Project Details

Project Name: MTSOLAR_LLKC93E41964

Location: St Marys, PA, USA

Unique ID: 4P-19.75-10TOP-HD-24-L-4Hx12W-C45C

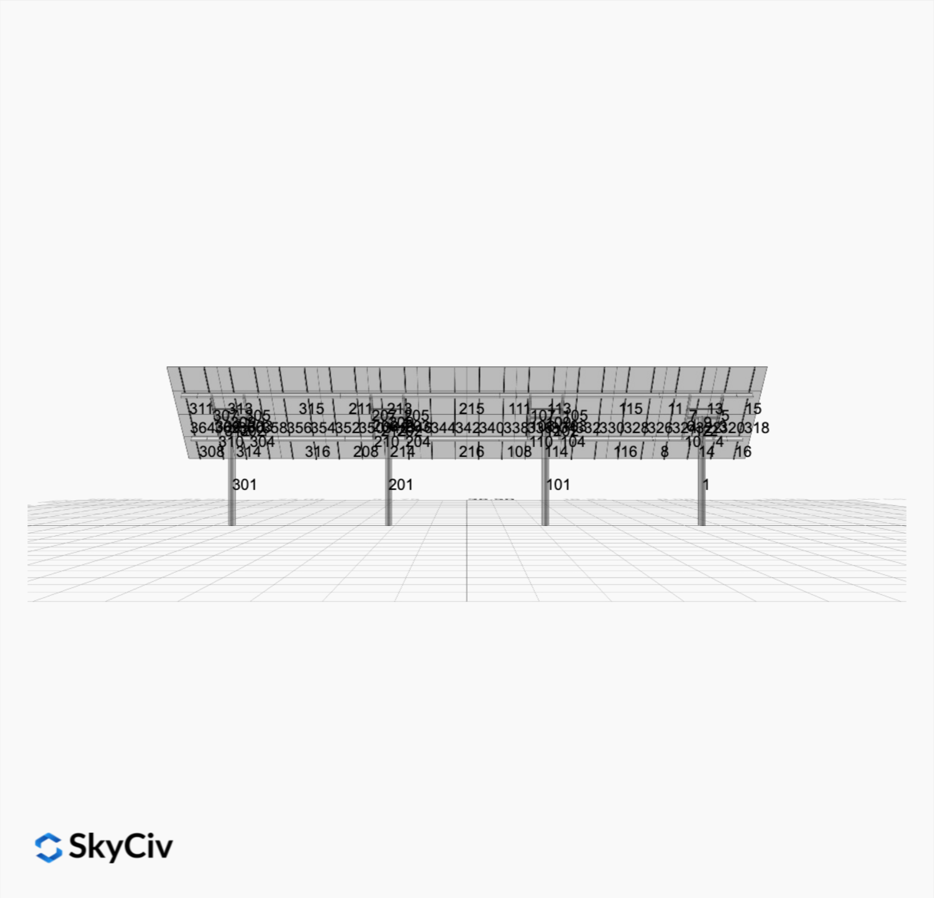
Dealer: ______________________________

Date: Wed Jul 30 2025

Number of Modules: 48

Number of Poles: 4

Date Sold: ______________________________



Array Dimensions N/S	15.83 ft
Array Dimensions E/W	73.00 ft
Winter Tilt Angle	45
Front Edge Clearance	8 ft

MT Solar Bill of Materials (4P-19.75-10TOP-HD-24-L-4Hx12W-C45C)

Part	Short Description	BOM Qty
MTS-PC-10	10IN Pole Cap Assembly	4
MTS-HF-HD	H-Frame Assembly-HD	4
MTS-HD-Wing-24	24IN HD Wing	4
MTS-HD-Splice-90	90IN HD Splice	6
MTS-HD-Splice-57	57IN HD Splice	6
MTS-CLAMP-HOOK-4PK	Hook Clamp	12

Rail Bill of Materials

Part	Qty
Rails (190in)	24
Rail Attachment	48

Part	Qty
Module Mid Clamp	72
Module End Clamp	48
Ground Lug	12

Site Details:

Site Address: St Marys, PA, USA

Array Specification

Duty Classification:	HD
Module Width:	47.00 in
Module Length:	72.00in
Number of Rows:	4
Number of Columns:	12
Total Number of Modules:	48
Winter Tilt Angle:	45
Front Edge Clearance:	8
Total Array Height at Tilt:	19.20 ft
Total Frame Length:	70.75 ft
Module Info/Notes:	
Array Dimensions N/S:	15.83 ft
Array Dimensions E/W:	73.00 ft
Rail Length:	190.00 in
Rail Spacing:	3.04 ft

Support Specifications

Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	13.60 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:	St Marys, PA, USA
Wind Speed:	104 mph

Snow Load:	30 psf

Design Disclaimer

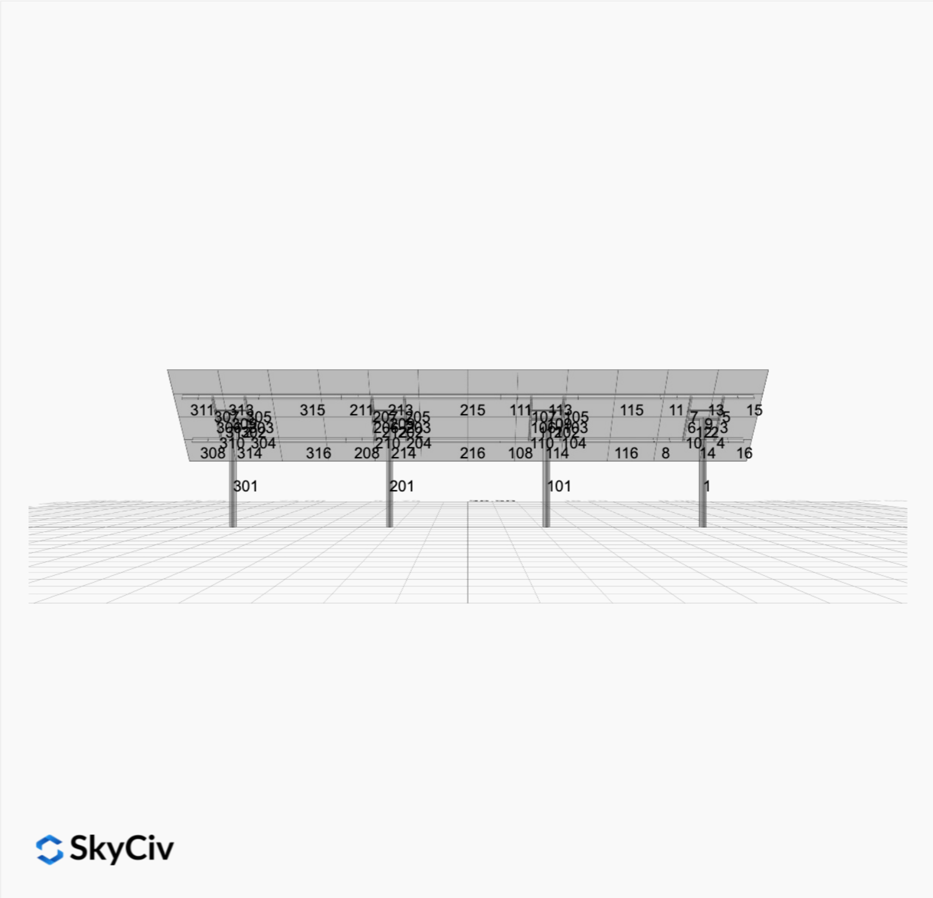
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

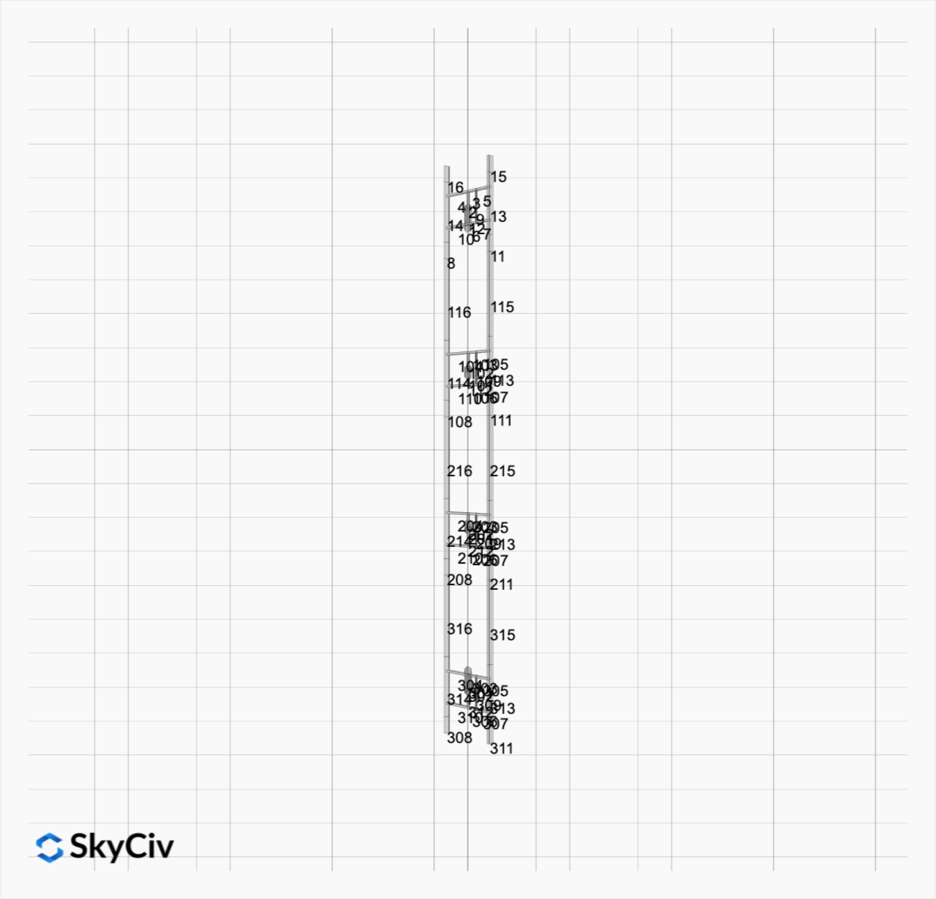
AutoDesigner Input

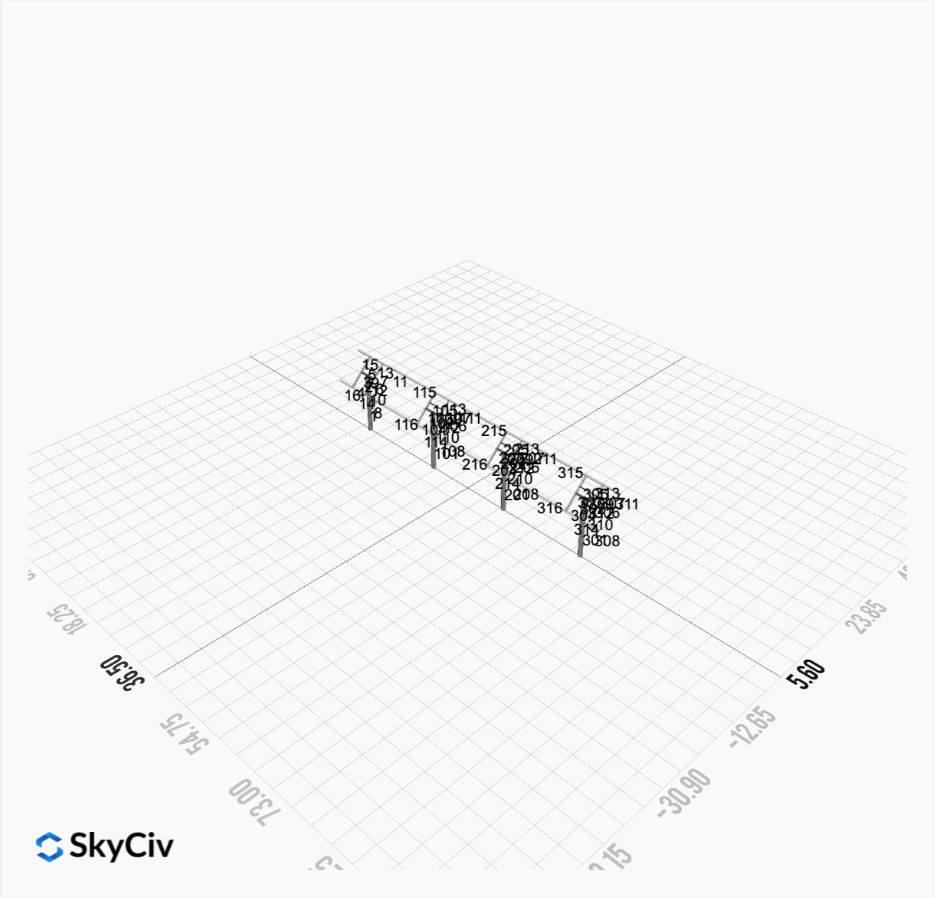
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"John Fisher","designer_email":"Info@elkcreekpower.com","designer_phone":"814-574-9961","project_id":"MTSOLAR_LLKC93E41964","site_address":"St Marys, PA, USA","module_info":"","module_width":47,"module_length":72,"number_rows":"4","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":45,"ground_clearance":8,"risk_category":"I","exposure_category":"B","frame_duty_override":"HD","pole_override":"10_40","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}

