Project Details

Project Name: Lebanon Woolen Mill - EXPB - V1Jb-5x12-1975

Location: 1 Foundry St, Lebanon, NH 03766, USA

Unique ID: 4P-19.75-8TOP-XD-12-L-5Hx12W-672I

Dealer: ______________________________

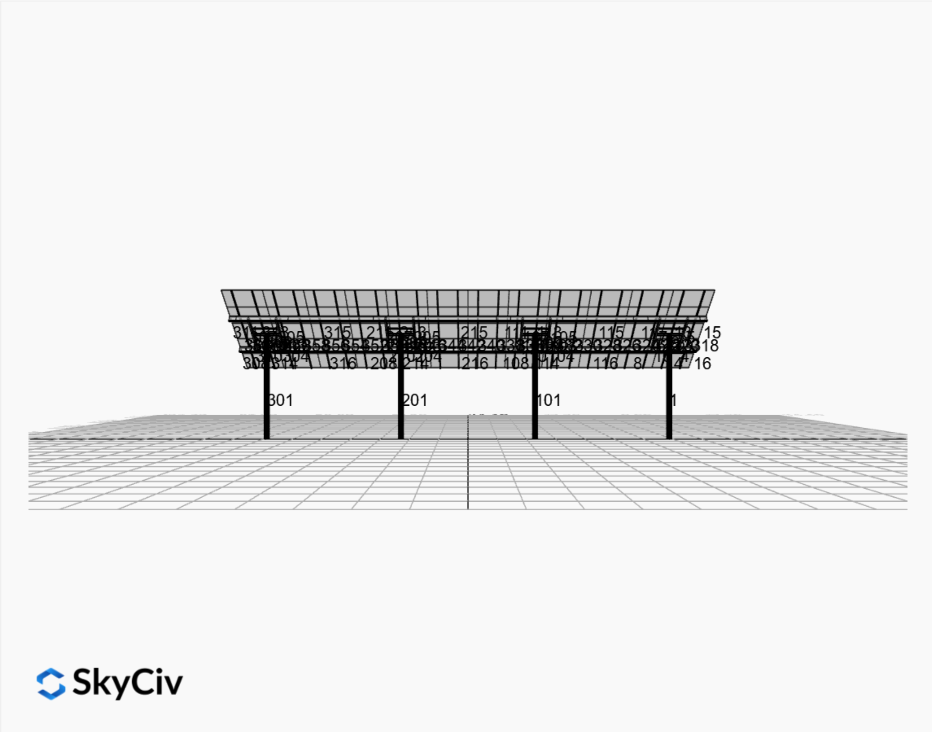
Date: Tue Jan 07 2025

Number of Modules: 60

Number of Poles: 4

Date Sold:

____



Array Dimensions N/S	18.79 ft
Array Dimensions E/W	68.80 ft
Winter Tilt Angle	35
Front Edge Clearance	10 ft

MT Solar Bill of Materials (4P-19.75-8TOP-XD-12-L-5Hx12W-672I)

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-ANGLE-4PK	Angle Clamp	12

Rail Bill of Materials

Part	Qty
Rails (223in)	24
Rail Attachment	96
Module Mid Clamp	96
Module End Clamp	48
Ground Lug	12

Site Details:

Site Address: 1 Foundry St, Lebanon, NH 03766, USA

Array Specification

Duty Classification:	XD
Module Width:	44.60 in
Module Length:	67.80in
Number of Rows:	5
Number of Columns:	12
Total Number of Modules:	60
Winter Tilt Angle:	35
Front Edge Clearance:	10
Total Array Height at Tilt:	20.78 ft
Total Frame Length:	68.75 ft
Frame Weight:	6682 lbs
Array Dimensions N/S:	18.79 ft
Array Dimensions E/W:	68.80 ft
Rail Length:	225.50 in
Rail Spacing:	2.87 ft

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	15.39 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.25 ft Pile 2: 7.75 ft Pile 3: 7.75 ft Pile 4: 7.25 ft
Foundation Volume:	17.778 y^3

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	1 Foundry St, Lebanon, NH 03766, USA
Wind Speed:	102 mph

Snow Load:	60 psf

Design Disclaimer

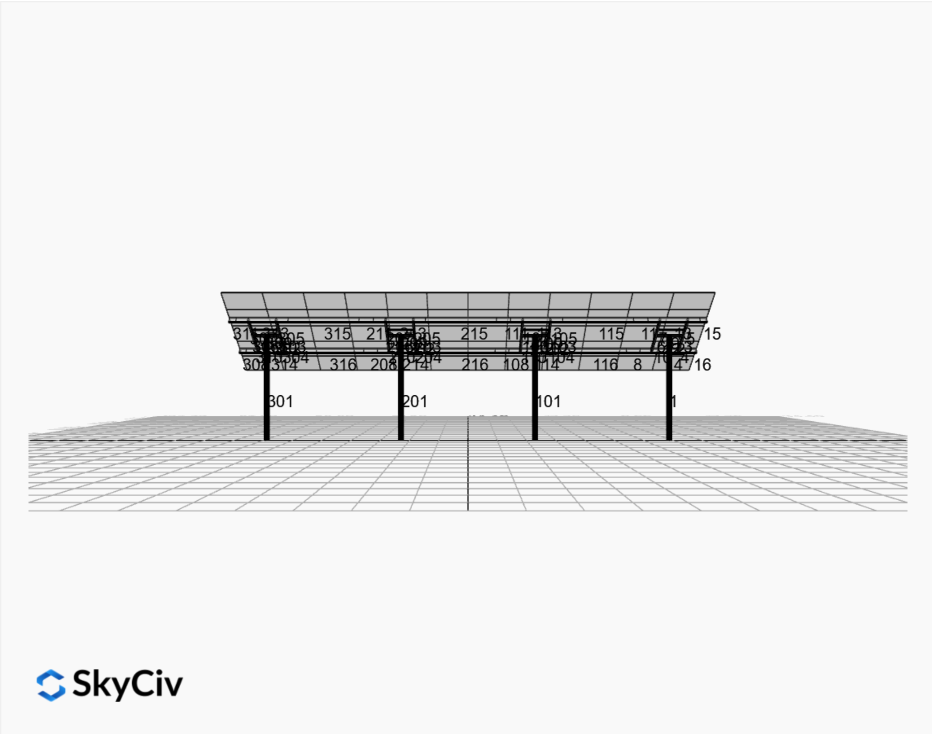
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

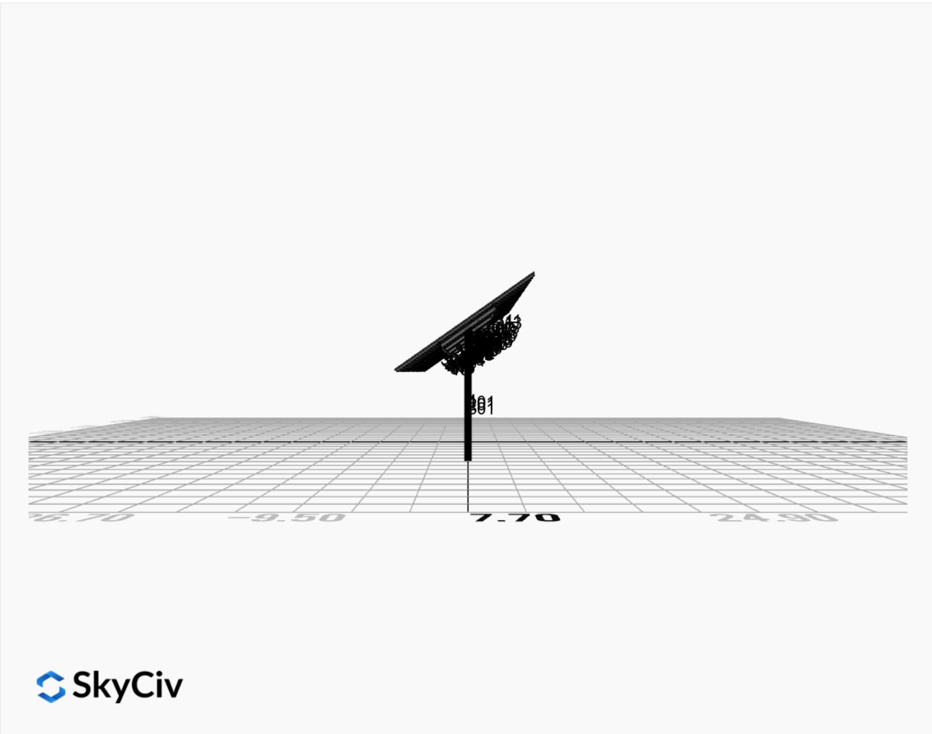
AutoDesigner Input

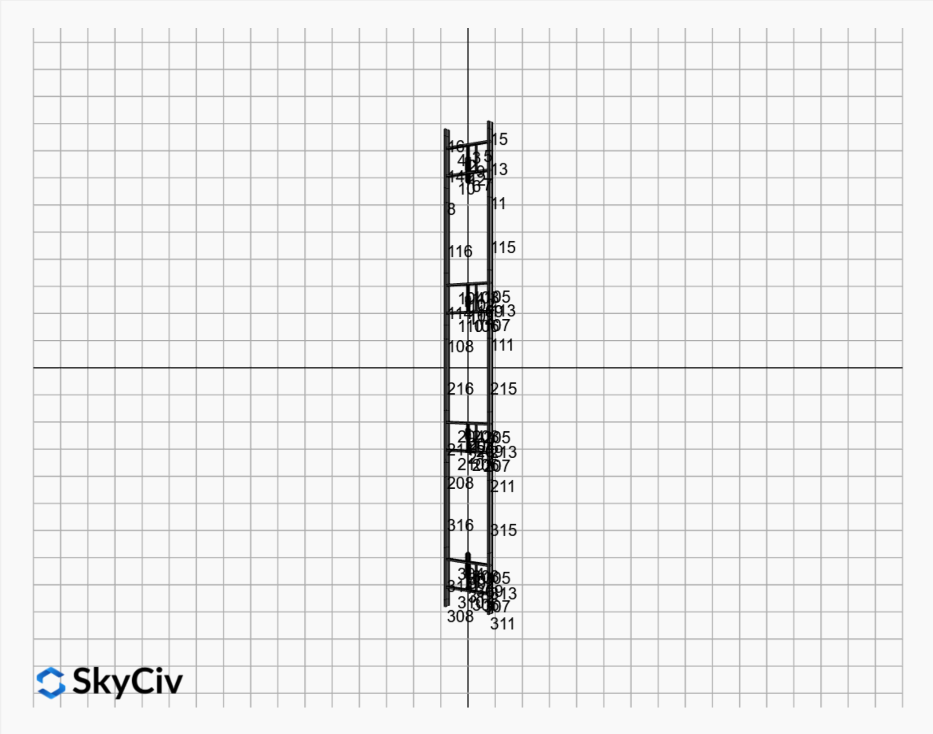
{"product_type":"Beam","designer_name":"Lebanon Woolen Mills","designer_email":"Evan@mainselectric.com","designer_phone":"603 833-3312","project_id":"Lebanon Woolen Mill - EXPB - V1Jb-5x12-1975","site_address":"1 Foundry St, Lebanon, NH 03766, USA","module_width":44.6,"module_length":67.8,"number_rows":"5","number_columns":12,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":35,"ground_clearance":10,"risk_category":"I","exposure_category":"B","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false,"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":true}

