_{e,z} = 5.0858\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.9464\ \text{ft}), (5.0858\ \text{ft})]$$

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

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.946\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.90811$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(6.408\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.90655\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.90655\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.45327$$

Status: **PASS**
Ratio: **0.450**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.729\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.3383\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.3383\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-0.729\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (8.3383\ \text{kipft/ft})) + (4 \times (-0.729\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.0796\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (8.3383\ \text{kipft/ft})) + (3 \times (-0.729\ \text{kip/ft}) \times (8.75\ \text{ft}))]^{\,2}}{(8.75\ \text{ft})^2 \times [(3 \times (8.3383\ \text{kipft/ft})) + (2 \times (-0.729\ \text{kip/ft}) \times (8.75\ \text{ft}))]}$$

$$p = 0.25372\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (8.3383\ \text{kipft/ft})) + ((-0.729\ \text{kip/ft}) \times (8.75\ \text{ft}))]}{(8.75\ \text{ft})^2}$$

$$s = 1.2677\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.0796\ \text{ft})}{2}$$

$$p_a = 0.45597\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25372\ \mathrm{kip/ft^2}\right)}{\left(0.45597\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.55643$$

Status: **PASS**
Ratio: **0.560**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.75\ \mathrm{ft})$$

$$p_s = 1.3125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2677\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96586$$

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

Considering z-direction:

$H_o = 0.14533\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.49233\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.49233\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.49233\ \mathrm{kipft/ft})) + (4 \times (0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.2946\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times \left[(4 \times (0.49233\ \mathrm{kipft/ft})) + (3 \times (0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))\right]^2}{(8.75\ \mathrm{ft})^2 \times \left[(3 \times (0.49233\ \mathrm{kipft/ft})) + (2 \times (0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))\right]}$$

$$p = 0.12805\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times \left[(2 \times (0.49233\ \mathrm{kipft/ft})) + ((0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))\right]}{(8.75\ \mathrm{ft})^2}$$

$$s = 0.27776\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.2946\ \mathrm{ft})}{2}$$

$$p_a = 0.4721\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.12805\ \mathrm{kip/ft^2}\right)}{\left(0.4721\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.27123$$

Status: **PASS**
Ratio: **0.270**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.75\ \mathrm{ft})$$

$$p_s = 1.3125\ \mathrm{kip/ft^2}$$

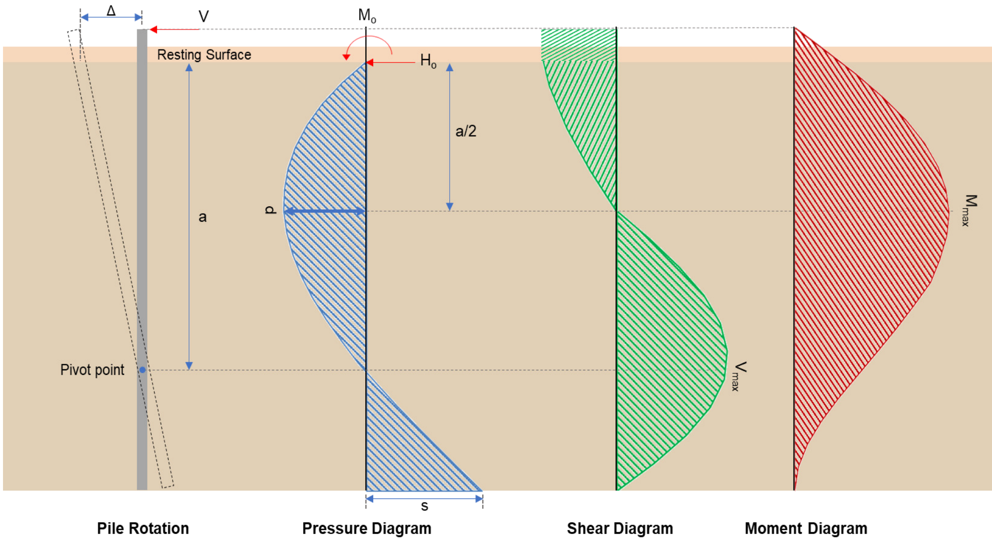
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27776\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.21163$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.685\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.2283\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(42.649\ \mathrm{kipft}) + ((-3.685\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 14.216\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.216\ \mathrm{kipft/ft})}{(-1.2283\ \mathrm{kip/ft})}$$

$$E = 11.574\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.216\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-1.2283\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (14.216\ \text{kipft/ft})) + (4 \times (-1.2283\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.0777\ \text{ft}$$