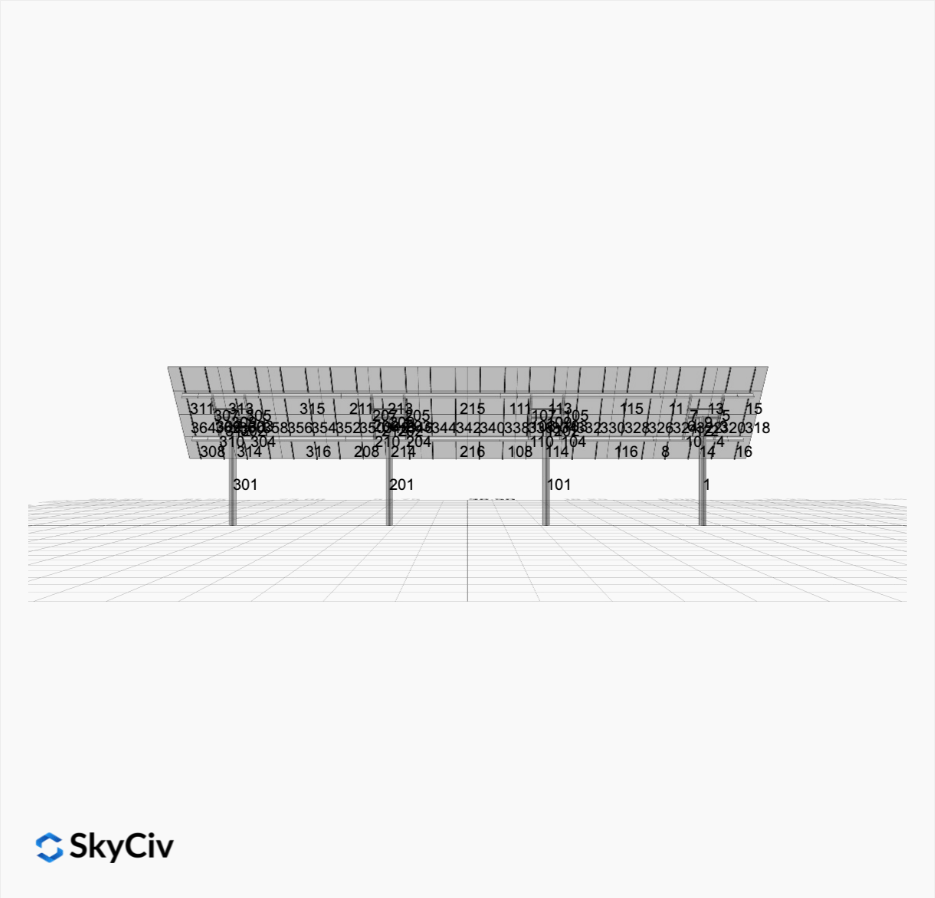
Design Notes:

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

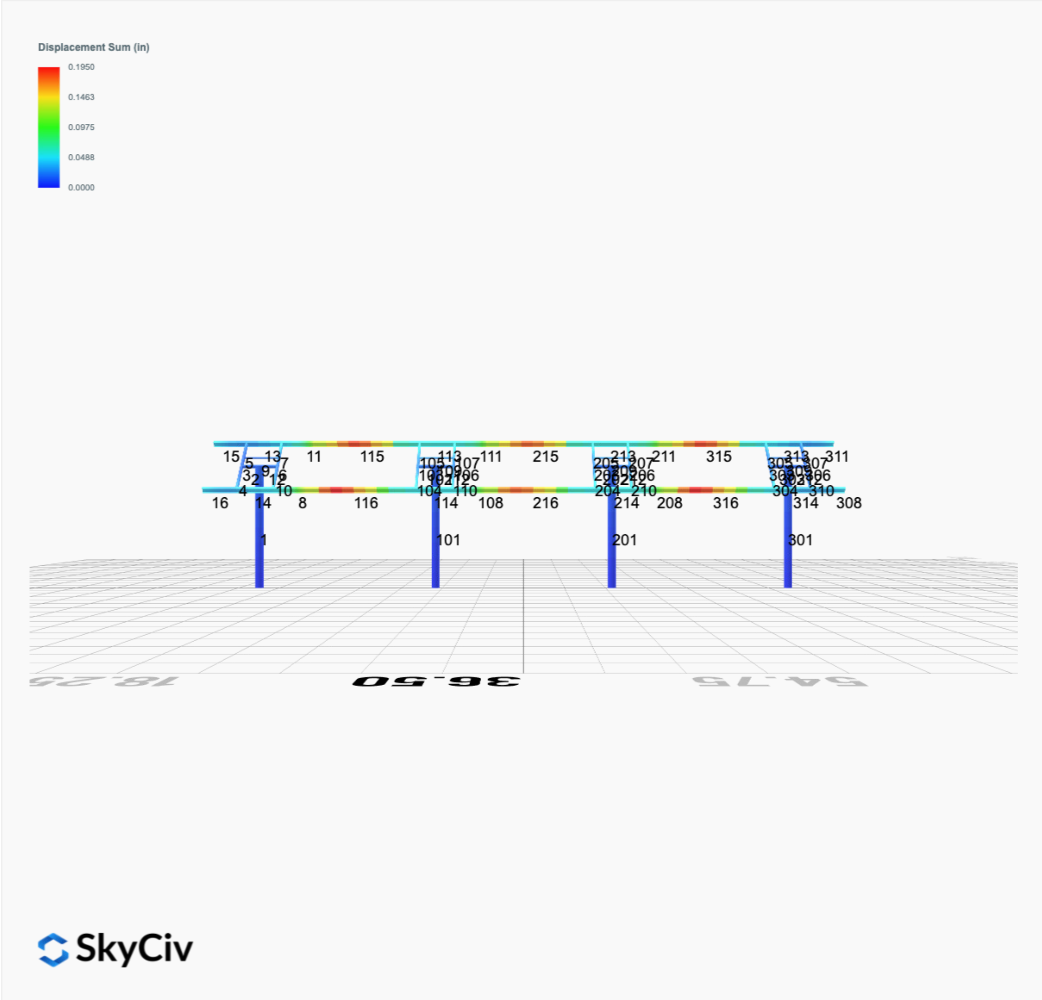


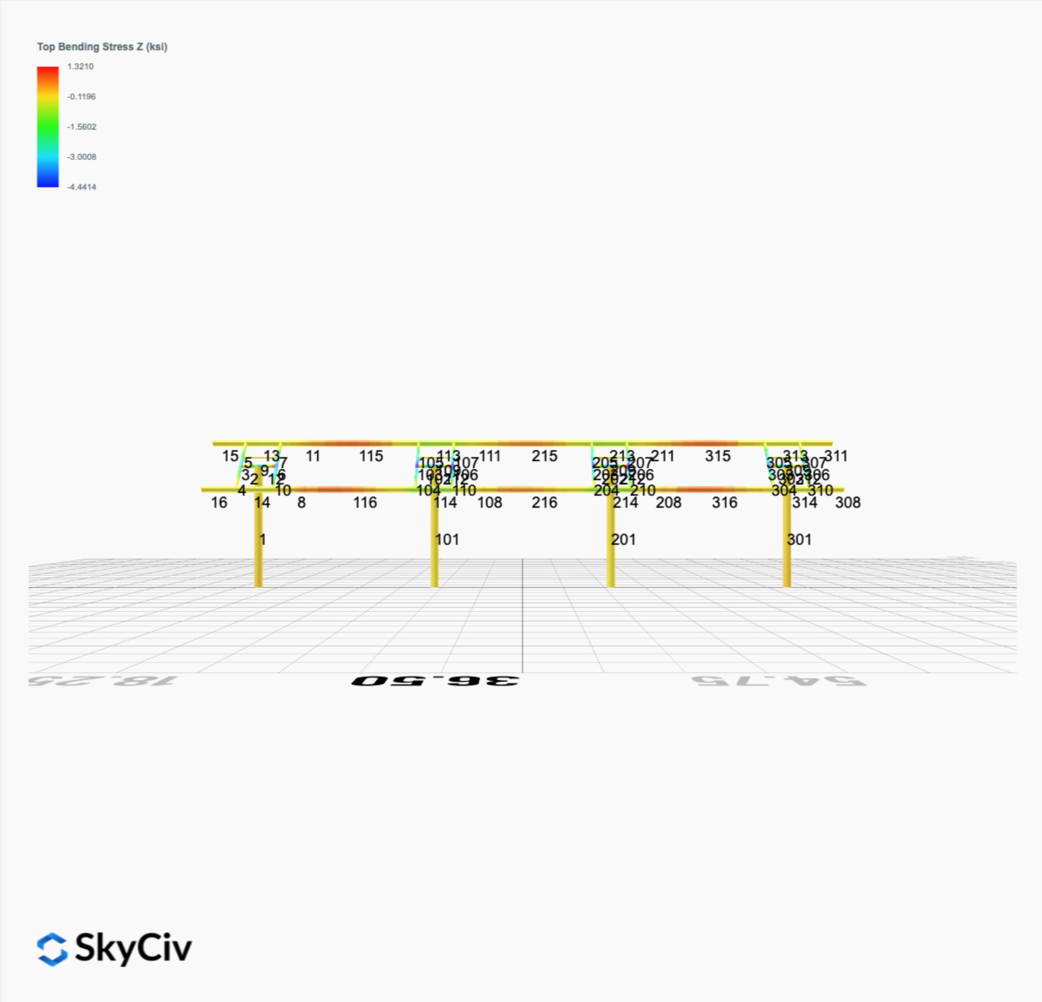


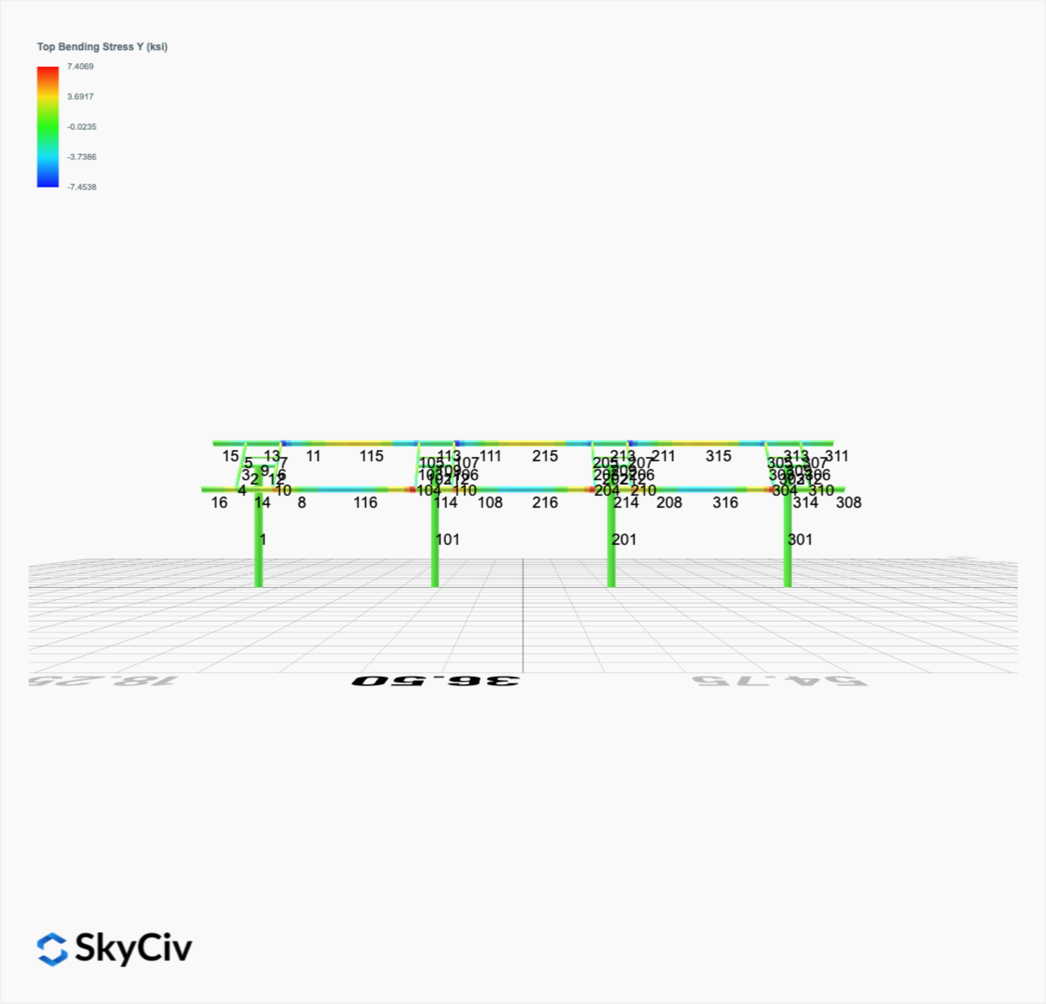


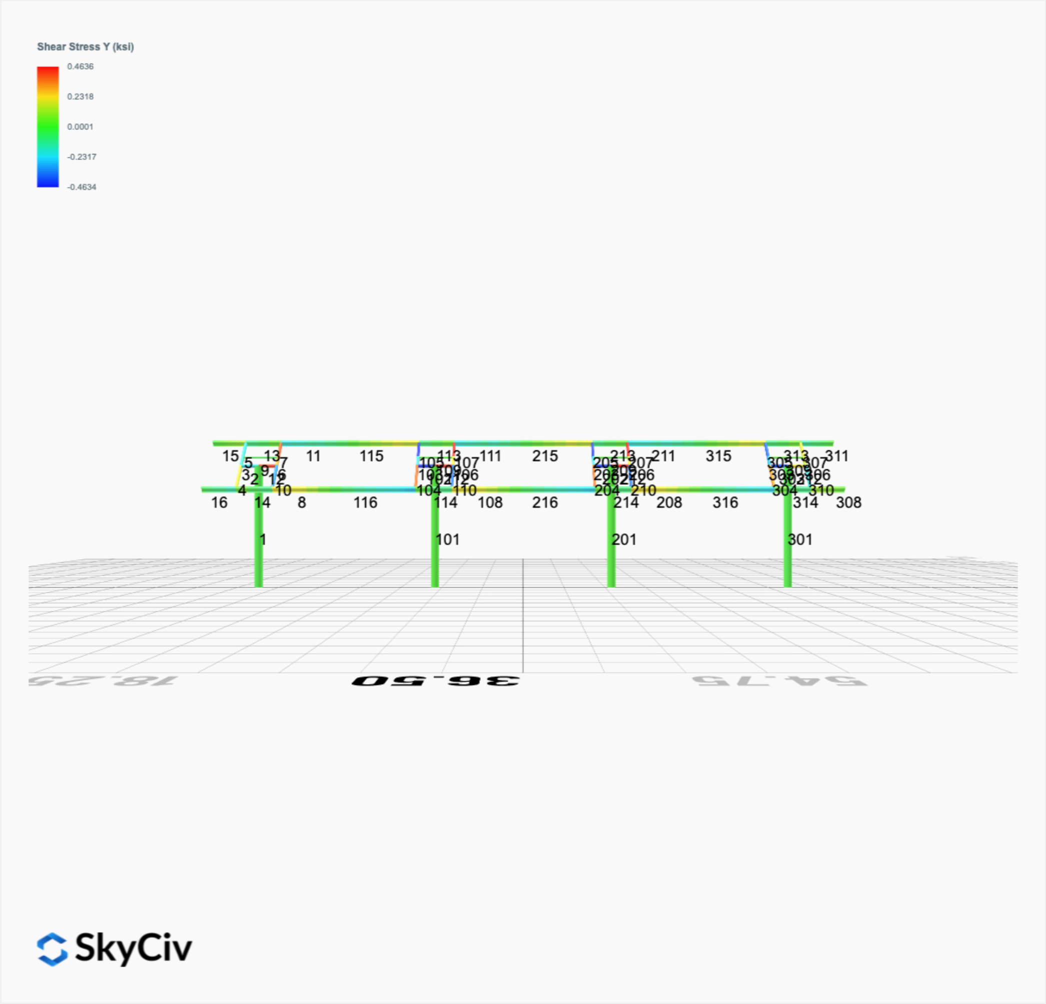


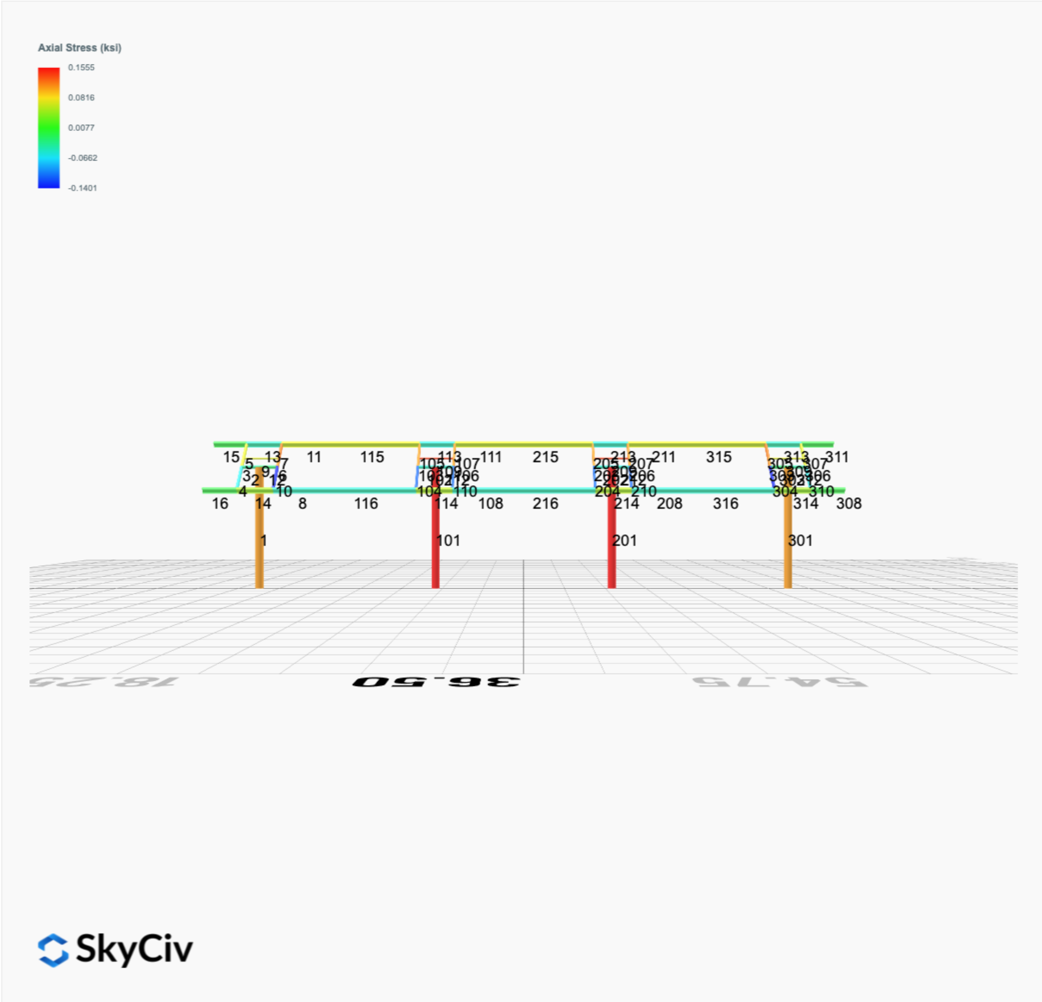
FEM Results (Envelope Worst Case for each member)




Top Bending Stress Z (ksi)
1.3210
-0.1196
-1.5602
-3.0008
-4.4414
15
13
11
115
111
215
211
315
311
16
14
8
116
114
108
216
214
208
316
314
308
1
101
201
301
36.50
SkyCiv


Top Bending Stress Y (ksi)
7.4069
3.6917
-0.0235
-3.7386
-7.4538


Shear Stress Y (ksi)
0.4636
0.2318
0.0001
-0.2317
-0.4634
SkyCiv


Axial Stress (ksi)
0.1555
0.0816
0.0077
-0.0662
-0.1401

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	0.0258	2.2290	0.0660	0.2517	-0.0907	-0.3190
ULS: 2. D + L	0.0258	2.2290	0.0660	0.2517	-0.0907	-0.3190
ULS: 3. D + (S or Lr or R)	0.0507	3.6440	0.1295	0.4919	-0.1793	-0.6478
ULS: 3. D + (S or Lr or R)	0.0258	2.2290	0.0660	0.2517	-0.0907	-0.3190
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0445	3.2903	0.1136	0.4319	-0.1571	-0.5656
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0258	2.2290	0.0660	0.2517	-0.0907	-0.3190
ULS: 5b. D + 0.7E	0.0258	2.2290	0.0660	0.2517	-0.0907	-0.3190
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0445	3.2903	0.1136	0.4319	-0.1571	-0.5656
ULS: 8. 0.6D + 0.7E	0.0155	1.3374	0.0396	0.1510	-0.0544	-0.1914
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.6920	4.8992	0.2596	0.8946	-1.3663	38.0460
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.6920	4.8992	0.2596	0.8946	-1.3663	38.0460
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9864	0.2972	-0.0761	-0.2818	0.8068	-26.3361
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.7718	0.5153	-0.0731	-0.2880	0.8036	-28.8772
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9939	5.2929	0.2589	0.9141	-1.1139	28.2082
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.9939	5.2929	0.2589	0.9141	-1.1139	28.2082
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5149	1.8414	0.0070	0.0317	0.5159	-20.0784
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3540	2.0050	0.0093	0.0271	0.5136	-21.9842
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0126	4.2316	0.2112	0.7339	-1.0474	28.4547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0126	4.2316	0.2112	0.7339	-1.0474	28.4547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4962	0.7801	-0.0406	-0.1485	0.5824	-19.8318
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3353	0.9437	-0.0383	-0.1531	0.5801	-21.7376
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.7024	4.0076	0.2333	0.7940	-1.3300	38.1736
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.7024	4.0076	0.2333	0.7940	-1.3300	38.1736
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9761	-0.5944	-0.1025	-0.3825	0.8430	-26.2085
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.7615	-0.3763	-0.0995	-0.3887	0.8399	-28.7496