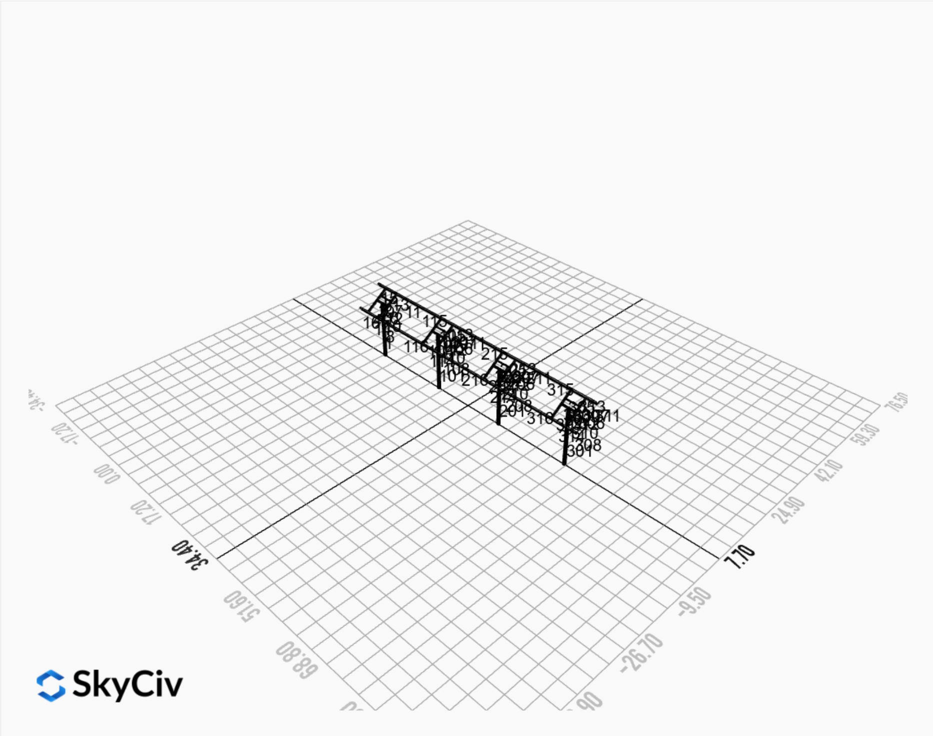
Design Notes:

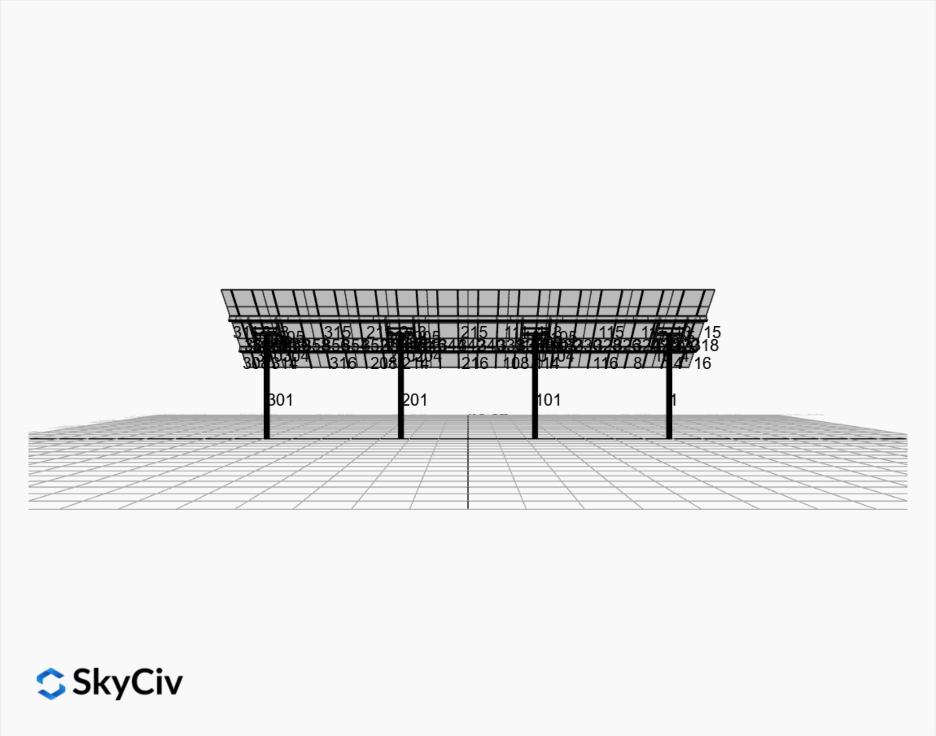
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