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

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

$$V_{max} = ((-1.2283\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.574\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.0777\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.574\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.0777\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.055\ \text{kip}$$

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

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

$$M_{max} = ((-1.2283\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(11.574\ \text{ft})}{(8.75\ \text{ft})} + \frac{(6.0777\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (11.574\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.0777\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.574\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.0777\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 45.449\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.679\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.22633\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.322\ \text{kipft}) + ((0.679\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.774\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.774\ \text{kipft/ft})}{(0.22633\ \text{kip/ft})}$$

$$E = 3.4197\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.774\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (0.22633\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (0.774\ \text{kipft/ft})) + (4 \times (0.22633\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.293\ \text{ft}$$

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

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

$$V_{max} = ((0.22633\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4197\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.293\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4197\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.293\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.9237\ \text{kip}$$

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

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

$$M_{max} = ((0.22633\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(3.4197\ \text{ft})}{(8.75\ \text{ft})} + \frac{(6.293\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.4197\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.293\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4197\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.293\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 3.5129\ \text{kipft}$$

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,
$A_g = 1017.9\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.304\ \text{kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(1017.9\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(1017.9\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -37.051\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.051\ \text{in}^2\right), \left(0.0018 \times \left(1017.9\ \text{in}^2\right)\right)\right]$$

$$A_{min} = 1.8322\ \text{in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322\ \text{in}^2\right)}{\left(0.3068\ \text{in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625\ \text{in})^2}{4}$$

$$A_{st} = 1.8408\ \text{in}^2$$

$Ratio$ - Capacity

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

$$\left(1.8322\ \text{in}^2\right)$$

$$Ratio = \frac{}{(1.8408\ \text{in}^2)}$$

$$Ratio = 0.99533$$

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,

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

$$s_{ties} = Min\left[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), (36\ \text{in})\right]$$

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

Summary:

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.304\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0082175$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.304 \text{ kip} \rightarrow 10304 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(10304 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.187 \text{ kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi}))\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.187 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.187 \text{ kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.187 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.332 \text{ kip}$$

Considering x-direction:

$V_{max} = 11.055 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.055 \text{ kip})}{(74.332 \text{ kip})}$$

$$Ratio = 0.14872$$

Status: **PASS**
Ratio: **0.150**

Considering z-direction:

$V_{max} = 0.9237 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.9237 \text{ kip})}{(74.332 \text{ kip})}$$

$$Ratio = 0.012427$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),
Allowable flexural strength:
M_n shall be the lesser of:
$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442 in^3$$

$$\phi M_{n,1} = 62.027 kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$

$$\phi M_{n,2} = 527.23 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$

$$\phi M_n = 62.027 \text{ kipft}$$

Considering x-direction:

$M_{max} = 45.449 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(45.449 \text{ kipft})}{(62.027 \text{ kipft})}$$

$$Ratio = 0.73272$$

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

Considering z-direction:

$M_{max} = 3.5129 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

$$Ratio = \frac{M_{max}}{\ldots}$$

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(3.5129 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.056636$$	Status: **PASS** Ratio: **0.060**

REFERENCES	CALCULATIONS	RESULTS

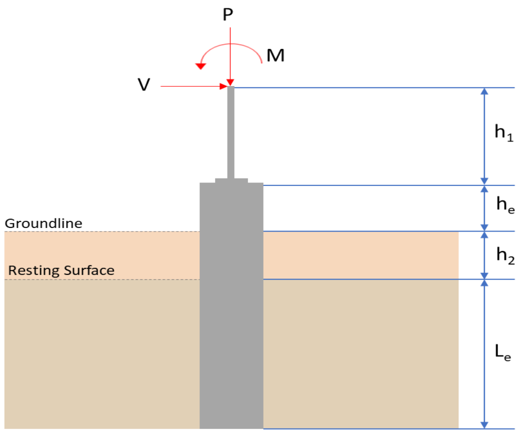
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 8.75\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.409	10.305
V_x (kip)	-2.188	-3.685
V_z (kip)	-0.436	-0.679
M_x (kipft)	-1.485	-2.336
M_z (kipft)	25.023	42.654