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	7.8309
Shear X	-4.5297
Shear Z	0.4364
Moment X	1.4606
Moment Y (Twist)	2.3290
Moment Z	63.9416

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	5.2929
Shear X	-2.7024
Shear Z	0.2596
Moment X	0.9141
Moment Y (Twist)	1.3663
Moment Z	38.1736

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	-0.0258	2.6809	-0.0039	-0.0172	0.0212	0.3607
ULS: 2. D + L	-0.0258	2.6809	-0.0039	-0.0172	0.0212	0.3607
ULS: 3. D + (S or Lr or R)	-0.0507	4.5322	-0.0078	-0.0351	0.0417	0.6911
ULS: 3. D + (S or Lr or R)	-0.0258	2.6809	-0.0039	-0.0172	0.0212	0.3607
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0445	4.0694	-0.0068	-0.0306	0.0366	0.6085

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0258	2.6809	-0.0039	-0.0172	0.0212	0.3607
ULS: 5b. D + 0.7E	-0.0258	2.6809	-0.0039	-0.0172	0.0212	0.3607
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0445	4.0694	-0.0068	-0.0306	0.0366	0.6085
ULS: 8. 0.6D + 0.7E	-0.0155	1.6085	-0.0023	-0.0103	0.0127	0.2164
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.5470	6.2496	0.0068	0.0083	-0.1076	49.8304
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.5470	6.2496	0.0068	0.0083	-0.1076	49.8304
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5270	0.0994	-0.0109	-0.0419	0.1036	-33.1572
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2105	0.4122	-0.0180	-0.0706	0.1540	-36.0400
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.6854	6.7460	0.0012	-0.0115	-0.0600	37.7108
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.6854	6.7460	0.0012	-0.0115	-0.0600	37.7108
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8700	2.1332	-0.0121	-0.0491	0.0984	-24.5299
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6327	2.3679	-0.0174	-0.0706	0.1362	-26.6921
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.6667	5.3574	0.0041	0.0019	-0.0754	37.4630
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.6667	5.3574	0.0041	0.0019	-0.0754	37.4630
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8888	0.7447	-0.0092	-0.0357	0.0830	-24.7777
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6515	0.9794	-0.0145	-0.0572	0.1208	-26.9399
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.5366	5.1773	0.0084	0.0152	-0.1160	49.6861
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.5366	5.1773	0.0084	0.0152	-0.1160	49.6861
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5373	-0.9730	-0.0094	-0.0350	0.0951	-33.3015
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2208	-0.6601	-0.0164	-0.0637	0.1456	-36.1843

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.0933
Shear X	-5.9134
Shear Z	-0.0302
Moment X	-0.1193
Moment Y (Twist)	0.2567
Moment Z	83.7010

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.7460
Shear X	-3.5470
Shear Z	-0.0180
Moment X	-0.0706
Moment Y (Twist)	0.1540
Moment Z	49.8304

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	-0.0258	2.6809	0.0039	0.0170	-0.0213	0.3608
ULS: 2. D + L	-0.0258	2.6809	0.0039	0.0170	-0.0213	0.3608
ULS: 3. D + (S or Lr or R)	-0.0507	4.5322	0.0077	0.0344	-0.0420	0.6915
ULS: 3. D + (S or Lr or R)	-0.0258	2.6809	0.0039	0.0170	-0.0213	0.3608
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0445	4.0694	0.0068	0.0301	-0.0368	0.6088
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0258	2.6809	0.0039	0.0170	-0.0213	0.3608
ULS: 5b. D + 0.7E	-0.0258	2.6809	0.0039	0.0170	-0.0213	0.3608
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0445	4.0694	0.0068	0.0301	-0.0368	0.6088
ULS: 8. 0.6D + 0.7E	-0.0155	1.6085	0.0023	0.0102	-0.0128	0.2165
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.5471	6.2500	-0.0068	-0.0099	0.1074	49.8338
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.5471	6.2500	-0.0068	-0.0099	0.1074	49.8338
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5270	0.0993	0.0110	0.0422	-0.1037	-33.1569
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.2106	0.4122	0.0181	0.0713	-0.1540	-36.0397

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	-2.6855	6.7462	-0.0013	0.0099	0.0597	37.7135
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.6855	6.7462	-0.0013	0.0099	0.0597	37.7135
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8701	2.1332	0.0121	0.0489	-0.0986	-24.5295
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6328	2.3678	0.0174	0.0708	-0.1364	-26.6916
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.6668	5.3577	-0.0042	-0.0032	0.0752	37.4655
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.6668	5.3577	-0.0042	-0.0032	0.0752	37.4655
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8888	0.7447	0.0092	0.0359	-0.0831	-24.7775
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.6515	0.9793	0.0145	0.0578	-0.1208	-26.9396
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.5368	5.1777	-0.0084	-0.0167	0.1159	49.6894
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.5368	5.1777	-0.0084	-0.0167	0.1159	49.6894
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5373	-0.9731	0.0094	0.0354	-0.0952	-33.3013
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.2209	-0.6602	0.0165	0.0645	-0.1455	-36.1840

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.0922
Shear X	-5.9116
Shear Z	0.0297
Moment X	0.1217
Moment Y (Twist)	0.2519
Moment Z	83.6828

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.7462
Shear X	-3.5471
Shear Z	0.0181
Moment X	0.0713
Moment Y (Twist)	0.1540
Moment Z	49.8338

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	0.0258	2.2290	-0.0660	-0.2520	0.0904	-0.3185
ULS: 2. D + L	0.0258	2.2290	-0.0660	-0.2520	0.0904	-0.3185
ULS: 3. D + (S or Lr or R)	0.0508	3.6440	-0.1295	-0.4927	0.1785	-0.6467
ULS: 3. D + (S or Lr or R)	0.0258	2.2290	-0.0660	-0.2520	0.0904	-0.3185
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0445	3.2902	-0.1136	-0.4325	0.1564	-0.5647
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0258	2.2290	-0.0660	-0.2520	0.0904	-0.3185
ULS: 5b. D + 0.7E	0.0258	2.2290	-0.0660	-0.2520	0.0904	-0.3185
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0445	3.2902	-0.1136	-0.4325	0.1564	-0.5647
ULS: 8. 0.6D + 0.7E	0.0155	1.3374	-0.0396	-0.1512	0.0542	-0.1911
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.6920	4.8990	-0.2596	-0.8960	1.3666	38.0472
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.6920	4.8990	-0.2596	-0.8960	1.3666	38.0472
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9864	0.2972	0.0761	0.2816	-0.8071	-26.3348
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.7718	0.5153	0.0730	0.2869	-0.8038	-28.8756
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9938	5.2927	-0.2589	-0.9156	1.1136	28.2096
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.9938	5.2927	-0.2589	-0.9156	1.1136	28.2096
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5150	1.8414	-0.0071	-0.0324	-0.5167	-20.0769
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3540	2.0050	-0.0094	-0.0284	-0.5142	-21.9824
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0126	4.2315	-0.2112	-0.7350	1.0476	28.4558
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.0126	4.2315	-0.2112	-0.7350	1.0476	28.4558
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4962	0.7801	0.0406	0.1482	-0.5828	-19.8307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.3353	0.9437	0.0382	0.1522	-0.5803	-21.7363

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.7023	4.0074	-0.2332	-0.7952	1.3305	38.1746
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.7023	4.0074	-0.2332	-0.7952	1.3305	38.1746
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9761	-0.5944	0.1025	0.3824	-0.8433	-26.2074
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.7615	-0.3763	0.0994	0.3877	-0.8399	-28.7482

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	7.8305
Shear X	-4.5296
Shear Z	-0.4343
Moment X	-1.4672
Moment Y (Twist)	2.2998
Moment Z	63.9429

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	5.2927
Shear X	-2.7023
Shear Z	-0.2596
Moment X	-0.9156
Moment Y (Twist)	1.3666
Moment Z	38.1746

Project Details

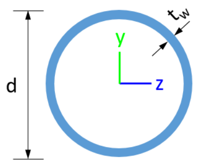
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

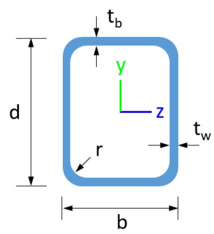
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

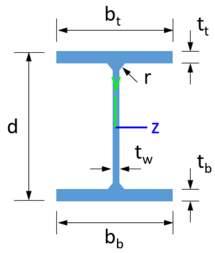
Section Dimensions



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



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



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

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

2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
11	10in Pipe Sch 40	11.91	321.47	160.73	160.73	0.00	39.38	39.38
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	11	28.56	28.56	13.60	-	300	200	1
2	5	4.20	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.20,1.09,1.17,1.17,1.14,1.16,1.17,1.17,1.16,1.17	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.65,1.78,1.67,1.67,1.66,1.51,1.67,1.67,1.74,1.68,1.67,1.67,1.64,1.73,1.67,1.67,1.66,1.62	300	200	1
5	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.60,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.20,1.16,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.70,1.63,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67	300	200	1
8	19	1.33	1.33	2.05	1.69,1.79,1.63,2.12,1.69,1.54,1.48,1.48,1.24,2.24,1.38,1.38,1.26,2.19,1.90,1.90,2.22,2.19,1.41,1.41,1.08,2.24,1.35,1.35,1.27,2.14	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.64,1.67,1.67,1.72,1.68,1.67,1.67,1.65,1.79,1.67,1.67,1.66,1.65	300	200	1
11	19	1.33	1.33	2.05	1.35,1.39,1.32,1.64,1.35,1.31,1.22,1.22,1.46,1.66,1.28,1.28,1.22,1.42,1.37,1.37,2.16,2.28,1.20,1.20,1.50,1.54,1.35,1.35,1.07,1.25	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.15,1.14,1.15,1.14,1.15,1.15,1.12,1.12,1.08,1.12,1.12,1.12,1.07,1.13,1.13,1.13,2.63,3.55,1.13,1.13,1.09,1.14,1.12,1.12,1.07,1.13	300	200	1
14	19	4.88	4.00	7.50	1.17,1.24,1.14,1.48,1.17,1.14,1.13,1.13,1.11,3.44,1.13,1.13,1.12,2.35,1.12,1.12,2.93,2.58,1.12,1.12,1.11,3.55,1.13,1.13,1.12,1.56	300	200	1
15	19	4.20	4.20	2.00	1.95,1.88,2.01,1.55,1.96,2.09,2.47,2.47,2.45,2.44,2.11,2.11,2.08,2.12,2.45,2.45,2.31,2.26,2.02,2.02,2.44,2.45,1.81,1.81,1.58,1.63	300	200	1
16	19	4.20	4.20	2.00	2.44,2.43,2.45,2.40,2.44,2.46,1.81,1.81,2.07,2.26,1.96,1.96,1.64,2.31,2.01,2.01,2.29,2.31,2.01,2.01,2.13,2.29,2.07,2.07,1.91,2.34	300	200	1
101	11	28.56	28.56	13.60	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.19,1.05,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.46,1.67,1.67,1.66,1.63,1.67,1.67,1.71,1.68,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.65	300	200	1
105	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.58,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.69,1.63,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67	300	200	1
108	19	1.33	1.33	2.05	2.18,2.19,2.17,2.22,2.18,2.16,2.07,2.07,1.72,2.25,2.05,2.05,2.02,2.23,2.17,2.17,2.26,2.29,2.08,2.08,1.14,2.26,2.04,2.04,2.05,2.20	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.58,1.67,1.67,1.66,1.64,1.67,1.67,1.72,1.67,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65	300	200	1
111	19	1.33	1.33	2.05	2.03,2.03,2.03,2.08,2.03,2.04,1.20,1.20,1.68,1.99,1.02,1.02,1.27,1.53,1.11,1.11,2.22,2.20,1.03,1.03,1.59,1.80,1.21,1.21,1.02,1.11	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1