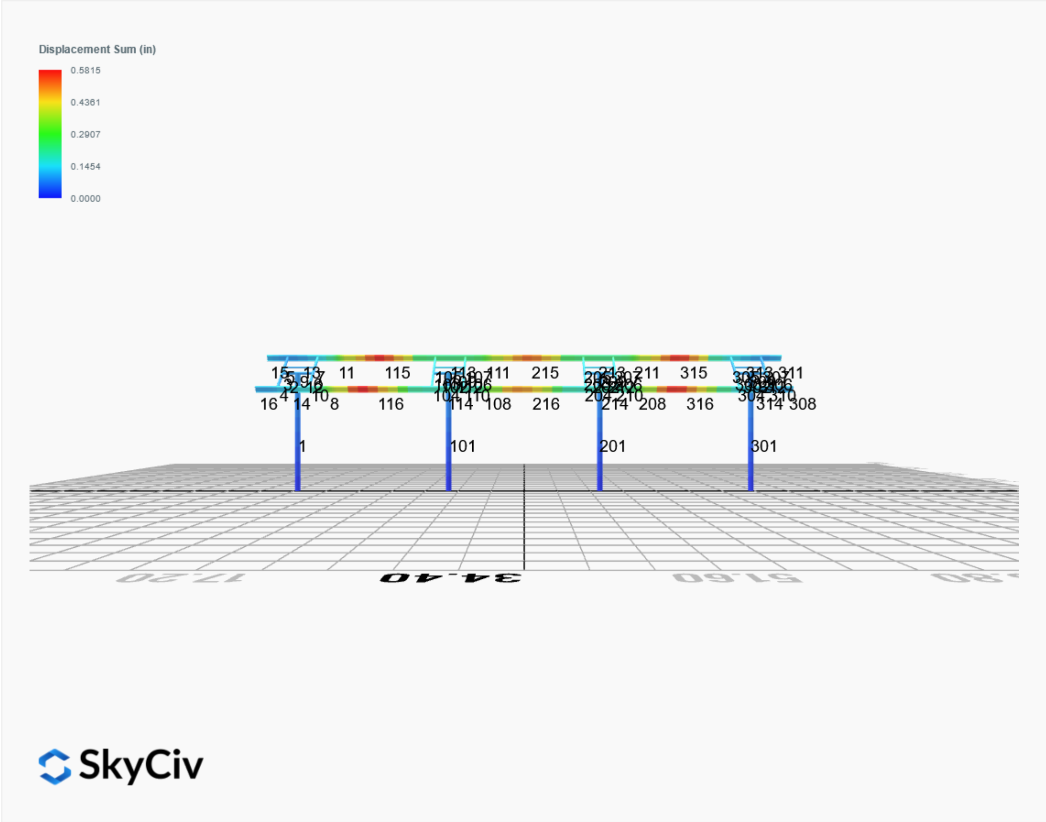


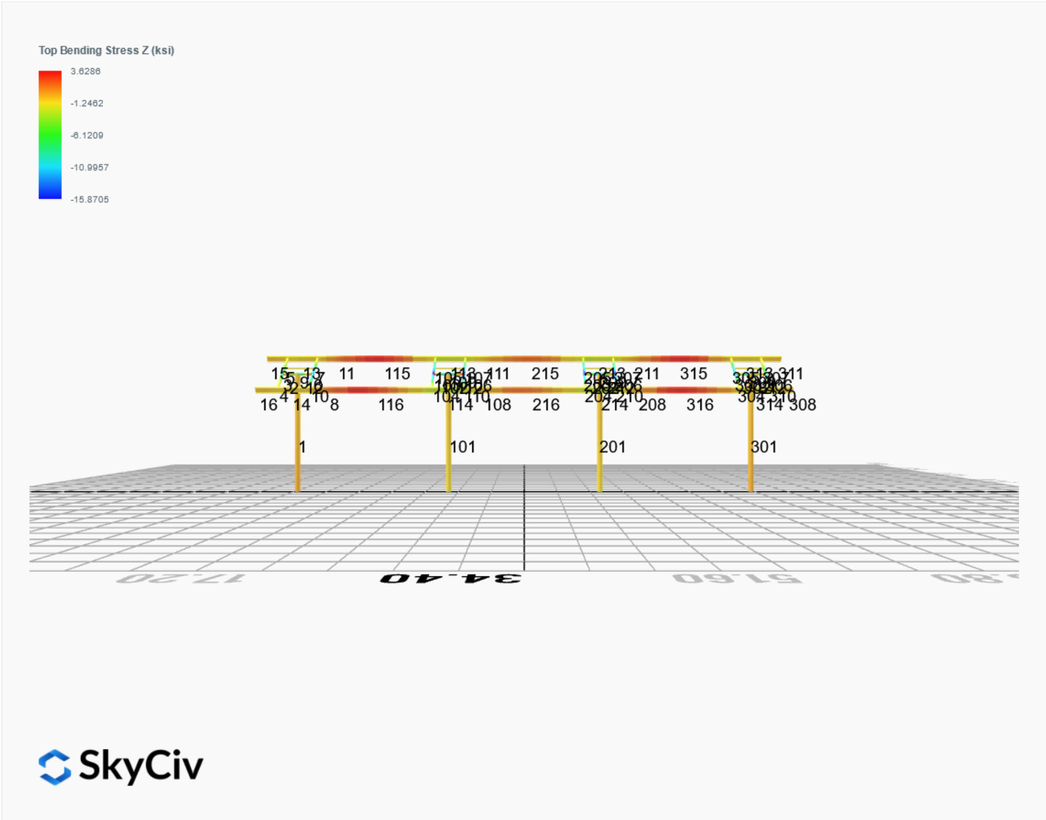

SkyCiv

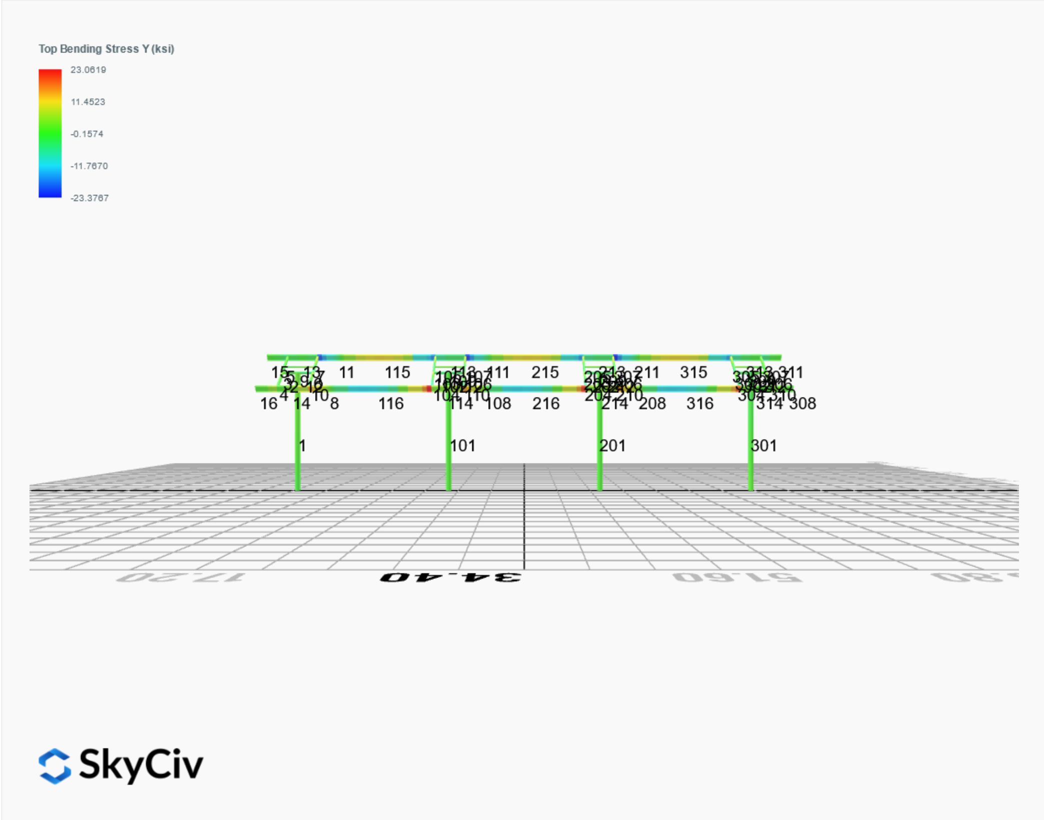

SkyCiv

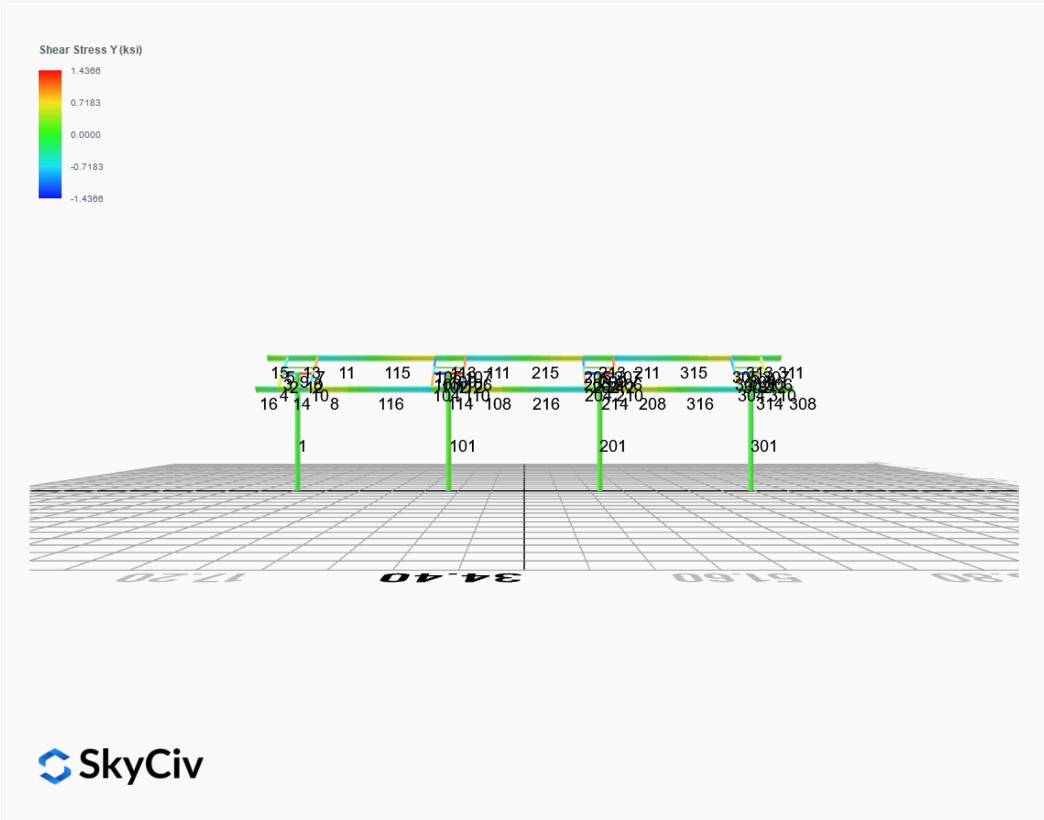


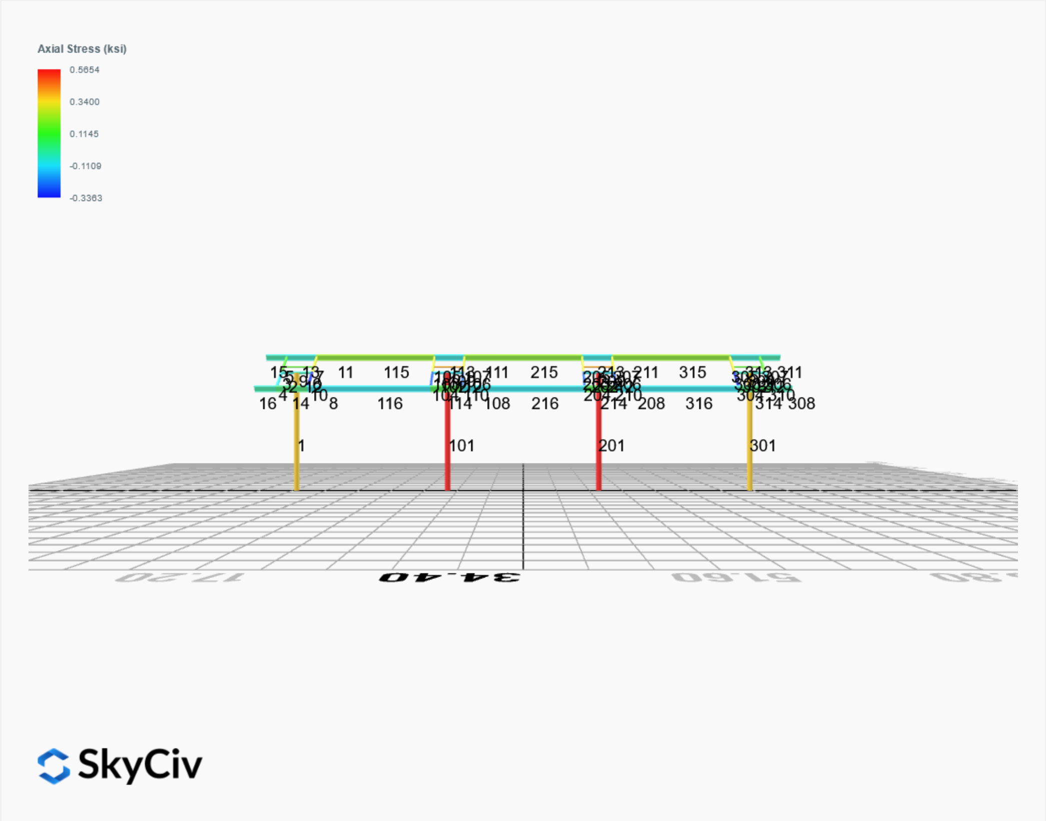
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
23.0619
11.4523
-0.1574
-11.7670
-23.3767
SkyCiv


Shear Stress Y (ksi)
1.4366
0.7183
0.0000
-0.7183
-1.4366
SkyCiv


Axial Stress (ksi)
0.5654
0.3400
0.1145
-0.1109
-0.3363
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0339	2.4840	0.0792	0.3832	-0.0843	-0.4594
ULS: 2. D + L	0.0339	2.4840	0.0792	0.3832	-0.0843	-0.4594
ULS: 3. D + (S or Lr or R)	0.1433	7.4866	0.3371	1.6353	-0.3612	-2.0229
ULS: 3. D + (S or Lr or R)	0.0339	2.4840	0.0792	0.3832	-0.0843	-0.4594
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.1160	6.2360	0.2726	1.3223	-0.2919	-1.6320
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0339	2.4840	0.0792	0.3832	-0.0843	-0.4594
ULS: 5b. D + 0.7E	0.0339	2.4840	0.0792	0.3832	-0.0843	-0.4594
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.1160	6.2360	0.2726	1.3223	-0.2919	-1.6320
ULS: 8. 0.6D + 0.7E	0.0204	1.4904	0.0475	0.2299	-0.0506	-0.2757
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1890	5.5262	0.3491	1.6559	-1.0949	35.0655
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1890	5.5262	0.3491	1.6559	-1.0949	35.0655
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8992	-0.0749	-0.1396	-0.6453	0.7341	-29.0332
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6260	0.3284	-0.1304	-0.6019	0.7092	-30.9806
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5512	8.5176	0.4751	2.2768	-1.0499	25.0117
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5512	8.5176	0.4751	2.2768	-1.0499	25.0117
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5150	4.3168	0.1086	0.5509	0.3218	-23.0623
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3100	4.6193	0.1155	0.5835	0.3032	-24.5229
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6332	4.7656	0.2816	1.3377	-0.8422	26.1843
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6332	4.7656	0.2816	1.3377	-0.8422	26.1843
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4329	0.5648	-0.0849	-0.3882	0.5295	-21.8898
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2280	0.8673	-0.0780	-0.3556	0.5109	-23.3503
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2025	4.5326	0.3174	1.5026	-1.0612	35.2493
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.2025	4.5326	0.3174	1.5026	-1.0612	35.2493
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8857	-1.0685	-0.1712	-0.7986	0.7678	-28.8494
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6124	-0.6652	-0.1621	-0.7552	0.7429	-30.7969

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.5277
Shear X	-3.7048
Shear Z	0.7443
Moment X	3.5907
Moment Y (Twist)	1.9593
Moment Z	59.4507

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	8.5176
Shear X	-2.2025
Shear Z	0.4751
Moment X	2.2768
Moment Y (Twist)	1.0949
Moment Z	35.2493

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	-0.0339	3.1678	-0.0017	-0.0090	0.0022	0.5183
ULS: 2. D + L	-0.0339	3.1678	-0.0017	-0.0090	0.0022	0.5183
ULS: 3. D + (S or Lr or R)	-0.1433	10.3844	-0.0068	-0.0364	0.0076	2.1735
ULS: 3. D + (S or Lr or R)	-0.0339	3.1678	-0.0017	-0.0090	0.0022	0.5183
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1160	8.5802	-0.0055	-0.0295	0.0063	1.7597