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,

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

$$H_o = \frac{(-2.188\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.72933\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(25.023\ \text{kipft}) + ((-2.188\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 8.341\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.9467\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.436\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.14533\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.485\ \text{kipft}) + ((-0.436\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.495\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.8503\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.9467\ \text{ft}), (2.8503\ \text{ft})]$$

$$L_{e,req} = 7.947\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.947\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.90823$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(6.409 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.90669 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.90669 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.45334$$

Status: **PASS**
Ratio: **0.450**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.72933 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 8.341 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.341 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (-0.72933 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (8.341 \text{ kipft/ft})) + (4 \times (-0.72933 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.0796 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (8.341 \text{ kipft/ft})) + (3 \times (-0.72933 \text{ kip/ft}) \times (8.75 \text{ ft}))]^2}{(8.75 \text{ ft})^2 \times [(3 \times (8.341 \text{ kipft/ft})) + (2 \times (-0.72933 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = 0.25374 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (8.341 \text{ kipft/ft})) + ((-0.72933 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = 1.268 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.0796 \text{ ft})}{2}$$

$$p_a = 0.45597 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.25374\ \mathrm{kip/ft^2}\right)}{\left(0.45597\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.55648$$

Status: **PASS**
Ratio: **0.560**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.75\ \mathrm{ft})$$

$$p_s = 1.3125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.268\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96609$$

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

Considering z-direction:

$H_o = -0.14533\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.495\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.495\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.495\ \mathrm{kipft/ft})) + (4 \times (-0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.2937\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.495\ \mathrm{kipft/ft})) + (3 \times (-0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.495\ \mathrm{kipft/ft})) + (2 \times (-0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = -0.048953\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.495\ \mathrm{kipft/ft})) + ((-0.14533\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = -0.034674\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.2937\ \mathrm{ft})}{2}$$

$$p_a = 0.47203\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.048953\ \mathrm{kip/ft^2}\right)}{\left(0.47203\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.10371$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (8.75\text{ ft})$$

$$p_s = 1.3125\text{ kip/ft}^2$$

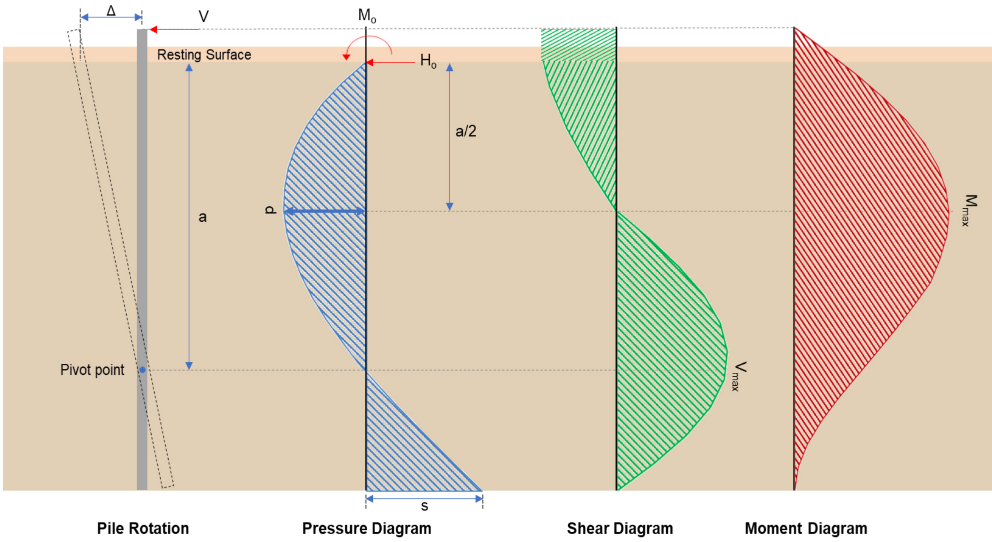
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.034674\text{ kip/ft}^2)}{(1.3125\text{ kip/ft}^2)}$$

$$Ratio = -0.026418$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.685\text{ kip})}{(36\text{ in})}$$

$$H_o = -1.2283\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(42.654\text{ kipft}) + ((-3.685\text{ kip}) \times (0\text{ ft}))}{(36\text{ in})}$$

$$M_o = 14.218\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.218\text{ kipft/ft})}{(-1.2283\text{ kip/ft})}$$

$$E = 11.575\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.218\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-1.2283\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (14.218\ \text{kipft/ft})) + (4 \times (-1.2283\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.0777\ \text{ft}$$

