Project Details

Project Name: MTSOLAR_LL541KKA74FG

Location: 3526 Bess Way, Monrovia, MD 21770, USA

Unique ID: 5P-19.75-8TOP-HD-24-L-4Hx16W-H6AC

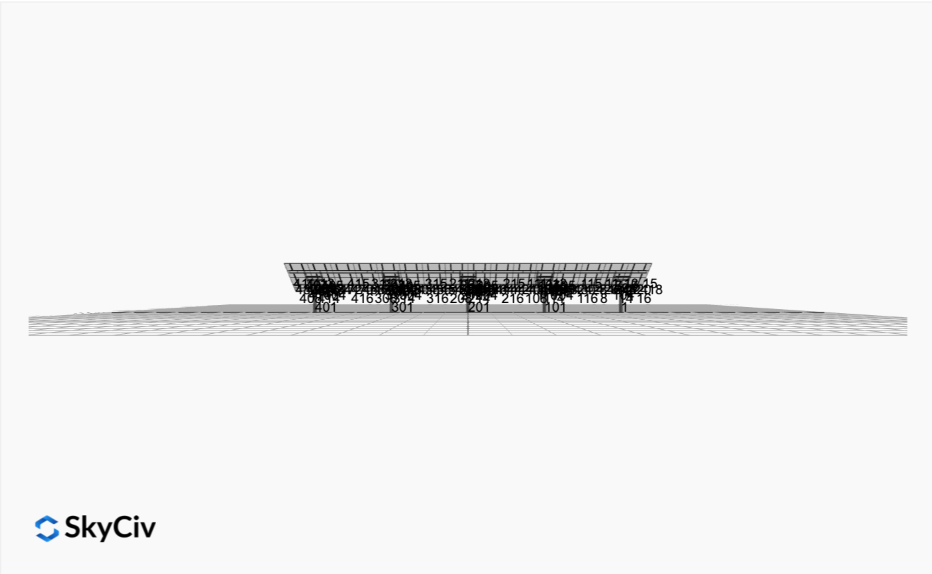
Dealer: ______________________________

Date: Sun Sep 07 2025

Number of Modules: 64

Number of Poles: 5

Date Sold: ______________________________



Array Dimensions N/S	13.83 ft
Array Dimensions E/W	92.00 ft
Winter Tilt Angle	30
Front Edge Clearance	5 ft

MT Solar Bill of Materials (5P-19.75-8TOP-HD-24-L-4Hx16W-H6AC)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	5
MTS-HF-HD	H-Frame Assembly-HD	5
MTS-HD-Wing-24	24IN HD Wing	4
MTS-HD-Splice-90	90IN HD Splice	8
MTS-HD-Splice-57	57IN HD Splice	8
MTS-CLAMP-HOOK-4PK	Hook Clamp	16

Rail Bill of Materials

Part	Qty
Rails (166in)	32
Rail Attachment	64
Module Mid Clamp	96
Module End Clamp	64
Ground Lug	16

Site Details:

Site Address: 3526 Bess Way, Monrovia, MD 21770, USA

Array Specification

Duty Classification:	HD
Module Width:	41.00 in
Module Length:	68.00in
Number of Rows:	4
Number of Columns:	16
Total Number of Modules:	64
Winter Tilt Angle:	30
Front Edge Clearance:	5
Total Array Height at Tilt:	11.92 ft
Total Frame Length:	90.50 ft
Module Info/Notes:	hyundai 440
Array Dimensions N/S:	13.83 ft
Array Dimensions E/W:	92.00 ft
Rail Length:	166.00 in
Rail Spacing:	2.88 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	8.46 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 8.25 ft Pile 2: 8.75 ft Pile 3: 8.75 ft Pile 4: 8.75 ft Pile 5: 8.25 ft
Foundation Volume:	11.192 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	3526 Bess Way, Monrovia, MD 21770, USA
Wind Speed:	105 mph

Snow Load:	25 psf

Design Disclaimer

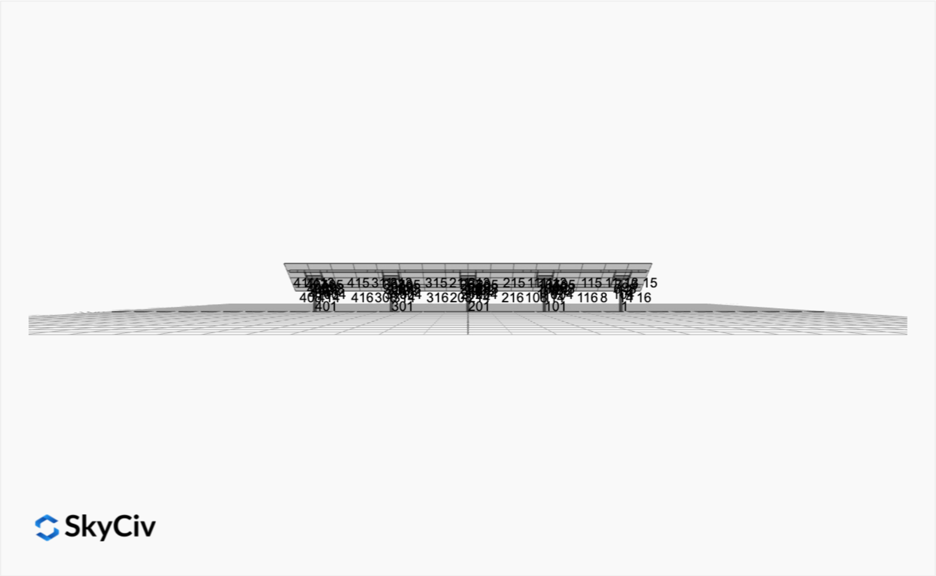
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

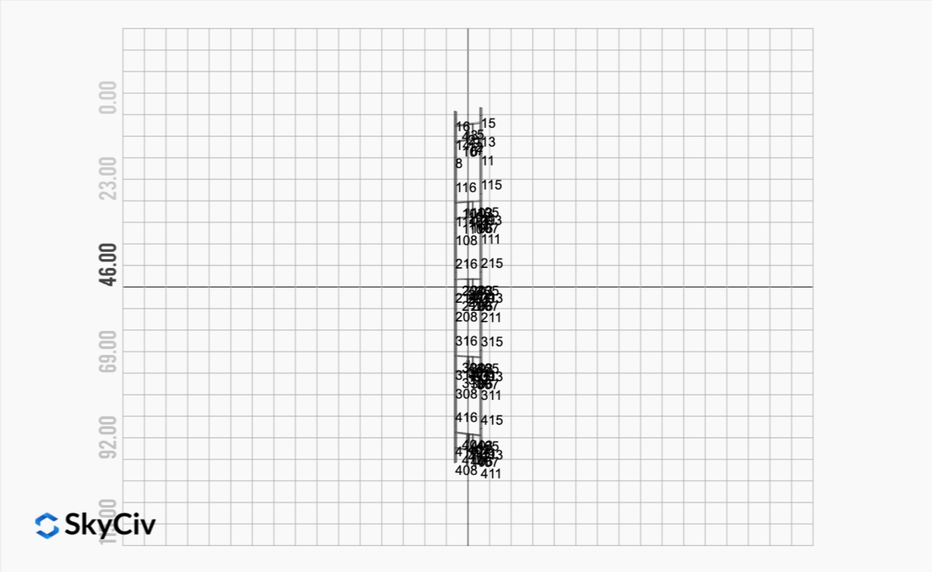
AutoDesigner Input

{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"","designer_email":"info@gotsolar4you.com","designer_phone":"","project_id":"MTSOLAR_LL541KKA74FG","site_address":"3526 Bess Way, Monrovia, MD 21770, USA","module_info":"hyundai 440","module_width":41,"module_length":68,"number_rows":"4","number_columns":16,"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":30,"ground_clearance":5,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"36_Round","foundation_type":"Round","foundation_size":36,"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