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0339	3.1678	-0.0017	-0.0090	0.0022	0.5183
ULS: 5b. D + 0.7E	-0.0339	3.1678	-0.0017	-0.0090	0.0022	0.5183
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1160	8.5802	-0.0055	-0.0295	0.0063	1.7597
ULS: 8. 0.6D + 0.7E	-0.0204	1.9007	-0.0010	-0.0054	0.0013	0.3110
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.9965	7.5312	0.0430	0.1985	-0.2228	47.2649
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.9965	7.5312	0.0430	0.1985	-0.2228	47.2649
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4759	-0.5217	-0.0341	-0.1587	0.1698	-36.9391
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.0200	0.1164	-0.0440	-0.2054	0.2104	-38.6397
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3379	11.8528	0.0280	0.1261	-0.1625	36.8196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.3379	11.8528	0.0280	0.1261	-0.1625	36.8196
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.7664	5.8131	-0.0299	-0.1418	0.1320	-26.3333
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.4245	6.2917	-0.0373	-0.1769	0.1625	-27.6087
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.2558	6.4404	0.0318	0.1467	-0.1666	35.5782
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.2558	6.4404	0.0318	0.1467	-0.1666	35.5782
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8485	0.4007	-0.0260	-0.1212	0.1279	-27.5748
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5065	0.8793	-0.0335	-0.1563	0.1583	-28.8502
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.9829	6.2641	0.0437	0.2021	-0.2237	47.0575
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.9829	6.2641	0.0437	0.2021	-0.2237	47.0575
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4895	-1.7888	-0.0334	-0.1551	0.1689	-37.1464
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.0336	-1.1507	-0.0434	-0.2018	0.2095	-38.8470

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	18.9765
Shear X	-5.0215
Shear Z	-0.0800
Moment X	-0.3746
Moment Y (Twist)	0.3948
Moment Z	81.5757

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	11.8528
Shear X	-2.9965
Shear Z	-0.0440
Moment X	-0.2054
Moment Y (Twist)	0.2237
Moment Z	47.2649

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	-0.0339	3.1678	0.0017	0.0090	-0.0021	0.5183
ULS: 2. D + L	-0.0339	3.1678	0.0017	0.0090	-0.0021	0.5183
ULS: 3. D + (S or Lr or R)	-0.1433	10.3844	0.0068	0.0362	-0.0072	2.1736
ULS: 3. D + (S or Lr or R)	-0.0339	3.1678	0.0017	0.0090	-0.0021	0.5183
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.1160	8.5802	0.0056	0.0294	-0.0060	1.7598
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0339	3.1678	0.0017	0.0090	-0.0021	0.5183
ULS: 5b. D + 0.7E	-0.0339	3.1678	0.0017	0.0090	-0.0021	0.5183
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.1160	8.5802	0.0056	0.0294	-0.0060	1.7598
ULS: 8. 0.6D + 0.7E	-0.0204	1.9007	0.0010	0.0054	-0.0013	0.3110
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.9965	7.5312	-0.0430	-0.1985	0.2229	47.2649
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.9965	7.5312	-0.0430	-0.1985	0.2229	47.2649
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4759	-0.5217	0.0341	0.1587	-0.1698	-36.9391
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.0200	0.1164	0.0440	0.2054	-0.2104	-38.6396

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	-2.3379	11.8528	-0.0280	-0.1262	0.1628	36.8197
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.3379	11.8528	-0.0280	-0.1262	0.1628	36.8197
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.7664	5.8131	0.0299	0.1417	-0.1317	-26.3333
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.4245	6.2917	0.0373	0.1767	-0.1622	-27.6087
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.2558	6.4404	-0.0318	-0.1467	0.1666	35.5782
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.2558	6.4404	-0.0318	-0.1467	0.1666	35.5782
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8485	0.4007	0.0260	0.1212	-0.1278	-27.5748
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5065	0.8793	0.0335	0.1563	-0.1583	-28.8502
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.9829	6.2641	-0.0437	-0.2021	0.2237	47.0575
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.9829	6.2641	-0.0437	-0.2021	0.2237	47.0575
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4895	-1.7888	0.0334	0.1551	-0.1689	-37.1464
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.0336	-1.1507	0.0434	0.2018	-0.2095	-38.8470

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	18.9765
Shear X	-5.0216
Shear Z	0.0800
Moment X	0.3753
Moment Y (Twist)	0.3956
Moment Z	81.5761

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	11.8528
Shear X	-2.9965
Shear Z	0.0440
Moment X	0.2054
Moment Y (Twist)	0.2237
Moment Z	47.2649

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	0.0339	2.4840	-0.0792	-0.3832	0.0843	-0.4594
ULS: 2. D + L	0.0339	2.4840	-0.0792	-0.3832	0.0843	-0.4594
ULS: 3. D + (S or Lr or R)	0.1433	7.4866	-0.3372	-1.6358	0.3615	-2.0225
ULS: 3. D + (S or Lr or R)	0.0339	2.4840	-0.0792	-0.3832	0.0843	-0.4594
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.1160	6.2360	-0.2727	-1.3226	0.2922	-1.6317
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0339	2.4840	-0.0792	-0.3832	0.0843	-0.4594
ULS: 5b. D + 0.7E	0.0339	2.4840	-0.0792	-0.3832	0.0843	-0.4594
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.1160	6.2360	-0.2727	-1.3226	0.2922	-1.6317
ULS: 8. 0.6D + 0.7E	0.0204	1.4904	-0.0475	-0.2299	0.0506	-0.2757
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1890	5.5262	-0.3491	-1.6559	1.0949	35.0656
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1890	5.5262	-0.3491	-1.6559	1.0949	35.0656
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8992	-0.0749	0.1396	0.6453	-0.7340	-29.0332
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6260	0.3284	0.1304	0.6018	-0.7092	-30.9806
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5512	8.5176	-0.4751	-2.2771	1.0502	25.0120
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5512	8.5176	-0.4751	-2.2771	1.0502	25.0120
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5149	4.3168	-0.1086	-0.5512	-0.3215	-23.0621
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3100	4.6193	-0.1155	-0.5838	-0.3029	-24.5226
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6332	4.7656	-0.2816	-1.3377	0.8422	26.1843
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6332	4.7656	-0.2816	-1.3377	0.8422	26.1843
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4329	0.5648	0.0849	0.3881	-0.5295	-21.8897
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2280	0.8673	0.0780	0.3556	-0.5108	-23.3503

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2025	4.5326	-0.3174	-1.5026	1.0612	35.2493
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.2025	4.5326	-0.3174	-1.5026	1.0612	35.2493
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8857	-1.0685	0.1712	0.7986	-0.7678	-28.8494
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6124	-0.6652	0.1621	0.7551	-0.7429	-30.7968

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	13.5275
Shear X	-3.7048
Shear Z	-0.7443
Moment X	-3.5926
Moment Y (Twist)	1.9599
Moment Z	59.4517

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	8.5176
Shear X	-2.2025
Shear Z	-0.4751
Moment X	-2.2771
Moment Y (Twist)	1.0949
Moment Z	35.2493

Project Details

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

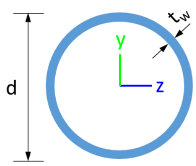
User Name: sales@mtsolar.us
Project Name: Lebanon Woolen Mill - EXPB - V1Jb-5x12-1975
Unit System: imperial

Design Input Information

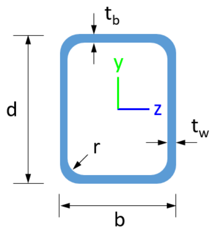
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

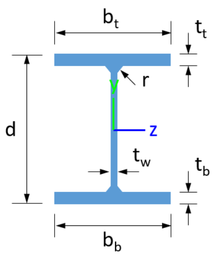
Section Dimensions



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



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



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

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

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

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	32.32	32.32	15.39	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.17,1.13,1.15,1.17,1.17,1.15,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.12,1.15,1.17,1.17,1.16,1.16	300	200	1
4	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.63,1.69,1.67,1.67,1.65,1.74,1.67,1.67,1.68,1.67,1.68,1.68,1.61,1.71,1.67,1.67,1.66,1.82	300	200	1
5	17	1.52	1.52	2.33	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.65,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.23,1.23,1.23,1.23,1.23,1.23,1.23,1.23,1.24,1.28,1.23,1.23,1.23,1.04,1.23,1.23,1.22,1.23,1.23,1.23,1.24,1.31,1.23,1.23,1.23,1.12	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.61,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.73,1.67,1.67,1.66,1.64	300	200	1
11	20	1.33	1.33	2.05	1.25,1.25,1.25,1.25,1.25,1.25,1.31,1.31,1.61,1.49,1.33,1.33,1.37,1.38,1.28,1.28,1.22,1.19,1.31,1.31,1.49,1.44,1.33,1.33,1.36,1.37	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.35,1.37,1.36,1.37,1.37,1.36,1.22,1.22,1.37,1.47,1.20,1.20,1.20,1.32,1.28,1.28,1.77,1.97,1.22,1.22,1.33,1.44,1.20,1.20,1.17,1.30	300	200	1
14	20	4.88	4.00	7.50	1.58,1.62,1.58,1.63,1.61,1.59,1.61,1.61,1.59,1.87,1.60,1.60,1.62,1.65,1.62,1.62,1.64,1.63,1.60,1.60,1.64,1.81,1.60,1.60,1.62,1.75	300	200	1
15	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	10	32.32	32.32	15.39	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
104	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.22,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.61	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
108	20	1.33	1.33	2.05	2.11,2.12,2.11,2.12,2.12,2.11,2.08,2.08,1.56,2.26,2.07,2.07,2.02,1.10,2.10,2.10,2.36,2.30,2.08,2.08,1.70,2.19,2.07,2.07,2.06,1.39	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.55,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.63	300	200	1
111	20	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.53,1.53,1.17,1.26,1.47,1.47,1.34,1.38,1.77,1.77,2.31,2.17,1.53,1.53,1.22,1.29,1.46,1.46,1.37,1.40	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1