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

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

$$V_{max} = ((-1.2283\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.575\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.0777\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.575\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.0777\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.056\ \text{kip}$$

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

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

$$M_{max} = ((-1.2283\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(11.575\ \text{ft})}{(8.75\ \text{ft})} + \frac{(6.0777\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (11.575\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.0777\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.575\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.0777\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 45.453\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.679\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.22633\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.336\ \text{kipft}) + ((-0.679\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.77867\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.77867\ \text{kipft/ft})}{(-0.22633\ \text{kip/ft})}$$

$$E = 3.4404\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.77867\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-0.22633\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (0.77867\ \text{kipft/ft})) + (4 \times (-0.22633\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.292\ \text{ft}$$

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

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

$$V_{max} = ((-0.22633\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4404\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.292\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4404\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.292\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.92648\ \text{kip}$$

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

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

$$M_{max} = ((-0.22633\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(3.4404\ \text{ft})}{(8.75\ \text{ft})} + \frac{(6.292\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.4404\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.292\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4404\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.292\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 3.5251\ \text{kipft}$$

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,
$A_g = 1017.9\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.305\ \text{kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5\ \text{ksi}) \times (1017.9\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (1017.9\ \text{in}^2))\right]$$

$$A_{st,required} = -37.051\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-37.051\ \text{in}^2), (0.0018 \times (1017.9\ \text{in}^2))\right]$$

$$A_{min} = 1.8322\ \text{in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(1.8322\ \text{in}^2)}{(0.3068\ \text{in}^2)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625\ \text{in})^2}{4}$$

$$A_{st} = 1.8408\ \text{in}^2$$

$Ratio$ - Capacity

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

$$(1.8322\ \text{in}^2)$$

	$$Ratio = \frac{}{(1.8408\ \text{in}^2)}$$ $$Ratio = 0.99533$$	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, $$s_{ties} = Min\left[(16\ d_{bar}), (48\ d_{ties}), D\right]$$ $$s_{ties} = Min\left[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), (36\ \text{in})\right]$$ $$s_{ties} = 10\ \text{in}$$	
	Summary: Main reinforcement: **6 - #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 $$\phi P_N = \phi\ 0.85\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 1253.9\ \text{kip}$$	
	$Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(10.305\ \text{kip})}{(1253.9\ \text{kip})}$$ $$Ratio = 0.0082183$$	Status: **PASS** Ratio: **0.010**
	Shear Strength (ACI 318-19, LRFD)	
	Parameters:	
	$b_w = 36\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (36\ \text{in})$$ $$d = 28.8\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$	
	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 $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$	

$$V_{c,max} = 186.09 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.305 \text{ kip} \rightarrow 10305 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(10305 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.187 \text{ kip}$$

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)

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi}))\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.187 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.187 \text{ kip}$$

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)

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 414.72 \text{ kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(414.72 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.187 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.332 \text{ kip}$$

Considering x-direction:

$V_{max} = 11.056 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.056\ \text{kip})}{(74.332\ \text{kip})}$$

$$Ratio = 0.14874$$

Status: **PASS**
Ratio: **0.150**

Considering z-direction:

$V_{max} = 0.92648\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.92648\ \text{kip})}{(74.332\ \text{kip})}$$

$$Ratio = 0.012464$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),
Allowable flexural strength:
M_n shall be the lesser of:
$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 4580.442 in^3$$

$$\phi M_{n,1} = 62.027 kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$

$$\phi M_{n,2} = 527.23\ \text{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$

$$\phi M_n = 62.027\ \text{kipft}$$

Considering x-direction:

$M_{max} = 45.453\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(45.453\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.7328$$

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

Considering z-direction:

$M_{max} = 3.5251\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(3.5251\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.056832$$	Status: **PASS** Ratio: **0.060**