113	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.07,1.07,1.10,1.10,1.07,1.07,1.09,1.09,1.06,1.06,1.56,2.98,1.07,1.07,1.12,1.11,1.07,1.07,1.08,1.09	300	200	1
114	19	4.88	4.00	7.50	1.06,1.09,1.05,1.19,1.07,1.05,1.06,1.06,1.07,3.48,1.06,1.06,1.07,1.47,1.06,1.06,2.06,1.91,1.06,1.06,1.08,2.98,1.06,1.06,1.07,1.10	300	200	1
115	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.12,1.12,1.10,1.11,1.11,1.11,1.11,1.12,1.13,1.13,1.36,1.45,1.12,1.12,1.09,1.10,1.11,1.11,1.12,1.12	300	200	1
116	19	6.63	6.63	10.20	1.16,1.16,1.16,1.17,1.16,1.16,1.15,1.15,1.15,1.17,1.15,1.15,1.15,1.17,1.16,1.16,1.29,1.18,1.15,1.15,1.14,1.20,1.15,1.15,1.15,1.17	300	200	1
201	11	28.56	28.56	13.60	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.58,1.67,1.67,1.66,1.64,1.67,1.67,1.72,1.68,1.67,1.67,1.65,1.74,1.67,1.67,1.66,1.65	300	200	1
205	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.69,1.63,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.19,1.06,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
207	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.69,1.59,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67	300	200	1
208	19	1.33	1.33	2.05	2.14,2.15,2.13,2.19,2.14,2.12,1.81,1.81,1.67,2.24,1.65,1.65,1.79,2.19,2.14,2.14,2.27,2.24,1.90,1.90,1.33,2.27,1.59,1.59,1.84,2.11	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.46,1.67,1.67,1.66,1.63,1.67,1.67,1.71,1.67,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.65	300	200	1
211	19	1.33	1.33	2.05	1.79,1.83,1.79,2.08,1.79,1.80,1.37,1.37,1.21,1.33,1.25,1.25,1.03,1.01,1.01,1.01,2.23,2.19,1.02,1.02,1.30,1.35,1.12,1.12,1.22,1.22	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.07,1.07,1.09,1.10,1.07,1.07,1.09,1.09,1.06,1.06,1.59,2.98,1.07,1.07,1.12,1.11,1.07,1.07,1.08,1.09	300	200	1
214	19	4.88	4.00	7.50	1.06,1.09,1.05,1.20,1.06,1.05,1.06,1.06,1.07,3.48,1.06,1.06,1.07,1.48,1.06,1.06,2.08,1.89,1.06,1.06,1.08,2.98,1.06,1.06,1.07,1.10	300	200	1
215	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.14,1.12,1.12,1.14,1.14,1.12,1.13,1.14,1.14,1.78,1.09,1.14,1.14,1.11,1.12,1.14,1.14,1.13,1.13	300	200	1
216	19	6.63	6.63	10.20	1.17,1.17,1.17,1.18,1.17,1.17,1.16,1.16,1.15,2.22,1.16,1.16,1.16,1.14,1.17,1.17,1.27,1.19,1.16,1.16,1.15,1.28,1.16,1.16,1.16,1.13	300	200	1
301	11	28.56	28.56	13.60	-	300	200	1
302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.16,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.64,1.67,1.67,1.73,1.68,1.67,1.67,1.65,1.79,1.67,1.67,1.66,1.65	300	200	1
305	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.70,1.63,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67	300	200	1
306	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.20,1.09,1.17,1.17,1.14,1.16,1.17,1.17,1.16,1.17	300	200	1
307	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.60,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
308	19	4.20	4.20	2.00	2.44,2.43,2.45,2.40,2.44,2.46,1.81,1.81,2.07,2.26,1.97,1.97,1.64,2.31,2.01,2.01,2.29,2.31,2.01,2.01,2.13,2.29,2.08,2.08,1.91,2.34	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.65,1.78,1.67,1.67,1.66,1.51,1.67,1.67,1.74,1.68,1.67,1.67,1.64,1.73,1.67,1.67,1.66,1.62	300	200	1
311	19	4.20	4.20	2.00	1.95,1.87,2.01,1.54,1.95,2.09,2.46,2.46,2.45,2.44,2.11,2.11,2.08,2.12,2.45,2.45,2.31,2.26,2.02,2.02,2.44,2.45,1.81,1.81,1.58,1.63	300	200	1
312	5	4.20	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.15,1.15,1.15,1.15,1.15,1.15,1.13,1.13,1.08,1.12,1.13,1.13,1.07,1.13,1.13,1.13,2.58,3.57,1.13,1.13,1.09,1.14,1.12,1.12,1.07,1.13	300	200	1
314	19	4.88	4.00	7.50	1.14,1.19,1.14,1.38,1.14,1.14,1.13,1.13,1.11,3.44,1.13,1.13,1.12,2.36,1.13,1.13,2.91,2.54,1.13,1.13,1.11,3.55,1.13,1.13,1.12,1.56	300	200	1

315	19	6.63	6.63	10. 20	1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.10,1.10,1.09,1.10,1.10,1.09,1.09,1.09,1.09,1.09,1.19,1.10,1.10,1.1 1,1.10,1.10,1.10,1.09,1.09	30 0	20 0	1
316	19	6.63	6.63	10. 20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.90,1.09,1.09,1.09,1.13,1.09,1.09,1.11,1.11,1.09,1.09,1.0 9,1.18,1.09,1.09,1.09,1.09	30 0	20 0	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	535.87	283.67	147.68	147.68	160.76	160.76
2	198.33	182.14	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	123.95	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	123.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	24.49	6.12	40.24	43.62
14	133.20	85.85	25.45	6.12	40.24	43.62
15	133.20	102.39	32.87	6.12	40.24	43.62
16	133.20	102.39	32.87	6.12	40.24	43.62
101	535.87	283.67	147.68	147.68	160.76	160.76
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	123.95	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	123.95	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	85.85	24.11	6.12	40.24	43.62
114	133.20	85.85	24.04	6.12	40.24	43.62
115	133.20	69.16	16.79	6.12	40.24	43.62
116	133.20	69.16	17.64	6.12	40.24	43.62
201	535.87	283.67	147.68	147.68	160.76	160.76
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	123.95	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	123.95	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50

212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	24.08	6.12	40.24	43.62
214	133.20	85.85	24.05	6.12	40.24	43.62
215	133.20	69.16	16.93	6.12	40.24	43.62
216	133.20	69.16	17.46	6.12	40.24	43.62
301	535.87	283.67	147.68	147.68	160.76	160.76
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	102.39	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	102.39	32.87	6.12	40.24	43.62
312	198.33	182.14	21.95	21.95	59.50	59.50
313	133.20	85.85	24.49	6.12	40.24	43.62
314	133.20	85.85	25.44	6.12	40.24	43.62
315	133.20	69.16	16.87	6.12	40.24	43.62
316	133.20	69.16	16.82	6.12	40.24	43.62

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.027	0.433	0.031	0.028	0.003	0.456	#13	0.466	Not Required	Pass
2	0.002	0.162	0.142	0.044	0.031	0.305	#13	0.114	Not Required	Pass
3	0.005	0.401	0.021	0.039	0.003	0.407	#13	0.045	Not Required	Pass
4	0.004	0.359	0.059	0.036	0.015	0.415	#13	0.080	Not Required	Pass
5	0.004	0.249	0.044	0.040	0.011	0.261	#13	0.074	Not Required	Pass
6	0.009	0.624	0.087	0.065	0.034	0.707	#13	0.045	Not Required	Pass
7	0.009	0.386	0.132	0.062	0.033	0.429	#13	0.074	Not Required	Pass
8	0.003	0.142	0.121	0.074	0.013	0.190	#21	0.095	Not Required	Pass
9	0.005	0.055	0.072	0.003	0.004	0.127	#13	0.204	Not Required	Pass
10	0.009	0.550	0.127	0.055	0.027	0.569	#13	0.080	Not Required	Pass
11	0.004	0.087	0.125	0.032	0.013	0.168	#16	0.095	Not Required	Pass
12	0.001	0.384	0.232	0.080	0.041	0.616	#13	0.053	Not Required	Pass
13	0.005	0.110	0.314	0.040	0.018	0.343	#24	0.286	Not Required	Pass
14	0.004	0.094	0.310	0.049	0.017	0.373	#24	0.286	Not Required	Pass
15	0.000	0.018	0.030	0.015	0.004	0.040	#24	0.300	Not Required	Pass
16	0.000	0.018	0.031	0.014	0.004	0.049	#24	0.300	Not Required	Pass
101	0.035	0.567	0.002	0.037	0.000	0.584	#13	0.466	Not Required	Pass
102	0.003	0.364	0.244	0.083	0.045	0.609	#13	0.035	Not Required	Pass
103	0.008	0.659	0.059	0.066	0.019	0.713	#13	0.045	Not Required	Pass
104	0.008	0.613	0.136	0.062	0.029	0.682	#13	0.080	Not Required	Pass
105	0.008	0.408	0.140	0.066	0.036	0.439	#13	0.074	Not Required	Pass
106	0.008	0.675	0.055	0.068	0.019	0.726	#13	0.045	Not Required	Pass
107	0.008	0.419	0.132	0.068	0.034	0.454	#13	0.074	Not Required	Pass
108	0.004	0.080	0.114	0.064	0.013	0.195	#24	0.095	Not Required	Pass
109	0.011	0.051	0.049	0.001	0.000	0.102	#13	0.204	Not Required	Pass
110	0.008	0.613	0.128	0.062	0.027	0.671	#13	0.080	Not Required	Pass