113	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.11,1.11,2.45,3.82,1.12,1.12,1.19,1.21,1.09,1.09,1.05,1.05,1.11,1.11,3.91,2.34,1.13,1.13,1.17,1.18	300	200	1
114	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.17,1.14,1.09,1.09,1.10,1.35,1.07,1.07,1.05,1.06,1.08,1.08,1.14,1.19,1.09,1.09,1.10,1.19	300	200	1
115	20	6.63	6.63	10.20	1.14,1.13,1.14,1.13,1.14,1.14,1.10,1.10,1.06,1.06,1.09,1.09,1.07,1.07,1.12,1.12,1.17,1.21,1.10,1.10,1.06,1.07,1.09,1.09,1.08,1.08	300	200	1
116	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.14,1.11,1.17,1.14,1.14,1.13,1.09,1.15,1.15,1.16,1.15,1.14,1.14,1.12,1.17,1.14,1.14,1.13,1.12	300	200	1
201	10	32.32	32.32	15.39	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.55,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.71,1.67,1.67,1.66,1.63	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	1.88,1.88,1.88,1.89,1.88,1.88,1.71,1.71,1.41,2.09,1.68,1.68,1.60,1.16,1.80,1.80,2.07,1.95,1.71,1.71,1.48,2.11,1.67,1.67,1.62,1.39	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.23,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.70,1.67,1.67,1.66,1.61	300	200	1
211	20	1.33	1.33	2.05	1.66,1.66,1.66,1.65,1.66,1.66,1.37,1.37,1.10,1.17,1.33,1.33,1.25,1.27,1.49,1.49,2.08,2.13,1.37,1.37,1.14,1.20,1.32,1.32,1.27,1.28	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.11,1.11,2.46,3.82,1.12,1.12,1.19,1.21,1.09,1.09,1.05,1.05,1.11,1.11,3.90,2.34,1.13,1.13,1.17,1.18	300	200	1
214	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.17,1.14,1.09,1.09,1.10,1.35,1.07,1.07,1.05,1.06,1.08,1.08,1.14,1.19,1.09,1.09,1.10,1.19	300	200	1
215	20	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.11,1.11,1.06,1.08,1.11,1.11,1.09,1.10,1.13,1.13,1.19,1.23,1.11,1.11,1.07,1.08,1.11,1.11,1.10,1.10	300	200	1
216	20	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.15,1.12,1.21,1.15,1.15,1.14,1.04,1.16,1.16,1.18,1.17,1.15,1.15,1.13,1.23,1.15,1.15,1.14,1.10	300	200	1
301	10	32.32	32.32	15.39	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.66,1.61,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.73,1.67,1.67,1.66,1.64	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.17,1.13,1.15,1.17,1.17,1.15,1.16,1.17,1.17,1.18,1.18,1.17,1.17,1.12,1.15,1.17,1.17,1.16,1.16	300	200	1
307	17	1.52	1.52	2.33	1.69,1.67,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.65,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
308	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.70,1.68,1.70,1.67,1.69,1.70,1.67,1.67,1.63,1.69,1.67,1.67,1.65,1.74,1.67,1.67,1.68,1.67,1.68,1.68,1.61,1.71,1.67,1.67,1.66,1.82	300	200	1
311	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.35,1.37,1.36,1.37,1.37,1.36,1.22,1.22,1.37,1.47,1.20,1.20,1.20,1.32,1.28,1.28,1.77,1.97,1.22,1.22,1.33,1.44,1.19,1.19,1.17,1.30	300	200	1
314	20	4.88	4.00	7.5[illegible]	1.58,1.62,1.58,1.63,1.60,1.58,1.61,1.61,1.60,1.87,1.60,1.60,1.62,1.65,1.62,1.62,1.64,1.63,1.60,1.60,1.6[illegible]	30[illegible]	20[illegible]	1

314	20	4.88	4.00	0	4,1.81,1.60,1.60,1.62,1.75	0	0	1
315	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.08,1.17,1.12,1.09,1.09,1.10,1.10,1.07,1.07,1.08,1.08,1.08,1.08,1.13,1.12,1.09,1.09,1.10,1.10	300	200	1
316	20	6.63	6.63	10.20	1.08,1.08,1.08,1.08,1.08,1.08,1.07,1.07,1.07,1.09,1.07,1.07,1.07,1.03,1.08,1.08,1.08,1.08,1.07,1.07,1.07,1.09,1.07,1.07,1.07,1.05	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	574.32	158.80	123.94	123.94	172.30	172.30
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	35.89	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	574.32	158.80	123.94	123.94	172.30	172.30
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	140.46	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	140.46	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	31.98	6.46	56.26	44.91
114	159.30	97.43	32.23	6.46	56.26	44.91
115	159.30	75.13	20.32	6.46	56.26	44.91
116	159.30	75.13	21.05	6.46	56.26	44.91
201	574.32	158.80	123.94	123.94	172.30	172.30
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	140.46	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	140.46	46.90	6.46	56.26	44.91

212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	97.43	31.98	6.46	56.26	44.91
214	159.30	97.43	32.24	6.46	56.26	44.91
215	159.30	75.13	20.44	6.46	56.26	44.91
216	159.30	75.13	20.04	6.46	56.26	44.91
301	574.32	158.80	123.94	123.94	172.30	172.30
302	251.01	248.88	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	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	35.90	6.46	56.26	44.91
314	159.30	97.43	46.90	6.46	56.26	44.91
315	159.30	75.13	20.69	6.46	56.26	44.91
316	159.30	75.13	19.89	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	0.085	0.480	0.063	0.021	0.004	0.539	#13	0.674	Not Required	Pass
2	0.002	0.226	0.097	0.059	0.020	0.297	#21	0.054	Not Required	Pass
3	0.006	0.402	0.029	0.038	0.006	0.418	#21	0.046	Not Required	Pass
4	0.005	0.396	0.077	0.040	0.018	0.475	#21	0.122	Not Required	Pass
5	0.006	0.250	0.037	0.040	0.011	0.259	#21	0.076	Not Required	Pass
6	0.014	0.669	0.136	0.068	0.039	0.812	#21	0.046	Not Required	Pass
7	0.015	0.415	0.229	0.066	0.056	0.461	#21	0.076	Not Required	Pass
8	0.006	0.142	0.243	0.037	0.028	0.289	#24	0.102	Not Required	Pass
9	0.007	0.070	0.104	0.004	0.007	0.156	#21	0.206	Not Required	Pass
10	0.015	0.626	0.212	0.062	0.046	0.731	#21	0.082	Not Required	Pass
11	0.009	0.136	0.255	0.040	0.028	0.292	#24	0.102	Not Required	Pass
12	0.002	0.515	0.169	0.110	0.030	0.638	#21	0.054	Not Required	Pass
13	0.014	0.074	0.641	0.053	0.035	0.652	#23	0.306	Not Required	Pass
14	0.006	0.069	0.624	0.049	0.035	0.643	#24	0.204	Not Required	Pass
15	0.000	0.004	0.016	0.007	0.004	0.020	#21	Not Required	Not Required	Pass
16	0.000	0.004	0.016	0.007	0.004	0.020	#21	Not Required	Not Required	Pass
101	0.120	0.658	0.007	0.029	0.000	0.707	#13	0.674	Not Required	Pass
102	0.005	0.528	0.185	0.120	0.031	0.680	#21	0.054	Not Required	Pass
103	0.014	0.748	0.085	0.074	0.011	0.840	#21	0.046	Not Required	Pass
104	0.014	0.761	0.249	0.076	0.054	0.931	#21	0.082	Not Required	Pass
105	0.014	0.464	0.257	0.073	0.066	0.530	#21	0.076	Not Required	Pass
106	0.013	0.772	0.082	0.077	0.012	0.853	#21	0.046	Not Required	Pass
107	0.013	0.480	0.234	0.076	0.061	0.545	#21	0.076	Not Required	Pass
108	0.007	0.049	0.237	0.043	0.027	0.277	#21	0.102	Not Required	Pass
109	0.024	0.061	0.058	0.002	0.000	0.125	#21	0.206	Not Required	Pass
110	0.013	0.763	0.222	0.076	0.049	0.914	#21	0.082	Not Required	Pass

110	0.013	0.763	0.222	0.076	0.049	0.914	#21	0.082	Not Required	Pass
111	0.010	0.082	0.247	0.043	0.027	0.281	#24	0.102	Not Required	Pass
112	0.005	0.541	0.200	0.121	0.036	0.701	#21	0.036	Not Required	Pass
113	0.014	0.187	0.700	0.059	0.036	0.844	#21	0.306	Not Required	Pass
114	0.011	0.234	0.690	0.061	0.037	0.881	#21	0.306	Not Required	Pass
115	0.018	0.422	0.350	0.046	0.029	0.779	#21	0.507	Not Required	Pass
116	0.006	0.394	0.344	0.049	0.029	0.739	#21	0.507	Not Required	Pass
201	0.120	0.658	0.007	0.029	0.000	0.707	#13	0.674	Not Required	Pass
202	0.005	0.541	0.200	0.121	0.036	0.701	#21	0.036	Not Required	Pass
203	0.013	0.772	0.082	0.077	0.012	0.853	#21	0.046	Not Required	Pass
204	0.013	0.763	0.222	0.076	0.049	0.914	#21	0.082	Not Required	Pass
205	0.013	0.480	0.234	0.076	0.061	0.545	#21	0.076	Not Required	Pass
206	0.014	0.748	0.085	0.074	0.011	0.840	#21	0.046	Not Required	Pass
207	0.014	0.464	0.257	0.073	0.066	0.530	#21	0.076	Not Required	Pass
208	0.006	0.085	0.293	0.049	0.029	0.312	#21	0.102	Not Required	Pass
209	0.024	0.061	0.058	0.002	0.000	0.125	#21	0.206	Not Required	Pass
210	0.014	0.761	0.249	0.076	0.054	0.931	#21	0.082	Not Required	Pass
211	0.009	0.109	0.302	0.046	0.029	0.318	#21	0.102	Not Required	Pass
212	0.005	0.528	0.185	0.120	0.031	0.680	#21	0.054	Not Required	Pass
213	0.014	0.187	0.700	0.059	0.036	0.845	#21	0.306	Not Required	Pass
214	0.011	0.234	0.690	0.061	0.037	0.880	#21	0.306	Not Required	Pass
215	0.018	0.315	0.350	0.043	0.027	0.667	#21	0.507	Not Required	Pass
216	0.009	0.248	0.343	0.043	0.027	0.592	#21	0.507	Not Required	Pass
301	0.085	0.480	0.063	0.021	0.004	0.539	#13	0.674	Not Required	Pass
302	0.002	0.515	0.169	0.110	0.030	0.638	#21	0.054	Not Required	Pass
303	0.014	0.669	0.136	0.068	0.039	0.812	#21	0.046	Not Required	Pass
304	0.015	0.626	0.212	0.062	0.046	0.731	#21	0.082	Not Required	Pass
305	0.015	0.415	0.229	0.066	0.056	0.461	#21	0.076	Not Required	Pass
306	0.006	0.402	0.029	0.038	0.006	0.418	#21	0.046	Not Required	Pass
307	0.006	0.250	0.037	0.040	0.011	0.259	#21	0.076	Not Required	Pass
308	0.000	0.004	0.016	0.007	0.004	0.020	#21	Not Required	Not Required	Pass
309	0.007	0.070	0.104	0.004	0.007	0.156	#21	0.206	Not Required	Pass
310	0.005	0.396	0.077	0.040	0.018	0.475	#21	0.122	Not Required	Pass
311	0.000	0.004	0.016	0.007	0.004	0.020	#21	Not Required	Not Required	Pass
312	0.002	0.226	0.097	0.059	0.020	0.297	#21	0.054	Not Required	Pass
313	0.014	0.074	0.640	0.053	0.035	0.651	#23	0.204	Not Required	Pass
314	0.006	0.069	0.624	0.049	0.035	0.644	#24	0.306	Not Required	Pass
315	0.018	0.435	0.350	0.040	0.028	0.787	#21	0.507	Not Required	Pass
316	0.006	0.422	0.339	0.037	0.028	0.759	#21	0.507	Not Required	Pass