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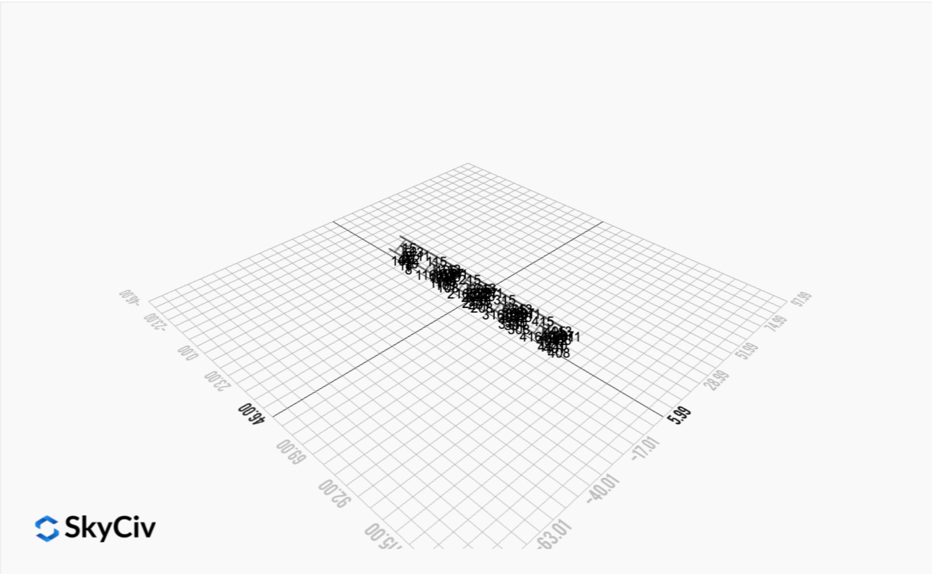
46.00
69.00
92.00
SkyCiv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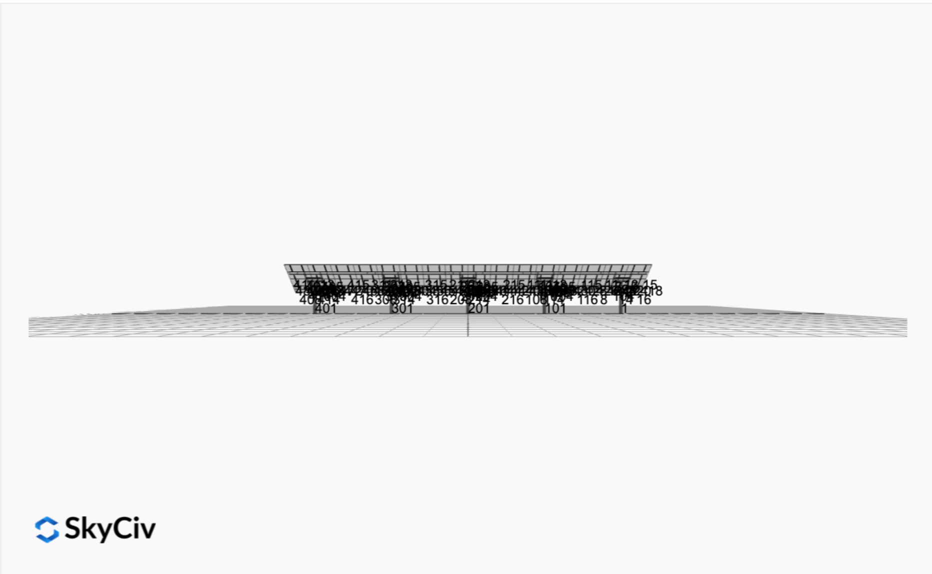
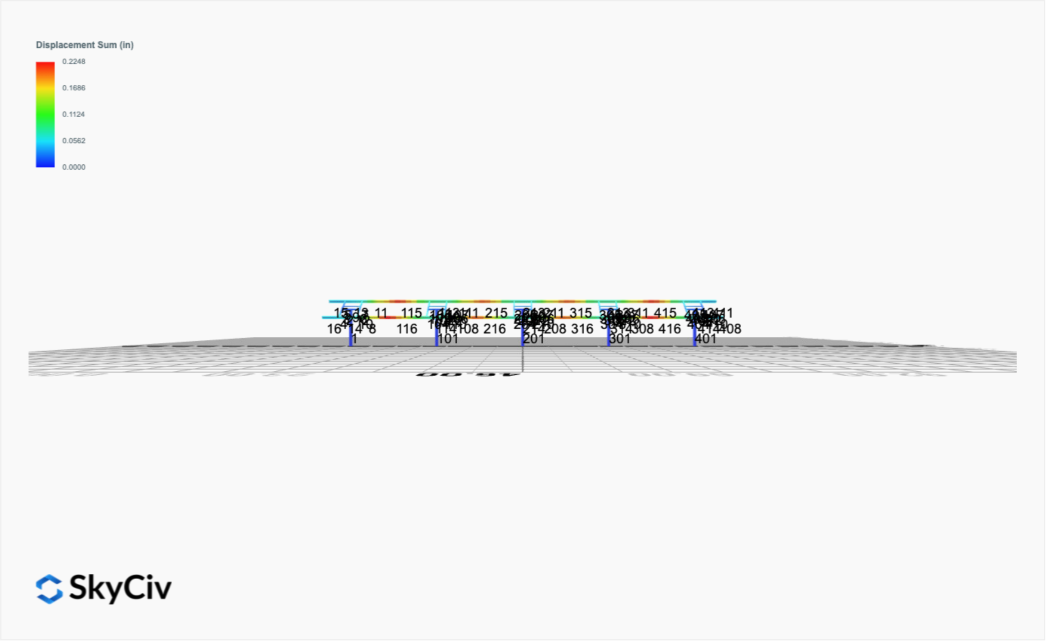
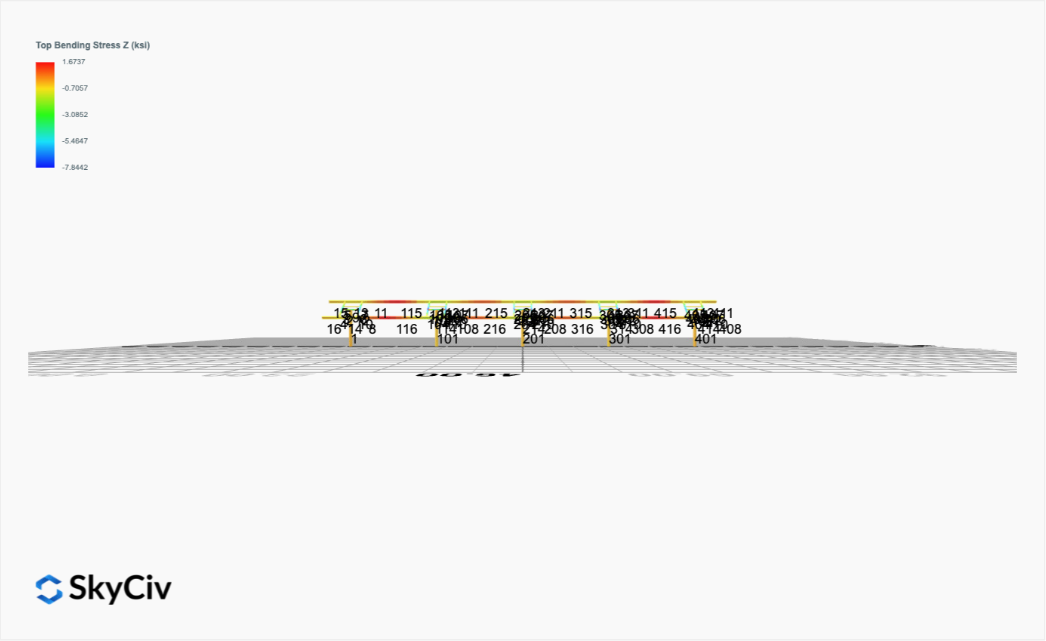
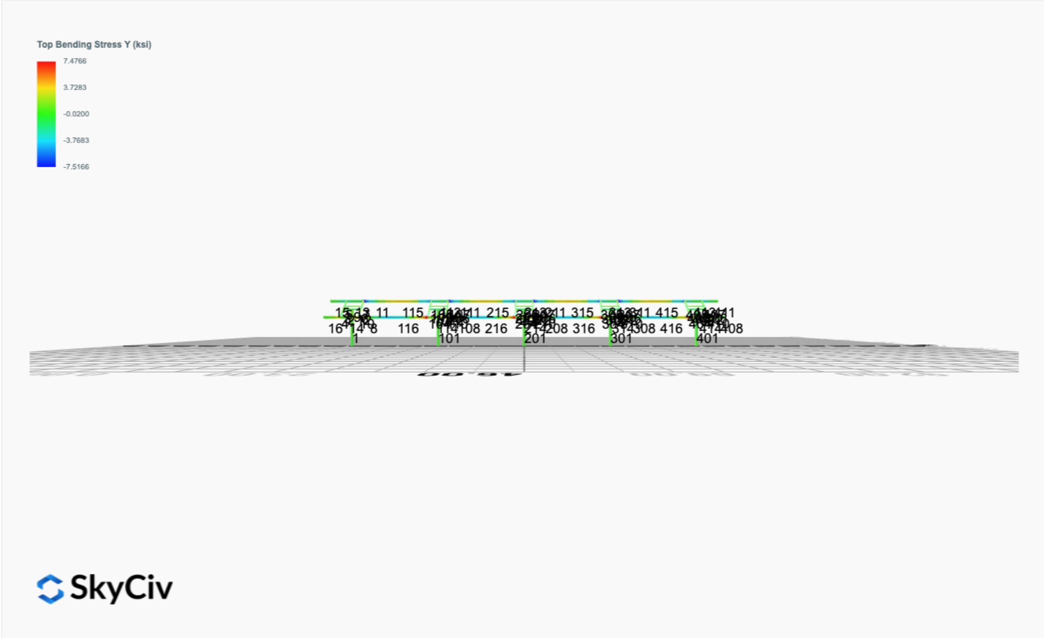
SkyCiv


SkyCiv

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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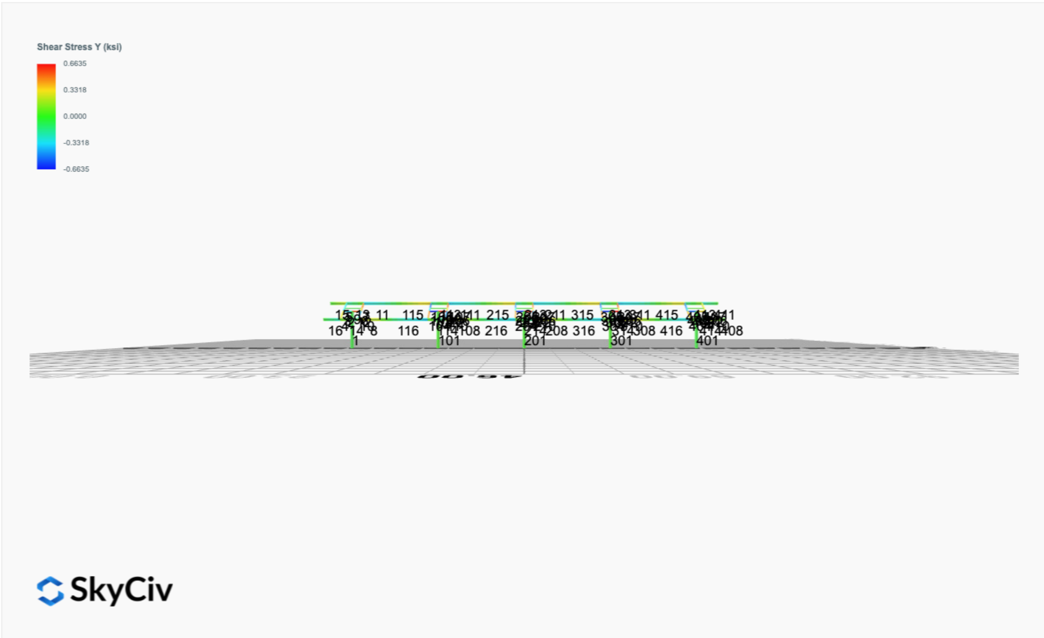
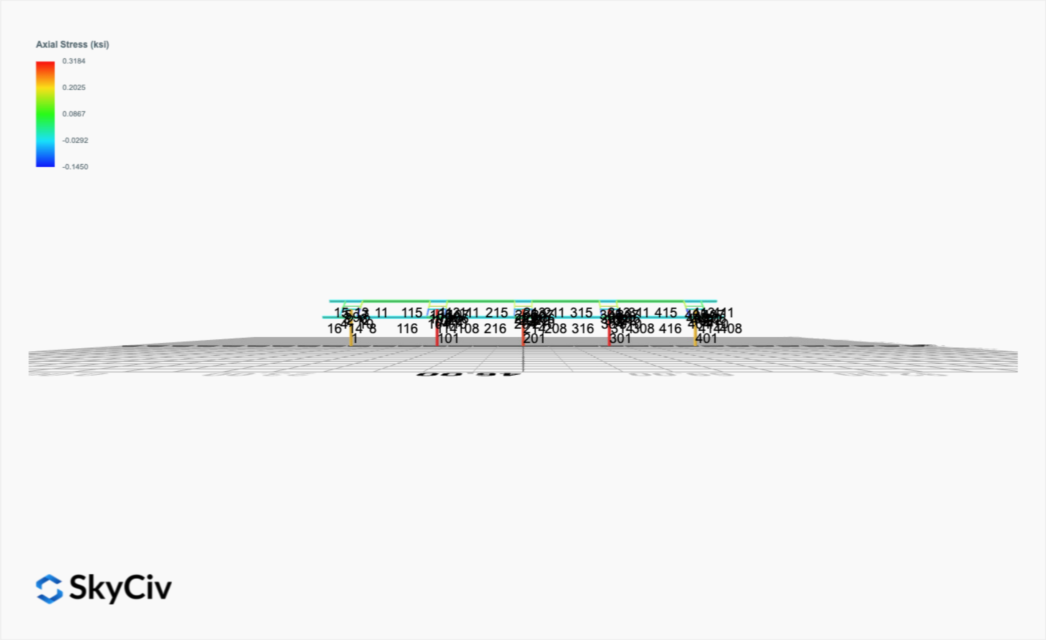
3.7283
-0.0200
-3.7683
-7.5166
101
201
301
401
SkyCiv