111	0.004	0.053	0.118	0.033	0.013	0.168	#24	0.095	Not Required	Pass
112	0.003	0.371	0.251	0.083	0.047	0.624	#13	0.035	Not Required	Pass
113	0.006	0.186	0.320	0.030	0.017	0.361	#21	0.286	Not Required	Pass
114	0.007	0.199	0.325	0.054	0.017	0.451	#21	0.286	Not Required	Pass
115	0.007	0.308	0.168	0.043	0.013	0.406	#13	0.473	Not Required	Pass
116	0.004	0.276	0.172	0.042	0.013	0.384	#13	0.473	Not Required	Pass
201	0.035	0.567	0.002	0.037	0.000	0.584	#13	0.466	Not Required	Pass
202	0.003	0.372	0.251	0.083	0.047	0.624	#13	0.035	Not Required	Pass
203	0.008	0.675	0.055	0.068	0.019	0.727	#13	0.045	Not Required	Pass
204	0.008	0.613	0.128	0.062	0.027	0.671	#13	0.080	Not Required	Pass
205	0.008	0.419	0.132	0.068	0.034	0.454	#13	0.074	Not Required	Pass
206	0.008	0.659	0.059	0.066	0.019	0.713	#13	0.045	Not Required	Pass
207	0.008	0.408	0.139	0.066	0.036	0.438	#13	0.074	Not Required	Pass
208	0.003	0.093	0.131	0.064	0.013	0.188	#21	0.095	Not Required	Pass
209	0.011	0.051	0.049	0.001	0.000	0.102	#13	0.204	Not Required	Pass
210	0.008	0.613	0.136	0.062	0.029	0.681	#13	0.080	Not Required	Pass
211	0.004	0.073	0.134	0.031	0.013	0.172	#13	0.095	Not Required	Pass
212	0.003	0.364	0.244	0.083	0.045	0.609	#13	0.035	Not Required	Pass
213	0.006	0.185	0.320	0.030	0.017	0.366	#21	0.286	Not Required	Pass
214	0.007	0.198	0.324	0.054	0.017	0.460	#21	0.286	Not Required	Pass
215	0.007	0.241	0.168	0.041	0.013	0.337	#13	0.473	Not Required	Pass
216	0.005	0.196	0.170	0.038	0.013	0.317	#21	0.473	Not Required	Pass
301	0.027	0.433	0.031	0.028	0.003	0.456	#13	0.466	Not Required	Pass
302	0.001	0.383	0.232	0.080	0.041	0.615	#13	0.053	Not Required	Pass
303	0.009	0.624	0.087	0.064	0.033	0.706	#13	0.045	Not Required	Pass
304	0.009	0.549	0.127	0.055	0.028	0.568	#13	0.080	Not Required	Pass
305	0.009	0.386	0.132	0.062	0.033	0.428	#13	0.074	Not Required	Pass
306	0.005	0.402	0.021	0.039	0.003	0.408	#13	0.045	Not Required	Pass
307	0.004	0.249	0.044	0.040	0.011	0.261	#13	0.074	Not Required	Pass
308	0.000	0.018	0.031	0.014	0.004	0.049	#24	0.300	Not Required	Pass
309	0.005	0.055	0.071	0.003	0.004	0.126	#13	0.204	Not Required	Pass
310	0.004	0.360	0.059	0.036	0.015	0.416	#13	0.080	Not Required	Pass
311	0.000	0.018	0.030	0.015	0.004	0.040	#24	0.300	Not Required	Pass
312	0.002	0.163	0.143	0.045	0.031	0.306	#13	0.114	Not Required	Pass
313	0.005	0.110	0.314	0.039	0.018	0.343	#24	0.286	Not Required	Pass
314	0.004	0.093	0.310	0.047	0.017	0.371	#24	0.286	Not Required	Pass
315	0.007	0.312	0.169	0.041	0.013	0.409	#13	0.473	Not Required	Pass
316	0.004	0.288	0.170	0.035	0.013	0.394	#13	0.473	Not Required	Pass

Definitions

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

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

REFERENCES	CALCULATIONS	RESULTS

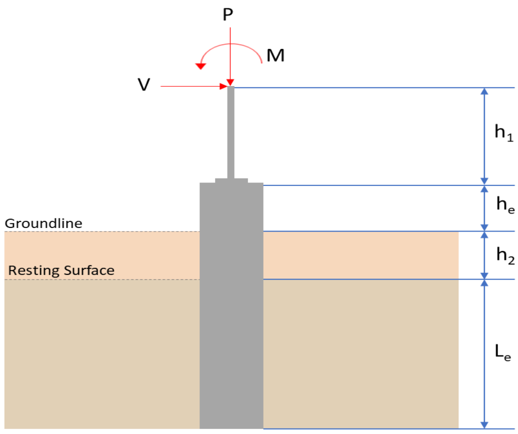
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - 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)	5.293	7.831
V_x (kip)	-2.702	-4.530
V_z (kip)	0.260	0.436
M_x (kipft)	0.914	1.461
M_z (kipft)	38.174	63.942

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,

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

$$H_o = \frac{(-2.702\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.43025\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(38.174\ \text{kipft}) + ((-2.702\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.0787\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.7776\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.26\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.041401\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.914\ \text{kipft}) + ((0.26\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.14554\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.6292\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.7776\ \text{ft}), (2.6292\ \text{ft})]$$

$$L_{e,req} = 6.778\ \text{ft}$$

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

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

$$Ratio = \frac{(6.778\ \text{ft})}{(7.25\ \text{ft})}$$

$$Ratio = 0.9349$$

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

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

$$q = \frac{(5.293\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.33081\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.33081\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.16541$$

Status: **PASS**
Ratio: **0.170**

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:

$H_o = -0.43025\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.0787\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.0787\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.43025\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (6.0787\ \mathrm{kipft/ft})) + (4 \times (-0.43025\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 4.9873\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.0787\ \mathrm{kipft/ft})) + (3 \times (-0.43025\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^{\ 2}}{(7.25\ \mathrm{ft})^2 \times [(3 \times (6.0787\ \mathrm{kipft/ft})) + (2 \times (-0.43025\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.26605\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.0787\ \mathrm{kipft/ft})) + ((-0.43025\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = 1.0317\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.9873\ \mathrm{ft})}{2}$$

$$p_a = 0.37405\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26605\ \mathrm{kip/ft^2}\right)}{\left(0.37405\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.71128$$

Status: **PASS**
Ratio: **0.710**

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

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

$$Ratio = \frac{\left(1.0317\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94867$$

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

Considering z-direction:

$H_o = 0.041401\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.14554\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.14554\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.14554\ \mathrm{kipft/ft})) + (4 \times (0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.1831\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.14554\ \mathrm{kipft/ft})) + (3 \times (0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (0.14554\ \mathrm{kipft/ft})) + (2 \times (0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = 0.030249\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.14554\ \mathrm{kipft/ft})) + ((0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})]}{(7.25\ \mathrm{ft})^2}$$

$$s = 0.06749\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1831\ \mathrm{ft})}{2}$$

$$p_a = 0.38873\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.030249\ \mathrm{kip/ft^2}\right)}{\left(0.38873\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.077813$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

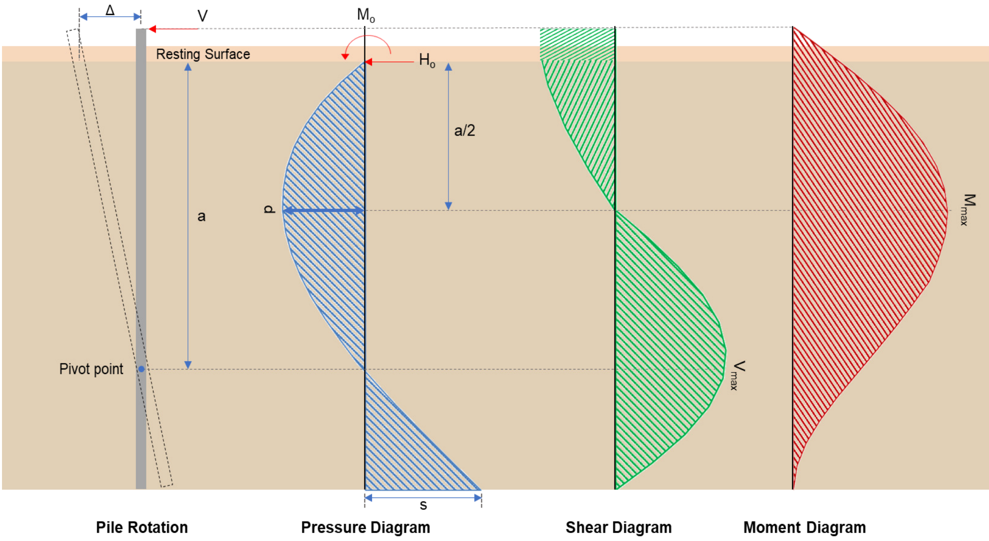
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.06749\ \mathrm{kip/ft^2})}{(1.0875\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.06206$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.53\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.72134\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(63.942\ \mathrm{kipft}) + ((-4.53\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 10.182\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.182\ \mathrm{kipft/ft})}{(-0.72134\ \mathrm{kip/ft})}$$

$$E = 14.115\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.182\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.72134\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (10.182\ \text{kipft/ft})) + (4 \times (-0.72134\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 4.9874\ \text{ft}$$

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

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

$$V_{max} = ((-0.72134\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.115\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9874\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.115\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9874\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.845\ \text{kip}$$

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

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

$$M_{max} = ((-0.72134\ \text{kip/ft}) \times (48\ \text{in}) \times (7.25\ \text{ft})) \times \left[\left(\frac{(14.115\ \text{ft})}{(7.25\ \text{ft})} + \frac{(4.9874\ \text{ft})}{2 \times (7.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.115\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9874\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.115\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9874\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 41.035\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.436\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.069427\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.461\ \text{kipft}) + ((0.436\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.23264\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.23264\ \text{kipft/ft})}{(0.069427\ \text{kip/ft})}$$

$$E = 3.3509\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.23264\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (0.069427\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (0.23264\ \text{kipft/ft})) + (4 \times (0.069427\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 5.1901\ \text{ft}$$

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

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

$$V_{max} = ((0.069427\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3509\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1901\ \mathrm{ft})}{(7.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.3509\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1901\ \mathrm{ft})}{(7.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.41237\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.069427\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.25\ \mathrm{ft})) \times \left[\left(\frac{(3.3509\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + \frac{(5.1901\ \mathrm{ft})}{2 \times (7.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (3.3509\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1901\ \mathrm{ft})}{2 \times (7.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.3509\ \mathrm{ft})}{(7.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1901\ \mathrm{ft})}{2 \times (7.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.3155\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.831\ \mathrm{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.336\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.336\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.831\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0029273$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.831 \text{ kip} \rightarrow 7831 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(7831 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.53 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.53 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.53 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.53 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.78 \text{ kip}$$

Considering x-direction:

$V_{max} = 11.845 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(11.845 \text{ kip})}{(110.78 \text{ kip})}$$ $$Ratio = 0.10693$$	Status: **PASS** Ratio: **0.110**
	Considering z-direction: $V_{max} = 0.41237 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.41237 \text{ kip})}{(110.78 \text{ kip})}$$ $$Ratio = 0.0037226$$	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:** $M_{max} = 41.035 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(41.035 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.1644$$	Status: **PASS** Ratio: **0.160**
	Considering z-direction: $M_{max} = 1.3155 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(1.3155 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0052703$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

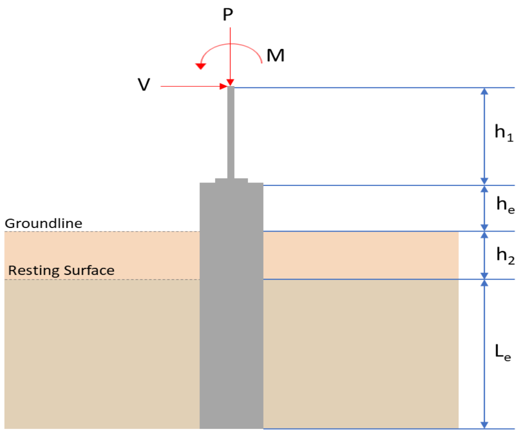
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.293	7.830
V_x (kip)	-2.702	-4.530
V_z (kip)	-0.260	-0.434
M_x (kipft)	-0.916	-1.467
M_z (kipft)	38.175	63.943

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.702 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.43025 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(38.175 \text{ kipft}) + ((-2.702 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.0788 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.7776 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.26 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.041401 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.916 \text{ kipft}) + ((-0.26 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.14586 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.9068 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.7776 \text{ ft}), (1.9068 \text{ ft})]$$

$$L_{e,req} = 6.778 \text{ ft}$$

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

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

$$Ratio = \frac{(6.778 \text{ ft})}{(7.25 \text{ ft})}$$

$$Ratio = 0.9349$$

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

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

$$q = \frac{(5.293 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.33081 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.33081 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.16541$$

Status: **PASS**
Ratio: **0.170**

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:

$H_o = -0.43025 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 6.0788 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.0788 \text{ kipft/ft}) \times (7.25 \text{ ft})) + \left(3 \times (-0.43025 \text{ kip/ft}) \times (7.25 \text{ ft})^2\right)}{(6 \times (6.0788 \text{ kipft/ft})) + (4 \times (-0.43025 \text{ kip/ft}) \times (7.25 \text{ ft}))}$$

$$a = 4.9873 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.0788 \text{ kipft/ft})) + (3 \times (-0.43025 \text{ kip/ft}) \times (7.25 \text{ ft}))]^2}{(7.25 \text{ ft})^2 \times [(3 \times (6.0788 \text{ kipft/ft})) + (2 \times (-0.43025 \text{ kip/ft}) \times (7.25 \text{ ft}))]}$$

$$p = 0.26607 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.0788 \text{ kipft/ft})) + ((-0.43025 \text{ kip/ft}) \times (7.25 \text{ ft}))]}{(7.25 \text{ ft})^2}$$

$$s = 1.0317 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.9873 \text{ ft})}{2}$$

$$p_a = 0.37405 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26607\ \mathrm{kip/ft^2}\right)}{\left(0.37405\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.71131$$

Status: **PASS**
Ratio: **0.710**

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

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

$$Ratio = \frac{\left(1.0317\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94871$$

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

Considering z-direction:

$H_o = -0.041401\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.14586\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.14586\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{(6 \times (0.14586\ \mathrm{kipft/ft})) + (4 \times (-0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))}$$

$$a = 5.1828\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.14586\ \mathrm{kipft/ft})) + (3 \times (-0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]^2}{(7.25\ \mathrm{ft})^2 \times [(3 \times (0.14586\ \mathrm{kipft/ft})) + (2 \times (-0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}$$

$$p = -0.0088129\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.14586\ \mathrm{kipft/ft})) + ((-0.041401\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft}))]}{(7.25\ \mathrm{ft})^2}$$

$$s = -0.00096337\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.1828\ \mathrm{ft})}{2}$$

$$p_a = 0.38871\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0088129\ \mathrm{kip/ft^2}\right)}{\left(0.38871\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.022672$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

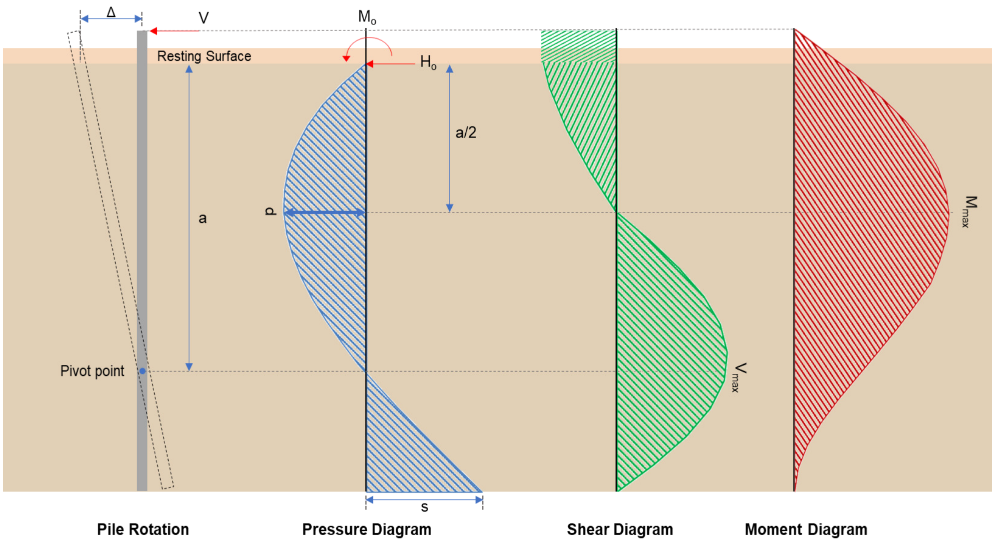
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00096337\ \mathrm{kip/ft^2}\right)}{\left(1.0875\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00088585$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.53\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.72134\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(63.943\ \mathrm{kipft}) + ((-4.53\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 10.182\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.182\ \mathrm{kipft/ft})}{(-0.72134\ \mathrm{kip/ft})}$$

$$E = 14.115\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.182\ \mathrm{kipft/ft}) \times (7.25\ \mathrm{ft})) + \left(3 \times (-0.72134\ \mathrm{kip/ft}) \times (7.25\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (10.182\ \text{kipft/ft})) + (4 \times (-0.72134\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 4.9874\ \text{ft}$$

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

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

$$V_{max} = ((-0.72134\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.115\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9874\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.115\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9874\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.845\ \text{kip}$$

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

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

$$M_{max} = ((-0.72134\ \text{kip/ft}) \times (48\ \text{in}) \times (7.25\ \text{ft})) \times \left[\left(\frac{(14.115\ \text{ft})}{(7.25\ \text{ft})} + \frac{(4.9874\ \text{ft})}{2 \times (7.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.115\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(4.9874\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.115\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(4.9874\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 41.036\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.434\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.069108\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.467\ \text{kipft}) + ((-0.434\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.2336\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.2336\ \text{kipft/ft})}{(-0.069108\ \text{kip/ft})}$$

$$E = 3.3802\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2336\ \text{kipft/ft}) \times (7.25\ \text{ft})) + \left(3 \times (-0.069108\ \text{kip/ft}) \times (7.25\ \text{ft})^2\right)}{(6 \times (0.2336\ \text{kipft/ft})) + (4 \times (-0.069108\ \text{kip/ft}) \times (7.25\ \text{ft}))}$$

$$a = 5.1889\ \text{ft}$$

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

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

$$V_{max} = ((-0.069108\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3802\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(5.1889\ \text{ft})}{(7.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.3802\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(5.1889\ \text{ft})}{(7.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.41243\ \text{kip}$$

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

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

$$M_{max} = ((-0.069108\ \text{kip/ft}) \times (48\ \text{in}) \times (7.25\ \text{ft})) \times \left[\left(\frac{(3.3802\ \text{ft})}{(7.25\ \text{ft})} + \frac{(5.1889\ \text{ft})}{2 \times (7.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.3802\ \text{ft})}{(7.25\ \text{ft})} + 3\right) \times \left(\frac{(5.1889\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.3802\ \text{ft})}{(7.25\ \text{ft})} + 2\right) \times \left(\frac{(5.1889\ \text{ft})}{2 \times (7.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.3165\ \text{kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(7.83\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.336\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-84.336\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(7.83\ \text{kip}\right)}{\left(2675.2\ \text{kip}\right)}$$

$$Ratio = 0.0029269$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.83 \text{ kip} \rightarrow 7830 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(7830 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.53 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.53 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.53 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.53 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.78 \text{ kip}$$

Considering x-direction:

$V_{max} = 11.845 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.845 \text{ kip})}{(110.78 \text{ kip})}$$

$$Ratio = 0.10693$$

Status: **PASS**
Ratio: **0.110**

Considering z-direction:

$V_{max} = 0.41243 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.41243 \text{ kip})}{(110.78 \text{ kip})}$$

$$Ratio = 0.0037232$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b\, D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

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

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

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

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

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 41.036 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(41.036 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.16441$$

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

Considering z-direction:

$M_{max} = 1.3165 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(1.3165 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0052744$$	Status: **PASS** Ratio: **0.010**

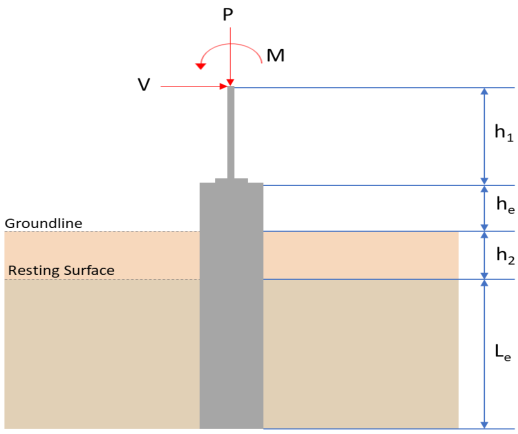
SkyCiv Foundation Design

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)	6.746	10.093
V_x (kip)	-3.547	-5.913
V_z (kip)	-0.018	-0.030
M_x (kipft)	-0.071	-0.119
M_z (kipft)	49.830	83.701

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,

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

$$H_o = \frac{(-3.547\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.56481\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(49.83 \text{ kipft}) + ((-3.547 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.9347 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.2916 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.018 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0028662 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.071 \text{ kipft}) + ((-0.018 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.011306 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.90794 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.2916 \text{ ft}), (0.90794 \text{ ft})]$$

$$L_{e,req} = 7.292 \text{ ft}$$

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

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

$$Ratio = \frac{(7.292 \text{ ft})}{(7.75 \text{ ft})}$$

$$Ratio = 0.9409$$

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

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

$$q = \frac{(6.746\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.42162\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.42162\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.21081$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.56481\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.9347\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.9347\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.56481\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (7.9347\ \text{kipft/ft})) + (4 \times (-0.56481\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.3403\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.9347\ \text{kipft/ft})) + (3 \times (-0.56481\ \text{kip/ft}) \times (7.75\ \text{ft}))]^2}{(7.75\ \text{ft})^2 \times [(3 \times (7.9347\ \text{kipft/ft})) + (2 \times (-0.56481\ \text{kip/ft}) \times (7.75\ \text{ft}))]}$$

$$p = 0.28727\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (7.9347\ \text{kipft/ft})) + ((-0.56481\ \text{kip/ft}) \times (7.75\ \text{ft}))]}{(7.75\ \text{ft})^2}$$

$$s = 1.148\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.3403\ \text{ft})}{2}$$

$$p_a = 0.40052\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.28727\ \text{kip/ft}^2\right)}{\left(0.40052\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.71723$$

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

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

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

$$Ratio = \frac{\left(1.148\ \text{kip/ft}^2\right)}{\left(1.1625\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.98754$$

Status: **PASS**
Ratio: **0.990**

Considering z-direction:

$H_o = -0.0028662\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.011306\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011306\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.0028662\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (0.011306\ \text{kipft/ft})) + (4 \times (-0.0028662\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.5329\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.011306\ \text{kipft/ft})) + (3 \times (-0.0028662\ \text{kip/ft}) \times (7.75\ \text{ft}))]^{\ 2}}{(7.75\ \text{ft})^2 \times [(3 \times (0.011306\ \text{kipft/ft})) + (2 \times (-0.0028662\ \text{kip/ft}) \times (7.75\ \text{ft}))]}$$

$$p = -0.000545\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.011306\ \text{kipft/ft})) + ((-0.0028662\ \text{kip/ft}) \times (7.75\ \text{ft}))]}{(7.75\ \text{ft})^2}$$

$$s = 0.000039768\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.5329\ \text{ft})}{2}$$

$$p_a = 0.41497\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.000545\ \text{kip/ft}^2\right)}{\left(0.41497\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.0013134$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