Definitions

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

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

REFERENCES	CALCULATIONS	RESULTS

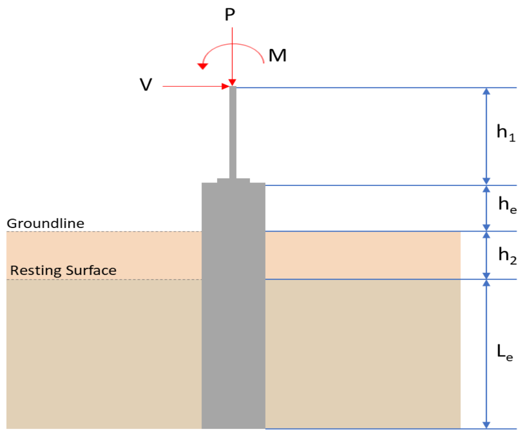
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

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

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

$L = 7.25 \text{ ft}$ - Total pile length

$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,

$h_2 = 0 \text{ ft}$ - Depth to resisting surface

$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.518	13.528
V_x (kip)	-2.203	-3.705
V_z (kip)	0.475	0.744
M_x (kipft)	2.277	3.591
M_z (kipft)	35.249	59.451

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.203 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.3508 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(35.249\ \text{kipft}) + ((-2.203\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 5.6129\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.7463\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.475\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.075637\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.277\ \text{kipft}) + ((0.475\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.36258\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 3.5613\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.7463\ \text{ft}), (3.5613\ \text{ft})]$$

$$L_{e,req} = 6.746\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.746\ \text{ft})}{(7.25\ \text{ft})}$$

$$Ratio = 0.93048$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.518\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.53238\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.53238\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.26619$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.8125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.3508\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.6129\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.6129\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (-0.3508\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (5.6129\ \text{kipft/ft})) + (4 \times (-0.3508\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 4.9735\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.6129\ \text{kipft/ft})) + (3 \times (-0.3508\ \text{kip/ft}) \times (7.25\ \text{ft}))]^{\ 2}}{(7.25\ \text{ft})^2 \times [(3 \times (5.6129\ \text{kipft/ft})) + (2 \times (-0.3508\ \text{kip/ft}) \times (7.25\ \text{ft}))]}$$

$$p = 0.26673\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.6129\ \text{kipft/ft})) + ((-0.3508\ \text{kip/ft}) \times (7.25\ \text{ft}))]}{(7.25\ \text{ft})^2}$$

$$s = 0.99111\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.9735\ \text{ft})}{2}$$

$$p_a = 0.37301\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26673\ \mathrm{kip/ft^2}\right)}{\left(0.37301\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.71506$$

Status: **PASS**
Ratio: **0.720**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.0875\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.99111\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91136$$

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

Considering z-direction:

$H_o = 0.075637\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.36258\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.36258\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.36258\ \mathrm{kipft/ft})) + (4 \times (0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.1367\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.36258\ \mathrm{kipft/ft})) + (3 \times (0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^{\ 2}}{(7.25\ \mathrm{ft})^2 \times [(3 \times (0.36258\ \mathrm{kipft/ft})) + (2 \times (0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.062586\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.36258\ \mathrm{kipft/ft})) + ((0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 0.14537\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1367\ \mathrm{ft})}{2}$$

$$p_a = 0.38525\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.062586\ \mathrm{kip/ft^2}\right)}{\left(0.38525\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.16246$$

Status: **PASS**
Ratio: **0.160**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.0875\ \mathrm{kip/ft^2}$$

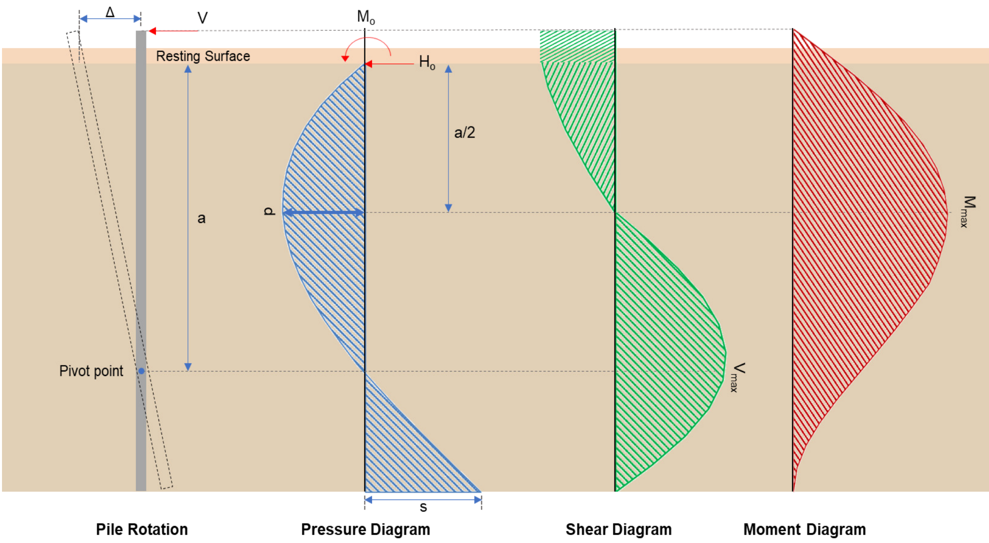
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.14537\ \mathrm{kip/ft^2})}{(1.0875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.13368$$

Status: **PASS**
Ratio: **0.130**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.705\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.58997\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(59.451\ \mathrm{kipft}) + ((-3.705\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 9.4667\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.4667\ \mathrm{kipft/ft})}{(-0.58997\ \mathrm{kip/ft})}$$

$$E = 16.046\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.4667\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.58997\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{\dots}$$

$$a = \frac{}{(6 \times (9.4667 \text{ kipft/ft})) + (4 \times (-0.58997 \text{ kip/ft}) \times (7.25 \text{ ft})}$$

$$a = 4.9732 \text{ ft}$$

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

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

$$V_{max} = ((-0.58997 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (16.046 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(4.9732 \text{ ft})}{(7.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (16.046 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(4.9732 \text{ ft})}{(7.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 10.802 \text{ kip}$$

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

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

$$M_{max} = ((-0.58997 \text{ kip/ft}) \times (48 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(16.046 \text{ ft})}{(7.25 \text{ ft})} + \frac{(4.9732 \text{ ft})}{2 \times (7.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (16.046 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(4.9732 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (16.046 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(4.9732 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 37.598 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.744 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.11847 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(3.591 \text{ kipft}) + ((0.744 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.57182 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.57182 \text{ kipft/ft})}{(0.11847 \text{ kip/ft})}$$

$$E = 4.8266 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.57182 \text{ kipft/ft}) \times (7.25 \text{ ft})) + \left(3 \times (0.11847 \text{ kip/ft}) \times (7.25 \text{ ft})^2\right)}{(6 \times (0.57182 \text{ kipft/ft})) + (4 \times (0.11847 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 5.1356 \text{ ft}$$

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

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

$$V_{max} = ((0.11847 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.8266 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(5.1356 \text{ ft})}{(7.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.8266 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(5.1356 \text{ ft})}{(7.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.87268 \text{ kip}$$

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

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

$$M_{max} = ((0.11847 \text{ kip/ft}) \times (48 \text{ in}) \times (7.25 \text{ ft})) \times \left[\left(\frac{(4.8266 \text{ ft})}{(7.25 \text{ ft})} + \frac{(5.1356 \text{ ft})}{2 \times (7.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (4.8266 \text{ ft})}{(7.25 \text{ ft})} + 3\right) \times \left(\frac{(5.1356 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.8266 \text{ ft})}{(7.25 \text{ ft})} + 2\right) \times \left(\frac{(5.1356 \text{ ft})}{2 \times (7.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 2.8558 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(13.528 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.147 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.147 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

	$$Ratio = 0.96556$$	Status: **PASS** Ratio: **0.970**
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max\left[1.5, \left(1.5\ d_{bar}\right)\right]$$ $$s_{rebar} = Max\left[1.5, \left(1.5 \times (0.625\ \text{in})\right)\right]$$ $$s_{rebar} = 1.5\ \text{in}$$	
	Ties:	
25.7.2.2 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $$s_{ties} = Min\left[\left(16\ d_{bar}\right), \left(48\ d_{ties}\right), Min\left(D, b\right)\right]$$ $$s_{ties} = Min\left[\left(16 \times (0.625\ \text{in})\right), \left(48 \times (0.375\ \text{in})\right), Min\left((48\ \text{in}), (48\ \text{in})\right)\right]$$ $$s_{ties} = 10\ \text{in}$$	
	Summary: Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.528\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0050569$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 22.5.5.1.3 22.5.5.1.1	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 13.528 \text{ kip} \rightarrow 13528 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(13528 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120.29 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120.29 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120.29 \text{ kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.29 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.27 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.802 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(10.802\ \mathrm{kip})}{(111.27\ \mathrm{kip})}$$ $$Ratio = 0.097079$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $V_{max} = 0.87268\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.87268\ \mathrm{kip})}{(111.27\ \mathrm{kip})}$$ $$Ratio = 0.007843$$	Status: **PASS** Ratio: **0.010**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 37.598\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(37.598\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.15063$$	Status: **PASS** Ratio: **0.150**
	Considering z-direction: $M_{max} = 2.8558\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(2.8558 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.011441$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

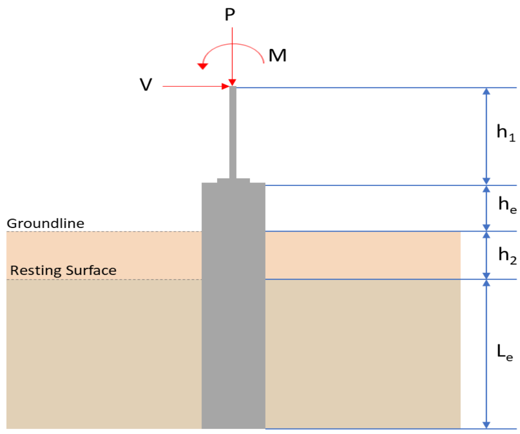
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 7.25\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.518	13.528
V_x (kip)	-2.203	-3.705
V_z (kip)	-0.475	-0.744
M_x (kipft)	-2.277	-3.593
M_z (kipft)	35.249	59.452