Shear Stress Y (ksi)
0.6635
0.3318
0.0000
-0.3318
-0.6635
101
201
301
401
SkyCiv


Axial Stress (ksi)
0.3184
0.2025
0.0867
-0.0292
-0.1450
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0232	1.7701	0.0871	0.1699	-0.0563	-0.1607
ULS: 2. D + L	0.0232	1.7701	0.0871	0.1699	-0.0563	-0.1607
ULS: 3. D + (S or Lr or R)	0.0585	3.7635	0.2195	0.4284	-0.1421	-0.4397
ULS: 3. D + (S or Lr or R)	0.0232	1.7701	0.0871	0.1699	-0.0563	-0.1607
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0497	3.2652	0.1864	0.3638	-0.1206	-0.3699
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0232	1.7701	0.0871	0.1699	-0.0563	-0.1607
ULS: 5b. D + 0.7E	0.0232	1.7701	0.0871	0.1699	-0.0563	-0.1607
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0497	3.2652	0.1864	0.3638	-0.1206	-0.3699
ULS: 8. 0.6D + 0.7E	0.0139	1.0621	0.0523	0.1019	-0.0338	-0.0964
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.2449	5.6627	0.3964	0.7168	-0.7840	19.3716
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.2449	5.6627	0.3964	0.7168	-0.7840	19.3716
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9666	-1.5657	-0.1748	-0.2933	0.5615	-16.5617
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6599	-1.0189	-0.1505	-0.2486	0.5167	-22.1282
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6514	6.1846	0.4184	0.7739	-0.6664	14.2793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6514	6.1846	0.4184	0.7739	-0.6664	14.2793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5072	0.7633	-0.0100	0.0164	0.3427	-12.6707
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2772	1.1734	0.0082	0.0499	0.3091	-16.8455
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6779	4.6895	0.3191	0.5800	-0.6021	14.4885
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6779	4.6895	0.3191	0.5800	-0.6021	14.4885
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4808	-0.7317	-0.1093	-0.1775	0.4070	-12.4615
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2508	-0.3216	-0.0911	-0.1440	0.3735	-16.6363
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2542	4.9546	0.3616	0.6488	-0.7615	19.4358
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.2542	4.9546	0.3616	0.6488	-0.7615	19.4358
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9573	-2.2737	-0.2096	-0.3612	0.5840	-16.4975
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6506	-1.7270	-0.1853	-0.3165	0.5392	-22.0639

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	9.6085
Shear X	-3.7802
Shear Z	0.6882
Moment X	1.2482
Moment Y (Twist)	1.3260
Moment Z	37.1855

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	6.1846
Shear X	-2.2542
Shear Z	0.4184
Moment X	0.7739
Moment Y (Twist)	0.7840
Moment Z	22.1282

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	-0.0254	2.2195	-0.0099	-0.0218	0.0229	0.2229
ULS: 2. D + L	-0.0254	2.2195	-0.0099	-0.0218	0.0229	0.2229
ULS: 3. D + (S or Lr or R)	-0.0640	4.8935	-0.0250	-0.0548	0.0576	0.5285
ULS: 3. D + (S or Lr or R)	-0.0254	2.2195	-0.0099	-0.0218	0.0229	0.2229
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0544	4.2250	-0.0213	-0.0466	0.0490	0.4521

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0254	2.2195	-0.0099	-0.0218	0.0229	0.2229
ULS: 5b. D + 0.7E	-0.0254	2.2195	-0.0099	-0.0218	0.0229	0.2229
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0544	4.2250	-0.0213	-0.0466	0.0490	0.4521
ULS: 8. 0.6D + 0.7E	-0.0153	1.3317	-0.0060	-0.0131	0.0137	0.1337
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0648	7.5217	-0.0382	-0.0876	0.0551	26.1070
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.0648	7.5217	-0.0382	-0.0876	0.0551	26.1070
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5808	-2.3265	0.0148	0.0352	-0.0069	-21.3954
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.1263	-1.5530	0.0013	0.0106	0.0337	-28.1474
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3339	8.2017	-0.0424	-0.0959	0.0731	19.8652
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.3339	8.2017	-0.0424	-0.0959	0.0731	19.8652
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9003	0.8156	-0.0027	-0.0038	0.0266	-15.7616
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5594	1.3957	-0.0129	-0.0223	0.0571	-20.8256
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3049	6.1961	-0.0311	-0.0711	0.0470	19.6360
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.3049	6.1961	-0.0311	-0.0711	0.0470	19.6360
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9292	-1.1900	0.0086	0.0209	0.0006	-15.9908
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5884	-0.6099	-0.0015	0.0025	0.0310	-21.0548
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0546	6.6339	-0.0342	-0.0789	0.0459	26.0179
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.0546	6.6339	-0.0342	-0.0789	0.0459	26.0179
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5909	-3.2143	0.0188	0.0439	-0.0160	-21.4846
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.1365	-2.4408	0.0052	0.0193	0.0246	-28.2366

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	12.8370
Shear X	-5.1148
Shear Z	-0.0663
Moment X	-0.1522
Moment Y (Twist)	0.1097
Moment Z	47.2838

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.2017
Shear X	-3.0648
Shear Z	-0.0424
Moment X	-0.0959
Moment Y (Twist)	0.0731
Moment Z	28.2366

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	0.0044	2.1622	0.0000	0.0000	0.0000	0.0088
ULS: 2. D + L	0.0044	2.1622	0.0000	0.0000	0.0000	0.0088
ULS: 3. D + (S or Lr or R)	0.0110	4.7494	0.0000	-0.0000	0.0000	-0.0111
ULS: 3. D + (S or Lr or R)	0.0044	2.1622	0.0000	0.0000	0.0000	0.0088
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0094	4.1026	0.0000	-0.0000	0.0000	-0.0062
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0044	2.1622	0.0000	0.0000	0.0000	0.0088
ULS: 5b. D + 0.7E	0.0044	2.1622	0.0000	0.0000	0.0000	0.0088
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0094	4.1026	0.0000	-0.0000	0.0000	-0.0062
ULS: 8. 0.6D + 0.7E	0.0026	1.2973	0.0000	0.0000	0.0000	0.0053
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.9447	7.2662	0.0000	-0.0000	0.0000	25.4229
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.9447	7.2662	0.0000	-0.0000	0.0000	25.4229
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5316	-2.2116	0.0000	-0.0000	0.0000	-21.2082
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.1161	-1.4959	0.0000	-0.0000	0.0000	-28.2886

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	-2.2024	7.9306	0.0000	-0.0000	0.0000	19.0545
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.2024	7.9306	0.0000	-0.0000	0.0000	19.0545
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9048	0.8223	0.0000	-0.0000	0.0000	-15.9189
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5932	1.3590	0.0000	-0.0000	0.0000	-21.2292
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.2074	5.9902	0.0000	-0.0000	0.0000	19.0694
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.2074	5.9902	0.0000	-0.0000	0.0000	19.0694
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8998	-1.1181	0.0000	-0.0000	0.0000	-15.9040
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5882	-0.5814	0.0000	-0.0000	0.0000	-21.2143
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.9464	6.4013	0.0000	-0.0000	0.0000	25.4194
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.9464	6.4013	0.0000	-0.0000	0.0000	25.4194
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5298	-3.0764	0.0000	-0.0000	0.0000	-21.2117
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.1143	-2.3608	0.0000	-0.0000	0.0000	-28.2921

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	12.3956
Shear X	-4.9151
Shear Z	0.0000
Moment X	0.0002
Moment Y (Twist)	0.0004
Moment Z	47.5481

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.9306
Shear X	-2.9464
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	28.2921

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	-0.0254	2.2195	0.0099	0.0218	-0.0229	0.2229
ULS: 2. D + L	-0.0254	2.2195	0.0099	0.0218	-0.0229	0.2229
ULS: 3. D + (S or Lr or R)	-0.0640	4.8935	0.0250	0.0548	-0.0575	0.5285
ULS: 3. D + (S or Lr or R)	-0.0254	2.2195	0.0099	0.0218	-0.0229	0.2229
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0544	4.2250	0.0213	0.0465	-0.0489	0.4521
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0254	2.2195	0.0099	0.0218	-0.0229	0.2229
ULS: 5b. D + 0.7E	-0.0254	2.2195	0.0099	0.0218	-0.0229	0.2229
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0544	4.2250	0.0213	0.0465	-0.0489	0.4521
ULS: 8. 0.6D + 0.7E	-0.0153	1.3317	0.0060	0.0131	-0.0137	0.1337
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.0648	7.5217	0.0382	0.0876	-0.0550	26.1070
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.0648	7.5217	0.0382	0.0876	-0.0550	26.1070
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5808	-2.3265	-0.0148	-0.0352	0.0069	-21.3954
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.1263	-1.5530	-0.0013	-0.0106	-0.0337	-28.1474
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3339	8.2017	0.0424	0.0959	-0.0730	19.8652
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.3339	8.2017	0.0424	0.0959	-0.0730	19.8652
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9003	0.8156	0.0027	0.0038	-0.0265	-15.7616
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5594	1.3957	0.0129	0.0223	-0.0570	-20.8256
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.3049	6.1961	0.0311	0.0711	-0.0470	19.6360
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.3049	6.1961	0.0311	0.0711	-0.0470	19.6360
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9292	-1.1900	-0.0086	-0.0210	-0.0005	-15.9908
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5884	-0.6099	0.0015	-0.0025	-0.0310	-21.0548

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.0546	6.6339	0.0342	0.0788	-0.0459	26.0179
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.0546	6.6339	0.0342	0.0788	-0.0459	26.0179
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5909	-3.2143	-0.0188	-0.0439	0.0161	-21.4846
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.1365	-2.4408	-0.0052	-0.0193	-0.0246	-28.2366

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	12.8370
Shear X	-5.1148
Shear Z	0.0663
Moment X	0.1521
Moment Y (Twist)	0.1089
Moment Z	47.2838

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.2017
Shear X	-3.0648
Shear Z	0.0424
Moment X	0.0959
Moment Y (Twist)	0.0730
Moment Z	28.2366