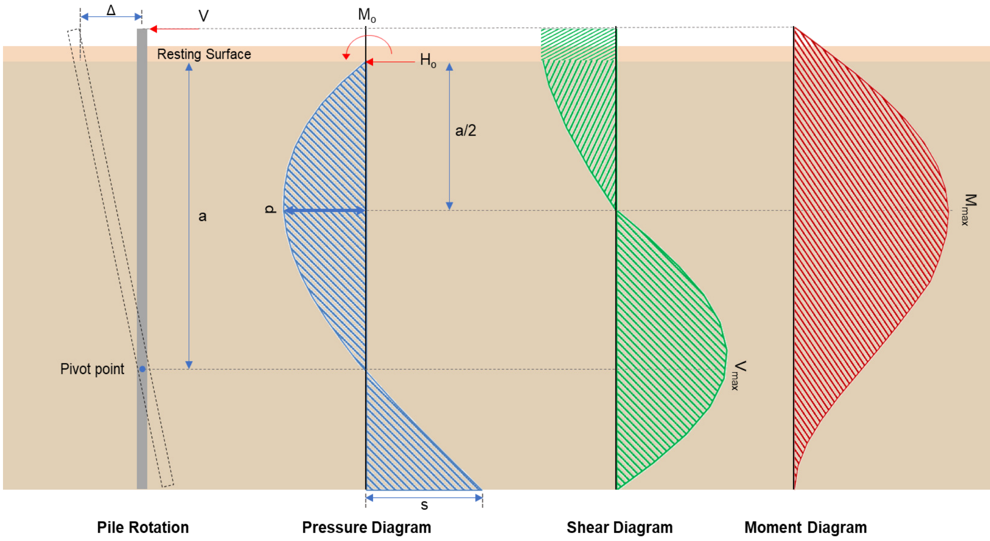
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.000039768\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.000034209$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.913\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.94156\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(83.701\ \mathrm{kipft}) + ((-5.913\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 13.328\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(13.328\ \mathrm{kipft/ft})}{(-0.94156\ \mathrm{kip/ft})}$$

$$E = 14.155\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.328\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.94156\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (13.328\ \text{kipft/ft})) + (4 \times (-0.94156\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.3394\ \text{ft}$$

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

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

$$V_{max} = ((-0.94156\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.155\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3394\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.155\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3394\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.657\ \text{kip}$$

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

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

$$M_{max} = ((-0.94156\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(14.155\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.3394\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.155\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.3394\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.155\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.3394\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 54.145\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.03\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0047771\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.119\ \text{kipft}) + ((-0.03\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.018949\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.018949\ \text{kipft/ft})}{(-0.0047771\ \text{kip/ft})}$$

$$E = 3.9667\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.018949\ \text{kipft/ft}) \times (7.75\ \text{ft})) + \left(3 \times (-0.0047771\ \text{kip/ft}) \times (7.75\ \text{ft})^2\right)}{(6 \times (0.018949\ \text{kipft/ft})) + (4 \times (-0.0047771\ \text{kip/ft}) \times (7.75\ \text{ft}))}$$

$$a = 5.532\ \text{ft}$$

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

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

$$V_{max} = ((-0.0047771\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.9667\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.532\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.9667\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.532\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.030033\ \text{kip}$$

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

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

$$M_{max} = ((-0.0047771\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(3.9667\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.532\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.9667\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.532\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.9667\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.532\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.10316\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.093\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.261\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.261\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.093 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0037728$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\; D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.093 \text{ kip} \rightarrow 10093 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(10093 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.83 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.83 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.83 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.83 \text{ kip}) + (50.894 \text{ kip}))$$

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

Considering x-direction:

$V_{max} = 14.657 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.657 \text{ kip})}{(110.97 \text{ kip})}$$

$$Ratio = 0.13208$$

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

Considering z-direction:

$V_{max} = 0.030033 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.030033 \text{ kip})}{(110.97 \text{ kip})}$$

$$Ratio = 0.00027064$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b\, D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

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

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

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

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

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 54.145 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(54.145 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.21693$$

Status: **PASS**
Ratio: **0.220**

Considering z-direction:

$M_{max} = 0.10316 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.10316 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00041332$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

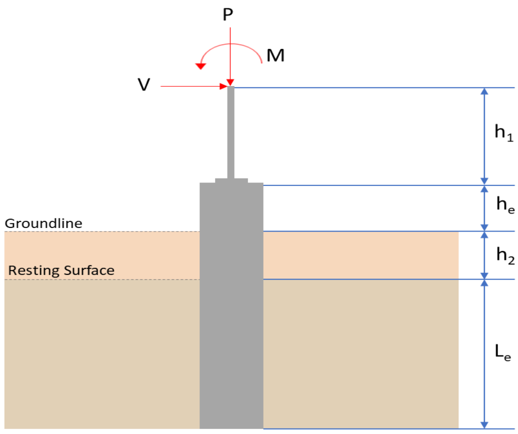
SkyCiv Foundation Design

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)	6.746	10.092
V_x (kip)	-3.547	-5.912
V_z (kip)	0.018	0.030
M_x (kipft)	0.071	0.122
M_z (kipft)	49.834	83.683

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,

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

$$H_o = \frac{(-3.547\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.56481\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(49.834\text{ kipft}) + ((-3.547\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 7.9354\text{ kipft/ft}$$

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:
$L_{e,x} = 7.2919\text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.018\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.0028662\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.071\text{ kipft}) + ((0.018\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.011306\text{ kipft/ft}$$

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:
$L_{e,z} = 1.0265\text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.2919\text{ ft}), (1.0265\text{ ft})]$$

$$L_{e,req} = 7.292\text{ ft}$$

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

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

$$Ratio = \frac{(7.292\text{ ft})}{(7.75\text{ ft})}$$

$$Ratio = 0.9409$$

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

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

$$q = \frac{(6.746 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.42162 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.42162 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.21081$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.56481 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.9354 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.9354 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-0.56481 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (7.9354 \text{ kipft/ft})) + (4 \times (-0.56481 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.3403 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.9354 \text{ kipft/ft})) + (3 \times (-0.56481 \text{ kip/ft}) \times (7.75 \text{ ft}))]^2}{(7.75 \text{ ft})^2 \times [(3 \times (7.9354 \text{ kipft/ft})) + (2 \times (-0.56481 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.28731 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (7.9354 \text{ kipft/ft})) + ((-0.56481 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.1481 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.3403 \text{ ft})}{2}$$

$$p_a = 0.40052 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.28731\ \mathrm{kip/ft^2}\right)}{\left(0.40052\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.71734$$ 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 $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.1481\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.98765$$	Status: **PASS** Ratio: **0.720** Status: **PASS** Ratio: **0.990**
	Considering z-direction: $H_o = 0.0028662\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.011306\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + \left(3\,H_o\,L_e^2\right)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.011306\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (0.0028662\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{(6 \times (0.011306\ \mathrm{kipft/ft})) + (4 \times (0.0028662\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))}$$ $$a = 5.5329\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.011306\ \mathrm{kipft/ft})) + (3 \times (0.0028662\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]^{\ 2}}{(7.75\ \mathrm{ft})^2 \times [(3 \times (0.011306\ \mathrm{kipft/ft})) + (2 \times (0.0028662\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}$$ $$p = 0.0019945\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.011306\ \mathrm{kipft/ft})) + ((0.0028662\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft}))]}{(7.75\ \mathrm{ft})^2}$$ $$s = 0.0044778\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.5329\ \mathrm{ft})}{2}$$ $$p_a = 0.41497\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.0019945\ \mathrm{kip/ft^2}\right)}{\left(0.41497\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = 0.0048063$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

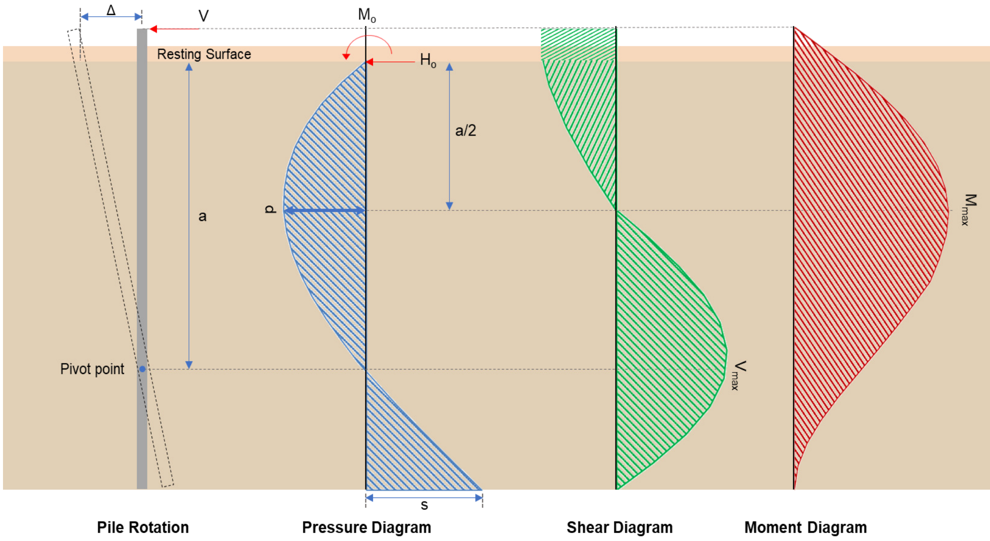
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0044778\ \mathrm{kip/ft^2}\right)}{\left(1.1625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0038519$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.912\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.9414\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(83.683\ \mathrm{kipft}) + ((-5.912\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 13.325\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(13.325\ \mathrm{kipft/ft})}{(-0.9414\ \mathrm{kip/ft})}$$

$$E = 14.155\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.325\ \mathrm{kipft/ft}) \times (7.75\ \mathrm{ft})) + \left(3 \times (-0.9414\ \mathrm{kip/ft}) \times (7.75\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (13.325 \text{ kipft/ft})) + (4 \times (-0.9414 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.3394 \text{ ft}$$

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

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

$$V_{max} = ((-0.9414 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.155 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.3394 \text{ ft})}{(7.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.155 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.3394 \text{ ft})}{(7.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 14.654 \text{ kip}$$

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

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

$$M_{max} = ((-0.9414 \text{ kip/ft}) \times (48 \text{ in}) \times (7.75 \text{ ft})) \times \left[\left(\frac{(14.155 \text{ ft})}{(7.75 \text{ ft})} + \frac{(5.3394 \text{ ft})}{2 \times (7.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (14.155 \text{ ft})}{(7.75 \text{ ft})} + 3\right) \times \left(\frac{(5.3394 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.155 \text{ ft})}{(7.75 \text{ ft})} + 2\right) \times \left(\frac{(5.3394 \text{ ft})}{2 \times (7.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 54.134 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.03 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0047771 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.122 \text{ kipft}) + ((0.03 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

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

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.019427 \text{ kipft/ft})}{(0.0047771 \text{ kip/ft})}$$

$$E = 4.0667 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.019427 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (0.0047771 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (0.019427 \text{ kipft/ft})) + (4 \times (0.0047771 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.5281 \text{ ft}$$

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

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

$$V_{max} = ((0.0047771\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.0667\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5281\ \text{ft})}{(7.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.0667\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5281\ \text{ft})}{(7.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.030464\ \text{kip}$$

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

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

$$M_{max} = ((0.0047771\ \text{kip/ft}) \times (48\ \text{in}) \times (7.75\ \text{ft})) \times \left[\left(\frac{(4.0667\ \text{ft})}{(7.75\ \text{ft})} + \frac{(5.5281\ \text{ft})}{2 \times (7.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.0667\ \text{ft})}{(7.75\ \text{ft})} + 3\right) \times \left(\frac{(5.5281\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.0667\ \text{ft})}{(7.75\ \text{ft})} + 2\right) \times \left(\frac{(5.5281\ \text{ft})}{2 \times (7.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.10483\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.092\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.261\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.261\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.092\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0037725$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.092 \text{ kip} \rightarrow 10092 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(10092 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.83 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.83 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.83 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.83 \text{ kip}) + (50.894 \text{ kip}))$$

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

Considering x-direction:

$V_{max} = 14.654 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(14.654 \text{ kip})}{(110.97 \text{ kip})}$$ $$Ratio = 0.13206$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $V_{max} = 0.030464 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.030464 \text{ kip})}{(110.97 \text{ kip})}$$ $$Ratio = 0.00027452$$	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:** $M_{max} = 54.134 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(54.134 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.21688$$	Status: **PASS** Ratio: **0.220**
	Considering z-direction: $M_{max} = 0.10483 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.10483 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00042$$	Status: **PASS** Ratio: **0.000**