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.203\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.3508\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(35.249\ \text{kipft}) + ((-2.203\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 5.6129\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.7463\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.475\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.075637\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.277\ \text{kipft}) + ((-0.475\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.36258\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.585\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.7463\ \text{ft}), (2.585\ \text{ft})]$$

$$L_{e,req} = 6.746\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.746\ \text{ft})}{(7.25\ \text{ft})}$$

$$Ratio = 0.93048$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\ D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(8.518\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.53238\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.53238\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.26619$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.8125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.3508\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.6129\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.6129\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.3508\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (5.6129\ \mathrm{kipft/ft})) + (4 \times (-0.3508\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 4.9735\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.6129\ \mathrm{kipft/ft})) + (3 \times (-0.3508\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^{\ 2}}{(7.25\ \mathrm{ft})^2 \times [(3 \times (5.6129\ \mathrm{kipft/ft})) + (2 \times (-0.3508\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.26673\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.6129\ \mathrm{kipft/ft})) + ((-0.3508\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 0.99111\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.9735\ \mathrm{ft})}{2}$$

$$p_a = 0.37301\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26673\ \mathrm{kip/ft^2}\right)}{\left(0.37301\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.71506$$

Status: **PASS**
Ratio: **0.720**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.0875\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.99111\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91136$$

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

Considering z-direction:

$H_o = -0.075637\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.36258\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.36258\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.36258\ \mathrm{kipft/ft})) + (4 \times (-0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.1367\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.36258\ \mathrm{kipft/ft})) + (3 \times (-0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (0.36258\ \mathrm{kipft/ft})) + (2 \times (-0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = -0.060174\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.36258\ \mathrm{kipft/ft})) + ((-0.075637\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 0.020181\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1367\ \mathrm{ft})}{2}$$

$$p_a = 0.38525\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.060174\ \mathrm{kip/ft^2}\right)}{\left(0.38525\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.15619$$

Status: **PASS**
Ratio: **-0.160**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.25\ \mathrm{ft})$$

$$p_s = 1.0875\ \mathrm{kip/ft^2}$$

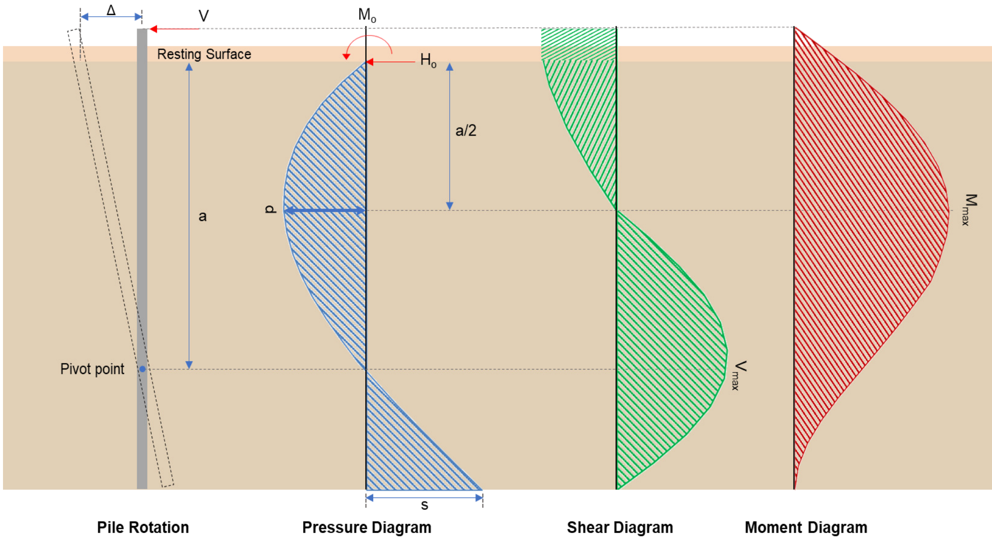
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.020181\ \mathrm{kip/ft^2})}{(1.0875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.018557$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.705\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.58997\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(59.452\ \mathrm{kipft}) + ((-3.705\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 9.4669\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.4669\ \mathrm{kipft/ft})}{(-0.58997\ \mathrm{kip/ft})}$$

$$E = 16.046\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.4669\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.58997\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{\quad}{(6 \times (9.4669\ \text{kipft/ft})) + (4 \times (-0.58997\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 4.9732\ \text{ft}$$

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

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

$$V_{max} = ((-0.58997\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (16.046\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9732\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (16.046\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9732\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.802\ \text{kip}$$

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

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

$$M_{max} = ((-0.58997\ \text{kip/ft}) \times (48\ \text{in}) \times (7.25\ \text{ft})) \times \left[\left(\frac{(16.046\ \text{ft})}{(7.25\ \text{ft})} + \frac{(4.9732\ \text{ft})}{2 \times (7.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (16.046\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9732\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (16.046\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9732\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 37.599\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.744\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.11847\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(3.593\ \text{kipft}) + ((-0.744\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.57213\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.57213\ \text{kipft/ft})}{(-0.11847\ \text{kip/ft})}$$

$$E = 4.8293\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.57213\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (-0.11847\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (0.57213\ \text{kipft/ft})) + (4 \times (-0.11847\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 5.1355\ \text{ft}$$

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

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

$$V_{max} = ((-0.11847\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.8293\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(5.1355\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.8293\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(5.1355\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.87299\ \text{kip}$$

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

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

$$M_{max} = ((-0.11847\ \text{kip/ft}) \times (48\ \text{in}) \times (7.25\ \text{ft})) \times \left[\left(\frac{(4.8293\ \text{ft})}{(7.25\ \text{ft})} + \frac{(5.1355\ \text{ft})}{2 \times (7.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.8293\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(5.1355\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.8293\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(5.1355\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.8569\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.528\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.147\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.147\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

	$$Ratio = 0.96556$$	Status: **PASS** Ratio: **0.970**
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max[1.5, (1.5\ d_{bar})]$$ $$s_{rebar} = Max[1.5, (1.5 \times (0.625\ \text{in}))]$$ $$s_{rebar} = 1.5\ \text{in}$$ **Ties:**	
25.7.2.2 25.7.2.1	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum spacing of ties, $$s_{ties} = Min[(16\ d_{bar}), (48\ d_{ties}), Min(D, b)]$$ $$s_{ties} = Min[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), Min((48\ \text{in}), (48\ \text{in}))]$$ $$s_{ties} = 10\ \text{in}$$ **Summary:** Main reinforcement: **14 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.528\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0050569$$	Status: **PASS** Ratio: **0.010**
22.5.2.2 22.5.5.1.3 22.5.5.1.1	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\ \text{in}$ - Effective width, d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 13.528\ \text{kip} \rightarrow 13528\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(13528\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.29\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.29\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.29\ \text{kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 737.28\ \text{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.29\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.27\ \text{kip}$$

Considering x-direction:

$V_{max} = 10.802\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(10.802\ \text{kip})}{(111.27\ \text{kip})}$$ $$Ratio = 0.09708$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $V_{max} = 0.87299\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.87299\ \text{kip})}{(111.27\ \text{kip})}$$ $$Ratio = 0.0078458$$	Status: **PASS** Ratio: **0.010**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 37.599\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(37.599\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.15064$$	Status: **PASS** Ratio: **0.150**
	Considering z-direction: $M_{max} = 2.8569\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(2.8569\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.011446$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

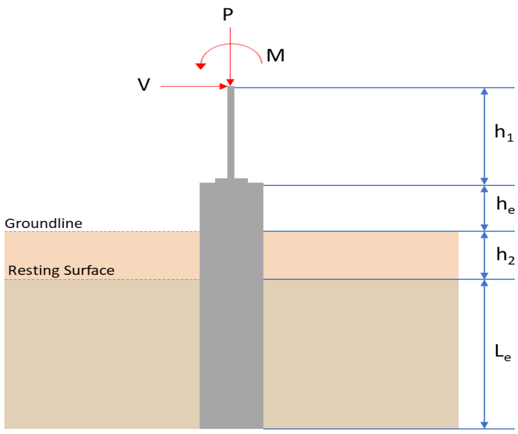
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.75\ \mathrm{ft}$ - 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)	11.853	18.977
V_x (kip)	-2.996	-5.022
V_z (kip)	-0.044	-0.080
M_x (kipft)	-0.205	-0.375
M_z (kipft)	47.265	81.576

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.996\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.47707\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(47.265 \text{ kipft}) + ((-2.996 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.5263 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.3218 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.044 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0070064 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.205 \text{ kipft}) + ((-0.044 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.032643 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.2754 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.3218 \text{ ft}), (1.2754 \text{ ft})]$$

$$L_{e,req} = 7.322 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.75 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.322 \text{ ft})}{(7.75 \text{ ft})}$$

$$Ratio = 0.94477$$

Status: **PASS**
Ratio: **0.940**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(11.853 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.74081 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.74081 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.37041$$

Status: **PASS**
Ratio: **0.370**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.47707 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.5263 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.5263 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (7.5263 \text{ kipft/ft})) + (4 \times (-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.326 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.5263 \text{ kipft/ft})) + (3 \times (-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (7.5263 \text{ kipft/ft})) + (2 \times (-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.29729 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (7.5263 \text{ kipft/ft})) + ((-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.1343 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

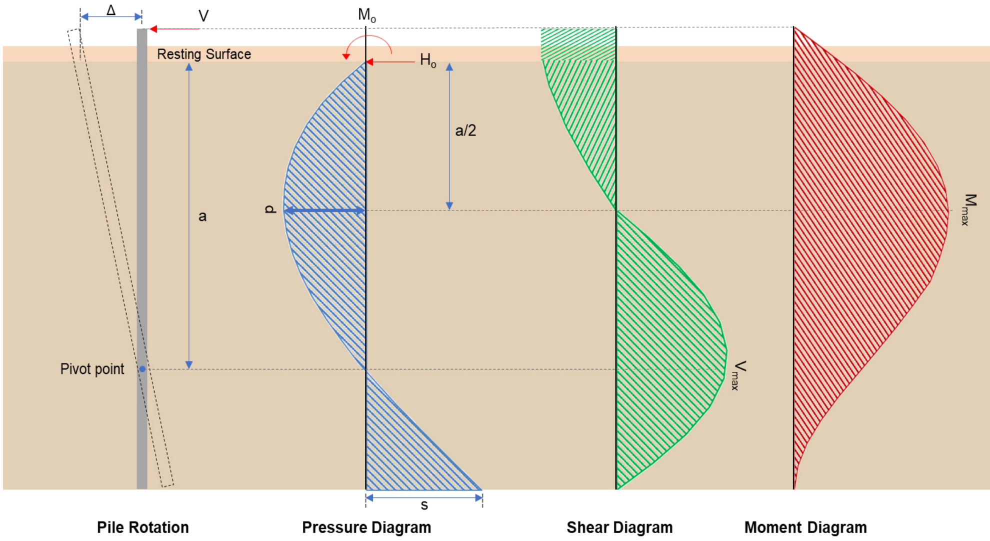
$$p_a = (150 \text{ psf/ft}) \times \frac{(5.326 \text{ ft})}{2}$$

$$p_a = 0.39945 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.29729\ \mathrm{kip/ft^2}\right)}{\left(0.39945\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.74424$$	Status: **PASS** Ratio: **0.740**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$ $$p_s = 1.1625\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.1343\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.97578$$	Status: **PASS** Ratio: **0.980**
	Considering z-direction: $H_o = -0.0070064\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.032643\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.032643\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.032643\ \mathrm{kipft/ft})) + (4 \times (-0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$ $$a = 5.5063\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.032643\ \mathrm{kipft/ft})) + (3 \times (-0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^{\ 2}}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.032643\ \mathrm{kipft/ft})) + (2 \times (-0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$ $$p = -0.001223\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.032643\ \mathrm{kipft/ft})) + ((-0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$ $$s = 0.0010976\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5063\ \mathrm{ft})}{2}$$ $$p_a = 0.41297\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.001223\ \mathrm{kip/ft^2}\right)}{\left(0.41297\ \mathrm{kip/ft^2}\right)}$$	

	$$Ratio = -0.0029614$$ p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\text{ psf/ft}) \times (7.75\text{ ft})$$ $$p_s = 1.1625\text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{(0.0010976\text{ kip/ft}^2)}{(1.1625\text{ kip/ft}^2)}$$ $$Ratio = 0.00094416$$	Status: **PASS** Ratio: **0.000** Status: **PASS** Ratio: **0.000**	