Reaction Forces for Foundation 5 (Node ID#401), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0232	1.7701	-0.0871	-0.1699	0.0563	-0.1607
ULS: 2. D + L	0.0232	1.7701	-0.0871	-0.1699	0.0563	-0.1607
ULS: 3. D + (S or Lr or R)	0.0585	3.7635	-0.2195	-0.4285	0.1422	-0.4396
ULS: 3. D + (S or Lr or R)	0.0232	1.7701	-0.0871	-0.1699	0.0563	-0.1607
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0497	3.2652	-0.1864	-0.3638	0.1207	-0.3699
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0232	1.7701	-0.0871	-0.1699	0.0563	-0.1607
ULS: 5b. D + 0.7E	0.0232	1.7701	-0.0871	-0.1699	0.0563	-0.1607
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0497	3.2652	-0.1864	-0.3638	0.1207	-0.3699
ULS: 8. 0.6D + 0.7E	0.0139	1.0621	-0.0523	-0.1019	0.0338	-0.0964
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.2449	5.6627	-0.3964	-0.7168	0.7840	19.3716
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.2449	5.6627	-0.3964	-0.7168	0.7840	19.3716
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.9666	-1.5657	0.1748	0.2932	-0.5615	-16.5617
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6599	-1.0189	0.1505	0.2486	-0.5167	-22.1282
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6514	6.1846	-0.4184	-0.7740	0.6665	14.2793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6514	6.1846	-0.4184	-0.7740	0.6665	14.2793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5072	0.7633	0.0100	-0.0165	-0.3426	-12.6707
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2772	1.1734	-0.0082	-0.0500	-0.3090	-16.8455
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6779	4.6895	-0.3191	-0.5801	0.6021	14.4885
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6779	4.6895	-0.3191	-0.5801	0.6021	14.4885
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4808	-0.7317	0.1093	0.1775	-0.4070	-12.4615
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2508	-0.3216	0.0911	0.1439	-0.3735	-16.6363
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.2542	4.9546	-0.3616	-0.6488	0.7615	19.4358
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.2542	4.9546	-0.3616	-0.6488	0.7615	19.4358
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.9573	-2.2737	0.2096	0.3612	-0.5840	-16.4975
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6506	-1.7270	0.1853	0.3165	-0.5392	-22.0639

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.

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	9.6085
Shear X	-3.7802
Shear Z	-0.6882
Moment X	-1.2482
Moment Y (Twist)	1.3265
Moment Z	37.1859

Result	Value (kip, kip-ft)
Axial	6.1846
Shear X	-2.2542
Shear Z	-0.4184
Moment X	-0.7740
Moment Y (Twist)	0.7840
Moment Z	22.1282

Project Details

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

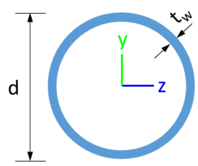
User Name: sales@mtsolar.us
Project Name: MTSOLAR_LL541KKA74FG
Unit System: imperial

Design Input Information

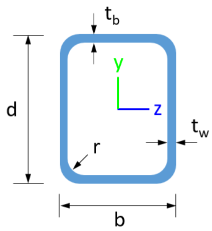
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

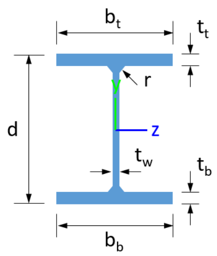
Section Dimensions



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					
9	8in Pipe Sch 40	8.63	0.32					



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
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
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	9	17.76	17.76	8.46	-	300	200	1
2	5	4.20	4.20	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.19,1.12,1.17,1.17,1.16,1.16,1.17,1.17,1.17,1.17	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,2.82,1.67,1.67,1.71,1.68,1.67,1.67,1.64,1.72,1.67,1.67,1.66,1.58	300	200	1
5	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.61,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.15,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.63,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
8	19	1.33	1.33	2.05	1.32,1.32,1.32,1.32,1.32,1.32,1.31,1.31,1.30,1.91,1.31,1.31,1.31,1.03,1.32,1.32,1.37,1.38,1.31,1.31,1.30,2.08,1.31,1.31,1.31,1.11	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.77,1.67,1.67,1.66,1.62,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.73,1.67,1.67,1.66,1.64	300	200	1
11	19	1.33	1.33	2.05	1.34,1.34,1.34,1.34,1.34,1.34,1.36,1.36,1.37,1.42,1.36,1.36,1.37,1.41,1.35,1.35,1.27,2.24,1.35,1.35,1.38,1.43,1.36,1.36,1.36,1.40	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.16,1.21,1.16,1.16,1.16,1.21,1.17,1.17,1.23,2.28,1.16,1.16,1.16,1.22,1.16,1.16,1.16,1.21	300	200	1
14	19	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.18,2.42,1.17,1.17,1.18,1.63,1.17,1.17,1.15,1.25,1.17,1.17,1.18,2.16,1.17,1.17,1.18,1.44	300	200	1
15	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	17.76	17.76	8.46	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.10,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.66,1.62,1.67,1.67,1.69,1.68,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.65	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.60,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	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	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.63,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
108	19	1.33	1.33	2.05	2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.14,1.27,2.12,2.12,2.14,1.54,2.12,2.12,2.11,2.09,2.12,2.12,2.16,1.59,2.12,2.12,2.13,1.85	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.73,1.67,1.67,1.66,1.61,1.67,1.67,1.69,1.67,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.64	300	200	1
111	19	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.09,2.09,2.07,2.06,2.08,2.08,2.08,2.06,2.09,2.09,2.28,1.18,2.09,2.09,2.07,2.06,2.08,2.08,2.08,2.07	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1

113	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.08,1.05,1.05,1.06,1.07,1.05,1.05,1.03,1.15,1.05,1.05,1.06,1.09,1.05,1.05,1.06,1.07	300	200	1
114	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.02,1.05,1.05,1.04,1.05,1.05,1.05,1.05,3.83,1.05,1.05,1.05,1.02	300	200	1
115	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.14,1.13,1.15,1.15,1.14,1.13,1.15,1.15,1.22,1.10,1.15,1.15,1.14,1.13,1.14,1.14,1.14,1.13	300	200	1
116	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.11,1.16,1.16,1.16,1.64,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.09,1.16,1.16,1.16,1.40	300	200	1
201	9	17.76	17.76	8.46	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
204	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.60,1.67,1.67,1.69,1.68,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.64	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.63,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.63,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
208	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.09,2.26,2.08,2.08,2.08,1.48,2.08,2.08,2.06,2.09,2.08,2.08,2.09,2.32,2.08,2.08,2.08,1.75	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.60,1.67,1.67,1.69,1.68,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.64	300	200	1
211	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.09,2.09,2.09,2.08,2.09,2.09,2.09,2.15,2.10,2.09,2.09,2.08,2.09,2.09,2.09,2.08,2.09	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.94,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04	300	200	1
214	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,3.87,1.04,1.04,1.04,1.02,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.59,1.04,1.04,1.04,1.03	300	200	1
215	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.20,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16	300	200	1
216	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.16,1.24,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.16,1.15,1.15,1.16,1.19,1.15,1.15,1.15,1.14	300	200	1
301	9	17.76	17.76	8.46	-	300	200	1
302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.15,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.73,1.67,1.67,1.66,1.61,1.67,1.67,1.69,1.68,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.64	300	200	1
305	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.63,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.10,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.60,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
308	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,1.10,2.08,2.08,2.08,1.49,2.08,2.08,2.07,1.95,2.08,2.08,2.08,1.31,2.08,2.08,2.08,1.79	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.66,1.62,1.67,1.67,1.69,1.68,1.67,1.67,1.65,1.72,1.67,1.67,1.66,1.65	300	200	1
311	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.90,1.90,1.78,1.66,1.89,1.89,1.82,1.69,1.98,1.98,2.30,1.06,1.92,1.92,1.74,1.63,1.88,1.88,1.84,1.70	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.08,1.05,1.05,1.06,1.07,1.05,1.05,1.03,1.15,1.05,1.05,1.06,1.09,1.05,1.05,1.06,1.07	300	200	1
314	19	4.88	4.00	7.5	1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.02,1.05,1.05,1.03,1.05,1.05,1.05,1.0	30	20	1

314	19	4.88	4.00	0	5,3.83,1.05,1.05,1.05,1.02	0	0	1
315	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.14,1.16,1.16,1.15,1.15,1.16,1.16,1.21,1.08,1.16,1.16,1.15,1.14,1.16,1.16,1.15,1.15	300	200	1
316	19	6.63	6.63	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.10,1.17,1.17,1.17,1.77,1.17,1.17,1.17,1.16,1.17,1.17,1.17,1.11,1.17,1.17,1.17,1.28	300	200	1
401	9	17.76	17.76	8.46	-	300	200	1
402	5	1.30	1.30	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.15,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18	300	200	1
404	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.77,1.67,1.67,1.66,1.62,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.73,1.67,1.67,1.66,1.64	300	200	1
405	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.63,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
406	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.19,1.12,1.17,1.17,1.16,1.16,1.17,1.17,1.17,1.17	300	200	1
407	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.61,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
408	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.71,1.67,1.67,1.66,2.81,1.67,1.67,1.71,1.68,1.67,1.67,1.64,1.72,1.67,1.67,1.66,1.58	300	200	1
411	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
412	5	4.20	4.20	2.00	-	300	200	1
413	19	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.16,1.21,1.16,1.16,1.16,1.21,1.17,1.17,1.23,2.28,1.16,1.16,1.16,1.22,1.16,1.16,1.16,1.21	300	200	1
414	19	4.88	4.00	7.50	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.18,2.42,1.17,1.17,1.18,1.63,1.17,1.17,1.15,1.25,1.17,1.17,1.18,2.16,1.17,1.17,1.18,1.44	300	200	1
415	19	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.34,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.09	300	200	1
416	19	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.37,1.09,1.09,1.09,1.21,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.16,1.09,1.09,1.09,1.12	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	257.21	83.29	83.29	113.39	113.39
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	26.47	6.12	40.24	43.62
14	133.20	85.85	26.39	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	377.97	257.21	83.29	83.29	113.39	113.39
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	23.68	6.12	40.24	43.62
114	133.20	85.85	23.26	6.12	40.24	43.62
115	133.20	69.16	17.08	6.12	40.24	43.62
116	133.20	69.16	16.83	6.12	40.24	43.62
201	377.97	257.21	83.29	83.29	113.39	113.39
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
213	133.20	85.85	23.74	6.12	40.24	43.62
214	133.20	85.85	23.39	6.12	40.24	43.62
215	133.20	69.16	17.88	6.12	40.24	43.62
216	133.20	69.16	17.64	6.12	40.24	43.62
301	377.97	257.21	83.29	83.29	113.39	113.39
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	123.95	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	123.95	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	85.85	23.68	6.12	40.24	43.62
314	133.20	85.85	23.28	6.12	40.24	43.62
315	133.20	69.16	16.65	6.12	40.24	43.62
316	133.20	69.16	16.96	6.12	40.24	43.62
401	377.97	257.21	83.29	83.29	113.39	113.39
402	198.33	196.72	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28

407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	102.39	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	102.39	32.87	6.12	40.24	43.62
412	198.33	182.14	21.95	21.95	59.50	59.50
413	133.20	85.85	26.47	6.12	40.24	43.62
414	133.20	85.85	26.38	6.12	40.24	43.62
415	133.20	69.16	16.83	6.12	40.24	43.62
416	133.20	69.16	16.83	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	0.037	0.446	0.055	0.033	0.006	0.453	#32	0.363	Not Required	Pass
2	0.002	0.258	0.133	0.063	0.028	0.391	#13	0.171	Not Required	Pass
3	0.005	0.482	0.017	0.047	0.003	0.493	#13	0.045	Not Required	Pass
4	0.003	0.482	0.063	0.049	0.015	0.542	#13	0.120	Not Required	Pass
5	0.004	0.299	0.036	0.048	0.009	0.308	#13	0.074	Not Required	Pass
6	0.007	0.693	0.078	0.071	0.020	0.749	#13	0.045	Not Required	Pass
7	0.007	0.429	0.114	0.069	0.029	0.452	#13	0.074	Not Required	Pass
8	0.003	0.134	0.104	0.044	0.011	0.169	#13	0.095	Not Required	Pass
9	0.004	0.071	0.068	0.003	0.004	0.139	#13	0.204	Not Required	Pass
10	0.008	0.673	0.107	0.068	0.023	0.684	#13	0.080	Not Required	Pass
11	0.004	0.128	0.107	0.045	0.011	0.157	#13	0.095	Not Required	Pass
12	0.002	0.465	0.193	0.094	0.036	0.659	#13	0.053	Not Required	Pass
13	0.006	0.119	0.267	0.059	0.014	0.326	#21	0.286	Not Required	Pass
14	0.004	0.113	0.264	0.058	0.014	0.303	#21	0.190	Not Required	Pass
15	0.000	0.020	0.026	0.016	0.004	0.042	#21	Not Required	Not Required	Pass
16	0.000	0.020	0.026	0.016	0.004	0.042	#21	Not Required	Not Required	Pass
101	0.050	0.568	0.005	0.045	0.001	0.574	#32	0.363	Not Required	Pass
102	0.002	0.504	0.230	0.107	0.043	0.734	#13	0.035	Not Required	Pass
103	0.007	0.792	0.045	0.080	0.007	0.821	#13	0.045	Not Required	Pass
104	0.007	0.806	0.110	0.081	0.023	0.848	#13	0.080	Not Required	Pass
105	0.007	0.491	0.118	0.079	0.030	0.509	#13	0.074	Not Required	Pass
106	0.007	0.779	0.043	0.078	0.007	0.800	#13	0.045	Not Required	Pass
107	0.007	0.484	0.112	0.078	0.028	0.499	#13	0.074	Not Required	Pass
108	0.003	0.052	0.099	0.050	0.011	0.141	#21	0.095	Not Required	Pass
109	0.009	0.072	0.048	0.001	0.000	0.123	#13	0.204	Not Required	Pass
110	0.007	0.782	0.111	0.079	0.024	0.829	#13	0.080	Not Required	Pass
111	0.004	0.061	0.101	0.049	0.011	0.139	#21	0.095	Not Required	Pass
112	0.002	0.485	0.225	0.104	0.043	0.711	#13	0.035	Not Required	Pass
113	0.006	0.243	0.270	0.067	0.014	0.448	#21	0.286	Not Required	Pass
114	0.007	0.269	0.270	0.069	0.014	0.461	#21	0.286	Not Required	Pass
115	0.008	0.353	0.143	0.053	0.011	0.432	#13	0.473	Not Required	Pass
116	0.005	0.345	0.145	0.055	0.011	0.427	#13	0.473	Not Required	Pass
201	0.048	0.571	0.000	0.043	0.000	0.574	#32	0.363	Not Required	Pass
202	0.002	0.477	0.218	0.102	0.041	0.696	#13	0.035	Not Required	Pass
203	0.007	0.766	0.042	0.077	0.006	0.792	#13	0.045	Not Required	Pass
204	0.007	0.756	0.106	0.076	0.023	0.797	#13	0.080	Not Required	Pass
205	0.007	0.475	0.111	0.076	0.028	0.491	#13	0.074	Not Required	Pass

205	0.007	0.475	0.111	0.076	0.028	0.491	#13	0.074	Not Required	Pass
206	0.007	0.766	0.042	0.077	0.006	0.792	#13	0.045	Not Required	Pass
207	0.007	0.475	0.111	0.076	0.028	0.491	#13	0.074	Not Required	Pass
208	0.003	0.060	0.096	0.048	0.011	0.128	#21	0.095	Not Required	Pass
209	0.009	0.069	0.043	0.001	0.000	0.114	#13	0.204	Not Required	Pass
210	0.007	0.756	0.106	0.076	0.023	0.797	#13	0.080	Not Required	Pass
211	0.004	0.061	0.099	0.049	0.011	0.135	#21	0.095	Not Required	Pass
212	0.002	0.477	0.218	0.102	0.041	0.696	#13	0.035	Not Required	Pass
213	0.006	0.247	0.257	0.063	0.014	0.442	#21	0.286	Not Required	Pass
214	0.007	0.247	0.253	0.063	0.014	0.431	#21	0.286	Not Required	Pass
215	0.007	0.261	0.144	0.049	0.011	0.356	#21	0.473	Not Required	Pass
216	0.005	0.253	0.144	0.048	0.011	0.349	#21	0.473	Not Required	Pass
301	0.050	0.568	0.005	0.045	0.001	0.574	#32	0.363	Not Required	Pass
302	0.002	0.485	0.225	0.104	0.043	0.711	#13	0.035	Not Required	Pass
303	0.007	0.779	0.043	0.078	0.007	0.800	#13	0.045	Not Required	Pass
304	0.007	0.782	0.111	0.079	0.024	0.829	#13	0.080	Not Required	Pass
305	0.007	0.484	0.112	0.078	0.028	0.499	#13	0.074	Not Required	Pass
306	0.007	0.792	0.045	0.080	0.007	0.821	#13	0.045	Not Required	Pass
307	0.007	0.491	0.118	0.079	0.030	0.510	#13	0.074	Not Required	Pass
308	0.003	0.077	0.108	0.055	0.011	0.141	#21	0.095	Not Required	Pass
309	0.009	0.072	0.048	0.001	0.000	0.123	#13	0.204	Not Required	Pass
310	0.007	0.806	0.110	0.081	0.023	0.848	#13	0.080	Not Required	Pass
311	0.004	0.088	0.110	0.053	0.011	0.135	#21	0.095	Not Required	Pass
312	0.002	0.504	0.230	0.107	0.043	0.734	#13	0.035	Not Required	Pass
313	0.006	0.243	0.270	0.067	0.014	0.448	#21	0.286	Not Required	Pass
314	0.007	0.269	0.270	0.069	0.014	0.461	#21	0.286	Not Required	Pass
315	0.007	0.261	0.144	0.049	0.011	0.356	#21	0.473	Not Required	Pass
316	0.005	0.250	0.144	0.050	0.011	0.346	#21	0.473	Not Required	Pass
401	0.037	0.446	0.055	0.033	0.006	0.453	#32	0.363	Not Required	Pass
402	0.002	0.465	0.193	0.094	0.036	0.659	#13	0.053	Not Required	Pass
403	0.007	0.693	0.078	0.071	0.020	0.749	#13	0.045	Not Required	Pass
404	0.008	0.673	0.107	0.068	0.023	0.684	#13	0.080	Not Required	Pass
405	0.007	0.429	0.114	0.069	0.029	0.452	#13	0.074	Not Required	Pass
406	0.005	0.482	0.017	0.047	0.003	0.493	#13	0.045	Not Required	Pass
407	0.004	0.299	0.035	0.048	0.009	0.308	#13	0.074	Not Required	Pass
408	0.000	0.020	0.026	0.016	0.004	0.042	#21	Not Required	Not Required	Pass
409	0.004	0.071	0.068	0.003	0.004	0.139	#13	0.204	Not Required	Pass
410	0.003	0.482	0.063	0.049	0.015	0.542	#13	0.120	Not Required	Pass
411	0.000	0.020	0.026	0.016	0.004	0.042	#21	Not Required	Not Required	Pass
412	0.002	0.258	0.133	0.063	0.028	0.391	#13	0.171	Not Required	Pass
413	0.006	0.119	0.267	0.059	0.014	0.326	#21	0.190	Not Required	Pass
414	0.004	0.113	0.264	0.058	0.014	0.303	#21	0.286	Not Required	Pass
415	0.008	0.370	0.144	0.045	0.011	0.447	#13	0.473	Not Required	Pass
416	0.005	0.369	0.144	0.044	0.011	0.451	#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

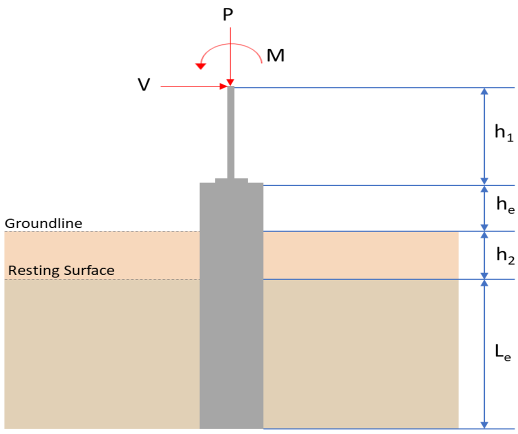
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 8.25 \text{ ft}$ - 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)	6.185	9.608
V_x (kip)	-2.254	-3.780
V_z (kip)	0.418	0.688
M_x (kipft)	0.774	1.248
M_z (kipft)	22.128	37.185

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.254 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.75133 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.128\ \text{kipft}) + ((-2.254\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.376\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.3897\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.418\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.13933\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.774\ \text{kipft}) + ((0.418\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.258\ \text{kipft/ft}$$

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:
$L_{e,z} = 4.5084\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.3897\ \text{ft}), (4.5084\ \text{ft})]$$

$$L_{e,req} = 7.39\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.39\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.89576$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(6.185\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.875\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.875\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.4375$$