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.022\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.79968\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(81.576\text{ kipft}) + ((-5.022\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 12.99\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.99\text{ kipft/ft})}{(-0.79968\text{ kip/ft})}$$

$$E = 16.244\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.99\text{ kipft/ft}) \times (7.75\text{ ft})) + \left(3 \times (-0.79968\text{ kip/ft}) \times (7.75\text{ ft})^2\right)}{}$$

$$a = \overline{(6 \times (12.99\ \text{kipft/ft})) + (4 \times (-0.79968\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.3225\ \text{ft}$$

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

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

$$V_{max} = ((-0.79968\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (16.244\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3225\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (16.244\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3225\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.976\ \text{kip}$$

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

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

$$M_{max} = ((-0.79968\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(16.244\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.3225\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (16.244\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3225\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (16.244\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3225\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 51.902\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.08\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.012739\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.375\ \text{kipft}) + ((-0.08\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.059713\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.059713\ \text{kipft/ft})}{(-0.012739\ \text{kip/ft})}$$

$$E = 4.6875\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.059713\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.012739\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (0.059713\ \text{kipft/ft})) + (4 \times (-0.012739\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.5053\ \text{ft}$$

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

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

$$V_{max} = ((-0.012739 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.6875 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.5053 \text{ ft})}{(7.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.6875 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.5053 \text{ ft})}{(7.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.08839 \text{ kip}$$

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

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

$$M_{max} = ((-0.012739 \text{ kip/ft}) \times (48 \text{ in}) \times (7.75 \text{ ft})) \times \left[\left(\frac{(4.6875 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.5053 \text{ ft})}{2 \times (7.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (4.6875 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.5053 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.6875 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.5053 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.3072 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.977 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -83.966 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-83.966 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3	s_{rebar} - Minimum spacing of reinforcement,	

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.977\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0070937$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

	$$V_{c,max} = 296.21\text{ kip}$$
	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 18.977\text{ kip} \rightarrow 18977\text{ lbf}$,
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(18977\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 121.02\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\text{ kip}), (121.02\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 121.02\text{ kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500\text{ psi})} \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{s,a} = 737.28\text{ kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((121.02\text{ kip}) + (50.894\text{ kip}))$$

$$\phi V_n = 111.74\text{ kip}$$

Considering x-direction:

$V_{max} = 13.976\text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(13.976 \text{ kip})}{(111.74 \text{ kip})}$$ $$Ratio = 0.12508$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $V_{max} = 0.08839$ kip - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.08839 \text{ kip})}{(111.74 \text{ kip})}$$ $$Ratio = 0.00079103$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$ $$S_m = 18432 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 51.902$ kipft - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(51.902 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.20794$$	Status: **PASS** Ratio: **0.210**
	Considering z-direction: $M_{max} = 0.3072$ kipft - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.3072 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0012308$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

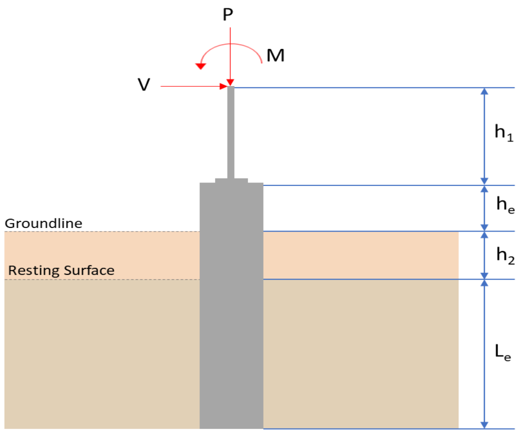
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48 \text{ in}$ - Pile width
$D = 48 \text{ in}$ - Pile depth
$L = 7.75 \text{ ft}$ - 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)	11.853	18.977
V_x (kip)	-2.996	-5.022
V_z (kip)	0.044	0.080
M_x (kipft)	0.205	0.375
M_z (kipft)	47.265	81.576

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.996 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.47707 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(47.265\text{ kipft}) + ((-2.996\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 7.5263\text{ kipft/ft}$$

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:
$L_{e,x} = 7.3218\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.044\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.0070064\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.205\text{ kipft}) + ((0.044\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.032643\text{ kipft/ft}$$

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:
$L_{e,z} = 1.4787\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.3218\text{ ft}), (1.4787\text{ ft})]$$

$$L_{e,req} = 7.322\text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75\text{ ft}) - (0\text{ ft}) - (0\text{ ft})$$

$$L_e = 7.75\text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.322\text{ ft})}{(7.75\text{ ft})}$$

$$Ratio = 0.94477$$

Status: **PASS**
Ratio: **0.940**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(11.853 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.74081 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.74081 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.37041$$

Status: **PASS**
Ratio: **0.370**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.75 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.47707 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.5263 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.5263 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (7.5263 \text{ kipft/ft})) + (4 \times (-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.326 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.5263 \text{ kipft/ft})) + (3 \times (-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft})]^{\ 2}}{(7.75 \text{ ft})^2 \times [(3 \times (7.5263 \text{ kipft/ft})) + (2 \times (-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.29729 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (7.5263 \text{ kipft/ft})) + ((-0.47707 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.1343 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.326 \text{ ft})}{2}$$

$$p_a = 0.39945 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.29729\ \mathrm{kip/ft^2})}{(0.39945\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.74424$$

Status: **PASS**
Ratio: **0.740**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.1343\ \mathrm{kip/ft^2})}{(1.1625\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.97578$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = 0.0070064\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.032643\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.032643\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.032643\ \mathrm{kipft/ft})) + (4 \times (0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$

$$a = 5.5063\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.032643\ \mathrm{kipft/ft})) + (3 \times (0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^{\ 2}}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.032643\ \mathrm{kipft/ft})) + (2 \times (0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$

$$p = 0.0052073\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.032643\ \mathrm{kipft/ft})) + ((0.0070064\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$

$$s = 0.011946\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5063\ \mathrm{ft})}{2}$$

$$p_a = 0.41297\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0052073\ \mathrm{kip/ft^2})}{(0.41297\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.012609$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.75\ \mathrm{ft})$$

$$p_s = 1.1625\ \mathrm{kip/ft^2}$$

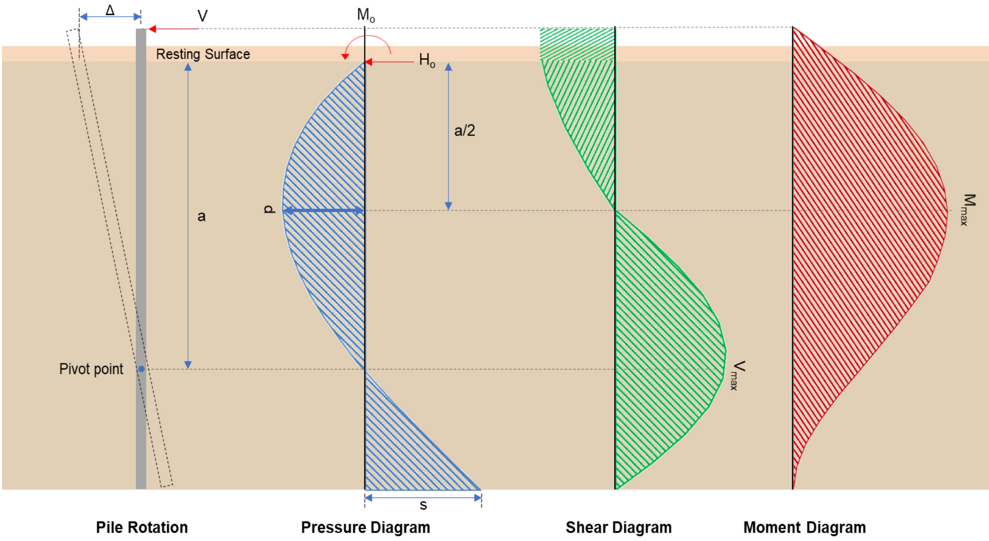
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.011946\ \mathrm{kip/ft^2})}{(1.1625\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.010276$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.022\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.79968\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(81.576\ \mathrm{kipft}) + ((-5.022\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 12.99\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.99\ \mathrm{kipft/ft})}{(-0.79968\ \mathrm{kip/ft})}$$

$$E = 16.244\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = (4 \times (12.99\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.79968\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)$$

$$a = \frac{}{(6 \times (12.99\ \text{kipft/ft})) + (4 \times (-0.79968\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.3225\ \text{ft}$$

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

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

$$V_{max} = ((-0.79968\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (16.244\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3225\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (16.244\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3225\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.976\ \text{kip}$$

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

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

$$M_{max} = ((-0.79968\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(16.244\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.3225\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (16.244\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3225\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (16.244\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3225\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 51.902\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.08\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.012739\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.375\ \text{kipft}) + ((0.08\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.059713\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.059713\ \text{kipft/ft})}{(0.012739\ \text{kip/ft})}$$

$$E = 4.6875\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.059713\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (0.012739\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (0.059713\ \text{kipft/ft})) + (4 \times (0.012739\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.5053\ \text{ft}$$

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

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

$$V_{max} = ((0.012739\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.6875\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5053\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.6875\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5053\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.08839\ \text{kip}$$

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

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

$$M_{max} = ((0.012739\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(4.6875\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.5053\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.6875\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5053\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.6875\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5053\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.3072\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(18.977\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -83.966\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-83.966\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(18.977\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0070937$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 18.977\ \text{kip} \rightarrow 18977\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(18977\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 121.02\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (121.02\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 121.02\ \text{kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 737.28\ \text{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((121.02\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.74\ \text{kip}$$

Considering x-direction:

$V_{max} = 13.976\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(13.976\ \text{kip})}{(111.74\ \text{kip})}$$ $$Ratio = 0.12508$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $V_{max} = 0.08839\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.08839\ \text{kip})}{(111.74\ \text{kip})}$$ $$Ratio = 0.00079103$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 51.902\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(51.902\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.20794$$	Status: **PASS** Ratio: **0.210**
	Considering z-direction: $M_{max} = 0.3072\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.3072\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.0012308$$	Status: **PASS** Ratio: **0.000**