Status: **PASS**
Ratio: **0.440**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 2.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.75133\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.376\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.376\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.75133\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (7.376\ \text{kipft/ft})) + (4 \times (-0.75133\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.7469\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (7.376\ \text{kipft/ft})) + (3 \times (-0.75133\ \text{kip/ft}) \times (8.25\ \text{ft}))]^2}{(8.25\ \text{ft})^2 \times [(3 \times (7.376\ \text{kipft/ft})) + (2 \times (-0.75133\ \text{kip/ft}) \times (8.25\ \text{ft}))]}$$

$$p = 0.21165\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (7.376\ \text{kipft/ft})) + ((-0.75133\ \text{kip/ft}) \times (8.25\ \text{ft}))]}{(8.25\ \text{ft})^2}$$

$$s = 1.1845\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.7469\ \text{ft})}{2}$$

$$p_a = 0.43101\ \text{kip/ft}^2$$

	$Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{(0.21165\ \mathrm{kip/ft^2})}{(0.43101\ \mathrm{kip/ft^2})}$$ $$Ratio = 0.49104$$	Status: **PASS** Ratio: **0.490**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$ $$p_s = 1.2375\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{(1.1845\ \mathrm{kip/ft^2})}{(1.2375\ \mathrm{kip/ft^2})}$$ $$Ratio = 0.95713$$	Status: **PASS** Ratio: **0.960**
	Considering z-direction: $H_o = 0.13933\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.258\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\,M_o\,L_e) + (3\,H_o\,L_e^2)}{(6\,M_o) + (4\,H_o\,L_e)}$$ $$a = \frac{(4 \times (0.258\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.258\ \mathrm{kipft/ft})) + (4 \times (0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$ $$a = 6.0143\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$ $$p = \frac{1.178 \times [(4 \times (0.258\ \mathrm{kipft/ft})) + (3 \times (0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^2}{(8.25\ \mathrm{ft})^2 \times [(3 \times (0.258\ \mathrm{kipft/ft})) + (2 \times (0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$ $$p = 0.11306\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$ $$s = \frac{9.425 \times [(2 \times (0.258\ \mathrm{kipft/ft})) + ((0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$ $$s = 0.23063\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\,\frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.0143\ \mathrm{ft})}{2}$$ $$p_a = 0.45108\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{(0.11306\ \mathrm{kip/ft^2})}{(0.45108\ \mathrm{kip/ft^2})}$$	

$$Ratio = 0.25066$$

Status: **PASS**
Ratio: **0.250**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

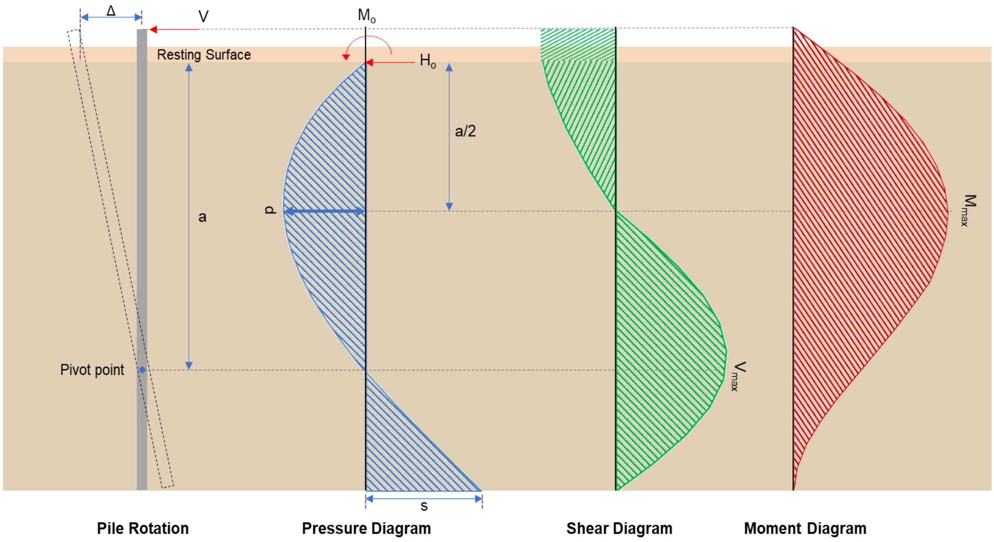
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23063\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.18637$$

Status: **PASS**
Ratio: **0.190**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.78\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.26\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.185\ \mathrm{kipft}) + ((-3.78\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 12.395\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.395\ \mathrm{kipft/ft})}{(-1.26\ \mathrm{kip/ft})}$$

$$E = 9.8373\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.395 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (-1.26 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (12.395 \text{ kipft/ft})) + (4 \times (-1.26 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.7465 \text{ ft}$$

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

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

$$V_{max} = ((-1.26 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.8373 \text{ ft})}{(8.25 \text{ ft})} + 3\right) \times \left(\frac{(5.7465 \text{ ft})}{(8.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.8373 \text{ ft})}{(8.25 \text{ ft})} + 2\right) \times \left(\frac{(5.7465 \text{ ft})}{(8.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 10.469 \text{ kip}$$

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

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

$$M_{max} = ((-1.26 \text{ kip/ft}) \times (36 \text{ in}) \times (8.25 \text{ ft})) \times \left[\left(\frac{(9.8373 \text{ ft})}{(8.25 \text{ ft})} + \frac{(5.7465 \text{ ft})}{2 \times (8.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (9.8373 \text{ ft})}{(8.25 \text{ ft})} + 3\right) \times \left(\frac{(5.7465 \text{ ft})}{2 \times (8.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.8373 \text{ ft})}{(8.25 \text{ ft})} + 2\right) \times \left(\frac{(5.7465 \text{ ft})}{2 \times (8.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 40.369 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.688 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.22933 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.248 \text{ kipft}) + ((0.688 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.416 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.416 \text{ kipft/ft})}{(0.22933 \text{ kip/ft})}$$

$$E = 1.814 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.416 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (0.22933 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (0.416 \text{ kipft/ft})) + (4 \times (0.22933 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 6.017 \text{ ft}$$

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

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

$$V_{max} = ((0.22933\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.814\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(6.017\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.814\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(6.017\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.73176\ \text{kip}$$

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

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

$$M_{max} = ((0.22933\ \text{kip/ft}) \times (36\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(1.814\ \text{ft})}{(8.25\ \text{ft})} + \frac{(6.017\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (1.814\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(6.017\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.814\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(6.017\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.517\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,
$f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.608\ \text{kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5\ \text{ksi}) \times (1017.9\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (1017.9\ \text{in}^2))\right]$$

$$A_{st,required} = -37.073\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-37.073\ \text{in}^2), (0.0018 \times (1017.9\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

	$$Ratio = \frac{}{(1.8408\ \text{in}^2)}$$ $$Ratio = 0.99533$$	Status: **PASS** Ratio: **1.000**
25.2.3	s_{rebar} - Minimum spacing of reinforcement, $$s_{rebar} = Max[1.5, (1.5\ d_{bar})]$$ $$s_{rebar} = Max[1.5, (1.5 \times (0.625\ \text{in}))]$$ $$s_{rebar} = 1.5\ \text{in}$$	
	Ties:	
25.7.2.2 *25.7.2.1*	Since longitudinal reinforcement is $\leq$ No. 10ø: Use #3(0.375 in) s_{ties} - Maximum center-to-center spacing of ties, $$s_{ties} = Min[(16\ d_{bar}), (48\ d_{ties}), D]$$ $$s_{ties} = Min[(16 \times (0.625\ \text{in})), (48 \times (0.375\ \text{in})), (36\ \text{in})]$$ $$s_{ties} = 10\ \text{in}$$	
	Summary: Main reinforcement: **6 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	
	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.85\ \left[\left(0.85\ f'_{ck}\ [A_g - A_{st}]\right) + (f_{yk}\ A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 1253.9\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(9.608\ \text{kip})}{(1253.9\ \text{kip})}$$ $$Ratio = 0.0076624$$	Status: **PASS** Ratio: **0.010**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 36\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (36\ \text{in})$$ $$d = 28.8\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.71796$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$	

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 9.608 \text{ kip} \rightarrow 9608 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(9608 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.069 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.069 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.069 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.069 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.256 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.469 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(10.469\ \text{kip})}{(74.256\ \text{kip})}$$ $$Ratio = 0.14099$$ **Considering z-direction:** $V_{max} = 0.73176\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.73176\ \text{kip})}{(74.256\ \text{kip})}$$ $$Ratio = 0.0098546$$	Status: **PASS** Ratio: **0.140** Status: **PASS** Ratio: **0.010**	
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$ $$S_m = 4580.4\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$ $$\phi M_n = 62.027\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 40.369\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(40.369\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.65084$$	Status: **PASS** Ratio: **0.650**	
	Considering z-direction: $M_{max} = 2.517\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{}$$		

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(2.517\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.040579$$	Status: **PASS** Ratio: **0.040**

REFERENCES	CALCULATIONS	RESULTS

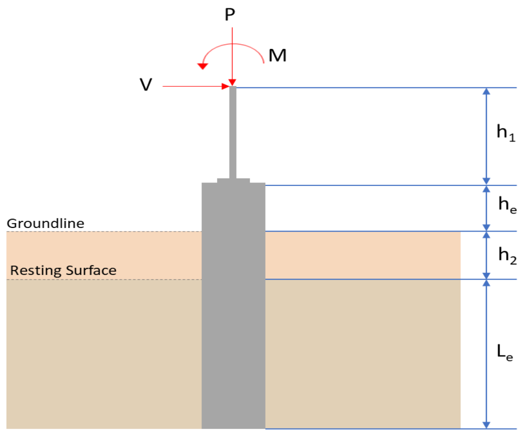
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 8.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.185	9.608
V_x (kip)	-2.254	-3.780
V_z (kip)	-0.418	-0.688
M_x (kipft)	-0.774	-1.248
M_z (kipft)	22.128	37.186

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.254\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.75133\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.128\ \text{kipft}) + ((-2.254\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.376\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.3897\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.418\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.13933\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.774\ \text{kipft}) + ((-0.418\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.258\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.9252\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.3897\ \text{ft}), (1.9252\ \text{ft})]$$

$$L_{e,req} = 7.39\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 8.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.39\ \text{ft})}{(8.25\ \text{ft})}$$

$$Ratio = 0.89576$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(6.185 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.875 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.875 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.4375$$

Status: **PASS**
Ratio: **0.440**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.75133 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.376 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.376 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (-0.75133 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (7.376 \text{ kipft/ft})) + (4 \times (-0.75133 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.7469 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (7.376 \text{ kipft/ft})) + (3 \times (-0.75133 \text{ kip/ft}) \times (8.25 \text{ ft}))]^{2}}{(8.25 \text{ ft})^2 \times [(3 \times (7.376 \text{ kipft/ft})) + (2 \times (-0.75133 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = 0.21165 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (7.376 \text{ kipft/ft})) + ((-0.75133 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = 1.1845 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.7469 \text{ ft})}{2}$$

$$p_a = 0.43101 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21165\ \mathrm{kip/ft^2}\right)}{\left(0.43101\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.49104$$

Status: **PASS**
Ratio: **0.490**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1845\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95713$$

Status: **PASS**
Ratio: **0.960**

Considering z-direction:

$H_o = -0.13933\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.258\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.258\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.258\ \mathrm{kipft/ft})) + (4 \times (-0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 6.0143\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.258\ \mathrm{kipft/ft})) + (3 \times (-0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\,2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (0.258\ \mathrm{kipft/ft})) + (2 \times (-0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = -0.066274\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.258\ \mathrm{kipft/ft})) + ((-0.13933\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = -0.087724\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.0143\ \mathrm{ft})}{2}$$

$$p_a = 0.45108\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.066274\ \mathrm{kip/ft^2}\right)}{\left(0.45108\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.14692$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

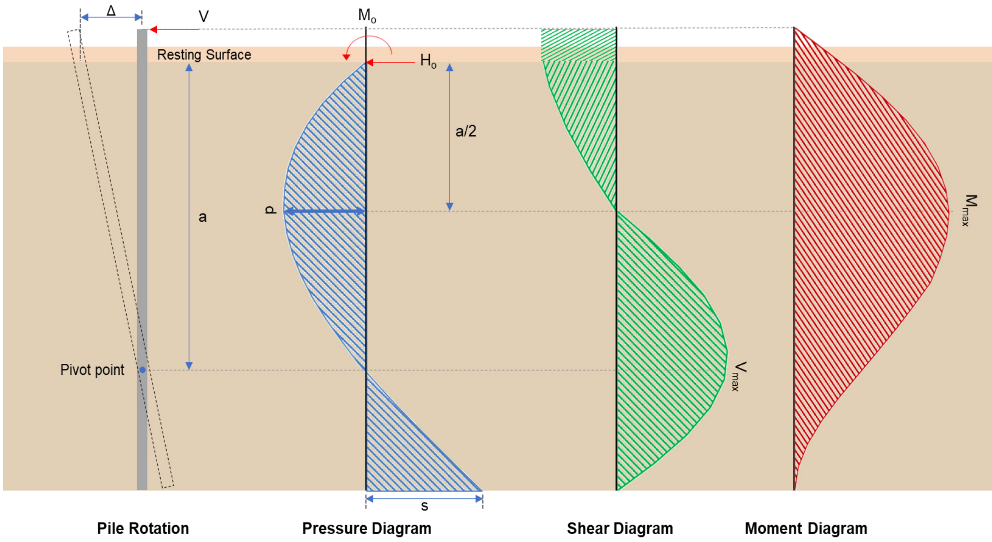
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.087724\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.070888$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.78\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.26\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.186\ \mathrm{kipft}) + ((-3.78\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 12.395\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.395\ \mathrm{kipft/ft})}{(-1.26\ \mathrm{kip/ft})}$$

$$E = 9.8376\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.395\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-1.26\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (12.395\ \text{kipft/ft})) + (4 \times (-1.26\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.7465\ \text{ft}$$

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

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

$$V_{max} = ((-1.26\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.8376\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.7465\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.8376\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.7465\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.47\ \text{kip}$$

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

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

$$M_{max} = ((-1.26\ \text{kip/ft}) \times (36\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(9.8376\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.7465\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (9.8376\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.7465\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.8376\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.7465\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 40.37\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.688\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.22933\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.248\ \text{kipft}) + ((-0.688\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.416\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.416\ \text{kipft/ft})}{(-0.22933\ \text{kip/ft})}$$

$$E = 1.814\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.416\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.22933\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.416\ \text{kipft/ft})) + (4 \times (-0.22933\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 6.017\ \text{ft}$$

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

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

$$V_{max} = ((-0.22933\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.814\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.017\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.814\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.017\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.73176\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.22933\ \mathrm{kip/ft}) \times (36\ \mathrm{in}) \times (8.25\ \mathrm{ft})) \times \left[\left(\frac{(1.814\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + \frac{(6.017\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (1.814\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.017\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.814\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.017\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.517\ \mathrm{kipft}$$

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 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9\ \mathrm{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.608\ \mathrm{kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (1017.9\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (1017.9\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -37.073\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-37.073\ \mathrm{in}^2), (0.0018 \times (1017.9\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

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

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

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(9.608\ \text{kip}\right)}{\left(1253.9\ \text{kip}\right)}$$

$$Ratio = 0.0076624$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 9.608 \text{ kip} \rightarrow 9608 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(9608 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.069 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.069 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.069 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.069 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.256 \text{ kip}$$

Considering x-direction:

$V_{max} = 10.47 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(10.47\ \mathrm{kip})}{(74.256\ \mathrm{kip})}$$ $$Ratio = 0.14099$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $V_{max} = 0.73176\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.73176\ \mathrm{kip})}{(74.256\ \mathrm{kip})}$$ $$Ratio = 0.0098546$$	Status: **PASS** Ratio: **0.010**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36\ \mathrm{in})^3}{32}$$ $$S_m = 4580.4\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442 in^3$$ $$\phi M_{n,1} = 62.027 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$$ $$\phi M_n = 62.027\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 40.37\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(40.37\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$$ $$Ratio = 0.65085$$	Status: **PASS** Ratio: **0.650**
	Considering z-direction: $M_{max} = 2.517\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{}$$	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(2.517 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.040579$$	Status: **PASS** Ratio: **0.040**

REFERENCES	CALCULATIONS	RESULTS

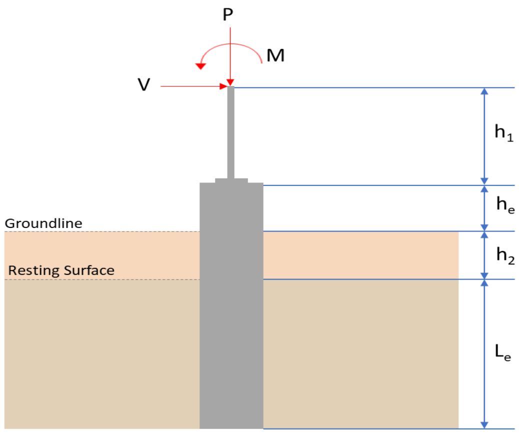
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.202	12.837
V_x (kip)	-3.065	-5.115
V_z (kip)	-0.042	-0.066
M_x (kipft)	-0.096	-0.152
M_z (kipft)	28.237	47.284

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.065\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -1.0217\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.237\ \text{kipft}) + ((-3.065\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 9.4123\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.6439\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.042\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.014\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.096\ \text{kipft}) + ((-0.042\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.032\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.3168\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.6439\ \text{ft}), (1.3168\ \text{ft})]$$

$$L_{e,req} = 7.644\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.644\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.8736$$

Status: **PASS**
Ratio: **0.870**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

	q - End-bearing pressure $$q = \frac{P_v}{A}$$ $$q = \frac{(8.202\ \text{kip})}{(7.0686\ \text{ft}^2)}$$ $$q = 1.1603\ \text{kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{(1.1603\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$ $$Ratio = 0.58017$$	Status: **PASS** Ratio: **0.580**
Czerniak	**Lateral Soil Pressure (ASD):** L/D - Length to least lateral dimension ratio, $$L/D = \frac{L}{D}$$ $$L/D = \frac{(8.75\ \text{ft})}{(36\ \text{in})}$$ $$L/D = 2.9167$$ Since L/D $\leq$ 10, Pile is short. **Considering x-direction:** $H_o = -1.0217\ \text{kip/ft}$ - Lateral force per length of pile, $M_o = 9.4123\ \text{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (9.4123\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (9.4123\ \text{kipft/ft})) + (4 \times (-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$ $$a = 6.116\ \text{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{1.178\ [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\ [(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{1.178 \times [(4 \times (9.4123\ \text{kipft/ft})) + (3 \times (-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft}))]^2}{(8.75\ \text{ft})^2 \times [(3 \times (9.4123\ \text{kipft/ft})) + (2 \times (-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft}))]}$$ $$p = 0.17425\ \text{kip/ft}^2$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{9.425\ [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{9.425 \times [(2 \times (9.4123\ \text{kipft/ft})) + ((-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft}))]}{(8.75\ \text{ft})^2}$$ $$s = 1.2169\ \text{kip/ft}^2$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\, \frac{a}{2}$$ $$p_a = (150\ \text{psf/ft}) \times \frac{(6.116\ \text{ft})}{2}$$ $$p_a = 0.4587\ \text{kip/ft}^2$$	

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.17425 \text{ kip/ft}^2\right)}{\left(0.4587 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.37987$$

Status: **PASS**
Ratio: **0.380**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2169 \text{ kip/ft}^2\right)}{\left(1.3125 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.92714$$

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

Considering z-direction:

$H_o = -0.014 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.032 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.032 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (-0.014 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (0.032 \text{ kipft/ft})) + (4 \times (-0.014 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.3572 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.032 \text{ kipft/ft})) + (3 \times (-0.014 \text{ kip/ft}) \times (8.75 \text{ ft}))]^2}{(8.75 \text{ ft})^2 \times [(3 \times (0.032 \text{ kipft/ft})) + (2 \times (-0.014 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = -0.0059232 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.032 \text{ kipft/ft})) + ((-0.014 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = -0.0072015 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.3572 \text{ ft})}{2}$$

$$p_a = 0.47679 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0059232 \text{ kip/ft}^2\right)}{\left(0.47679 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.012423$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

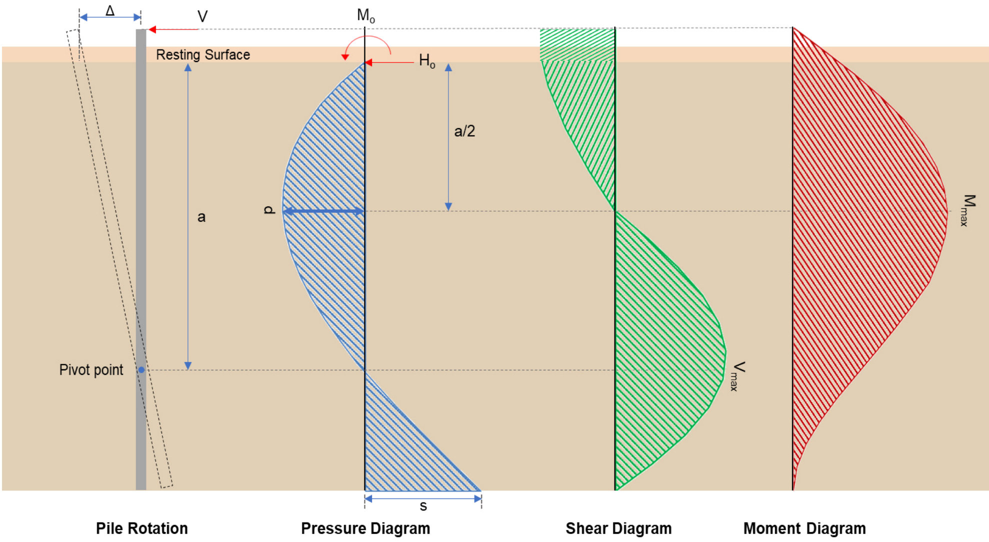
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0072015\text{ kip/ft}^2\right)}{\left(1.3125\text{ kip/ft}^2\right)}$$

$$Ratio = -0.0054868$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.115\text{ kip})}{(36\text{ in})}$$

$$H_o = -1.705\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(47.284\text{ kipft}) + ((-5.115\text{ kip}) \times (0\text{ ft}))}{(36\text{ in})}$$

$$M_o = 15.761\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.761\text{ kipft/ft})}{(-1.705\text{ kip/ft})}$$

$$E = 9.2442\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.761\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-1.705\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (15.761\ \text{kipft/ft})) + (4 \times (-1.705\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.1154\ \text{ft}$$

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

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

$$V_{max} = ((-1.705\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.2442\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.1154\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.2442\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.1154\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.939\ \text{kip}$$

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

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

$$M_{max} = ((-1.705\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(9.2442\ \text{ft})}{(8.75\ \text{ft})} + \frac{(6.1154\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (9.2442\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.1154\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.2442\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.1154\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 52.573\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.066\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.022\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.152\ \text{kipft}) + ((-0.066\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.050667\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.050667\ \text{kipft/ft})}{(-0.022\ \text{kip/ft})}$$

$$E = 2.303\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.050667\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-0.022\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (0.050667\ \text{kipft/ft})) + (4 \times (-0.022\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.3561\ \text{ft}$$

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

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

$$\left[\left(L_e \right) \left(L_e \right) \right] \right]$$

$$V_{max} = ((-0.022 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.303 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.3561 \text{ ft})}{(8.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.303 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.3561 \text{ ft})}{(8.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.075145 \text{ kip}$$

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

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

$$M_{max} = ((-0.022 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(2.303 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.3561 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.303 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.3561 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.303 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.3561 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.27765 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.837 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -36.972 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-36.972 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

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

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

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(12.837\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.010238$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 12.837\ \text{kip} \rightarrow 12837\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(12837\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.617\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (76.617\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.617\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.617\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.612\ \text{kip}$$

Considering x-direction:

$V_{max} = 12.939\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(12.939 \text{ kip})}{(74.612 \text{ kip})}$$ $$Ratio = 0.17342$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $V_{max} = 0.075145 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.075145 \text{ kip})}{(74.612 \text{ kip})}$$ $$Ratio = 0.0010072$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi D^3}{32}$$ $$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$ $$S_m = 4580.4 \text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi \, 0.85 \, f'_{ck} \, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$$ $$\phi M_{n,2} = 527.23 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$$ $$\phi M_n = 62.027 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 52.573 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(52.573 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.84759$$	Status: **PASS** Ratio: **0.850**
	Considering z-direction: $M_{max} = 0.27765 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{}$$	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(0.27765 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0044762$$		Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

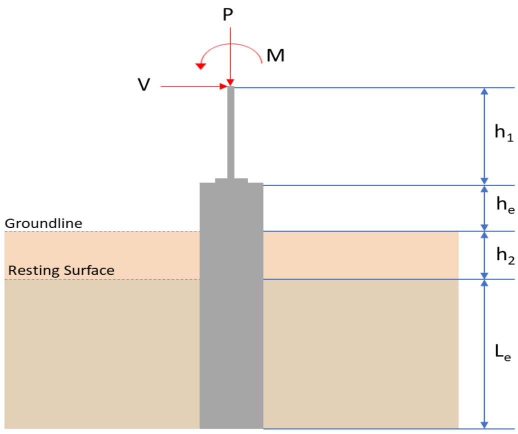
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.931	12.396
V_x (kip)	-2.946	-4.915
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	28.292	47.548

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.946\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.982\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.292\ \text{kipft}) + ((-2.946\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 9.4307\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.7581\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

$L_{e,z} = 0\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7581\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 7.758\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.758\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.88663$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(7.931\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.122\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.122\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.561$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.982\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.4307\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.4307\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-0.982\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (9.4307\ \text{kipft/ft})) + (4 \times (-0.982\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.1089\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (9.4307\ \text{kipft/ft})) + (3 \times (-0.982\ \text{kip/ft}) \times (8.75\ \text{ft}))]^2}{(8.75\ \text{ft})^2 \times [(3 \times (9.4307\ \text{kipft/ft})) + (2 \times (-0.982\ \text{kip/ft}) \times (8.75\ \text{ft}))]}$$

$$p = 0.19766\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (9.4307\ \text{kipft/ft})) + ((-0.982\ \text{kip/ft}) \times (8.75\ \text{ft}))]}{(8.75\ \text{ft})^2}$$

$$s = 1.2641\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.1089\ \text{ft})}{2}$$

$$p_a = 0.45817\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.19766\ \text{kip/ft}^2)}{(0.45817\ \text{kip/ft}^2)}$$

$$Ratio = 0.43141$$

Status: **PASS**
Ratio: **0.430**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\ L_e$$

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

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

$Ratio$ - Lateral soil capacity

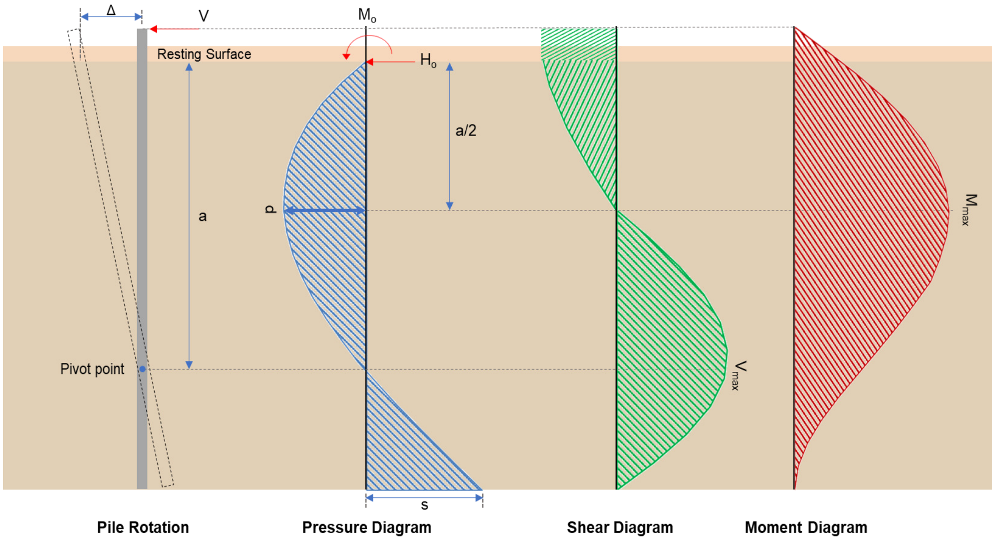
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(1.2641\ \text{kip/ft}^2)}{}$$

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

$$Ratio = 0.96313$$

Status: **PASS**
Ratio: **0.960**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.915\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.6383\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(47.548\ \mathrm{kipft}) + ((-4.915\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 15.849\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.849\ \mathrm{kipft/ft})}{(-1.6383\ \mathrm{kip/ft})}$$

$$E = 9.6741\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.849\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-1.6383\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (15.849\ \mathrm{kipft/ft})) + (4 \times (-1.6383\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.1076\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.6383\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.6741\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1076\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.6741\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1076\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.859\ \text{kip}$$

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

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

$$M_{max} = ((-1.6383\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(9.6741\ \text{ft})}{(8.75\ \text{ft})} + \frac{(6.1076\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (9.6741\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.1076\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.6741\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.1076\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 52.38\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,
$f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.396\ \text{kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5\ \text{ksi}) \times (1017.9\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (1017.9\ \text{in}^2))\right]$$

$$A_{st,required} = -36.986\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.986\ \text{in}^2), (0.0018 \times (1017.9\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.8322\ \text{in}^2)}{(1.8408\ \text{in}^2)}$$

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

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

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

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(12.396\text{ kip})}{(1253.9\text{ kip})}$$

$$Ratio = 0.0098859$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 12.396\text{ kip} \rightarrow 12396\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(12396\ \text{lbf})}{6 \times (1017.9\ \text{in}^2)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 76.542\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (76.542\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 76.542\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.542\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 74.563\ \text{kip}$$

Considering x-direction:

$V_{max} = 12.859\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.859\ \text{kip})}{(74.563\ \text{kip})}$$

$$Ratio = 0.17246$$

Status: **PASS**

		Ratio: **0.170**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi D^3}{32}$$ $$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$ $$S_m = 4580.4\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$ $$\phi M_n = 62.027\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 52.38\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(52.38\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.84447$$	Status: **PASS** Ratio: **0.840**

REFERENCES	CALCULATIONS	RESULTS

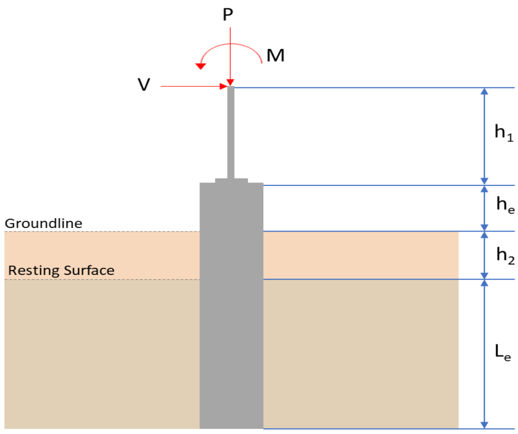
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

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

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.202	12.837
V_x (kip)	-3.065	-5.115
V_z (kip)	0.042	0.066
M_x (kipft)	0.096	0.152
M_z (kipft)	28.237	47.284

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.065\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.0217\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.237\ \text{kipft}) + ((-3.065\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 9.4123\ \text{kipft/ft}$$

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:
$L_{e,x} = 7.6439\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.042\ \text{kip})}{(36\ \text{in})}$$

$$H_o = 0.014\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.096\ \text{kipft}) + ((0.042\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.032\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.8645\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.6439\ \text{ft}), (1.8645\ \text{ft})]$$

$$L_{e,req} = 7.644\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.644\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.8736$$

Status: **PASS**
Ratio: **0.870**

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(8.202\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.1603\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.1603\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.58017$$

Status: **PASS**
Ratio: **0.580**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.0217\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.4123\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.4123\ \text{kipft/ft}) \times (8.75\ \text{ft})) + \left(3 \times (-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft})^2\right)}{(6 \times (9.4123\ \text{kipft/ft})) + (4 \times (-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft}))}$$

$$a = 6.116\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (9.4123\ \text{kipft/ft})) + (3 \times (-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft}))]^{\ 2}}{(8.75\ \text{ft})^2 \times [(3 \times (9.4123\ \text{kipft/ft})) + (2 \times (-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft}))]}$$

$$p = 0.17425\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (9.4123\ \text{kipft/ft})) + ((-1.0217\ \text{kip/ft}) \times (8.75\ \text{ft}))]}{(8.75\ \text{ft})^2}$$

$$s = 1.2169\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.116\ \text{ft})}{2}$$

$$p_a = 0.4587\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.17425\ \mathrm{kip/ft^2})}{(0.4587\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.37987$$

Status: **PASS**
Ratio: **0.380**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(1.2169\ \mathrm{kip/ft^2})}{(1.3125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.92714$$

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

Considering z-direction:

$H_o = 0.014\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.032\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.032\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (0.014\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.032\ \mathrm{kipft/ft})) + (4 \times (0.014\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.3572\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.032\ \mathrm{kipft/ft})) + (3 \times (0.014\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^2}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.032\ \mathrm{kipft/ft})) + (2 \times (0.014\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.011078\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.032\ \mathrm{kipft/ft})) + ((0.014\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 0.022959\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.3572\ \mathrm{ft})}{2}$$

$$p_a = 0.47679\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.011078\ \mathrm{kip/ft^2})}{(0.47679\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.023235$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

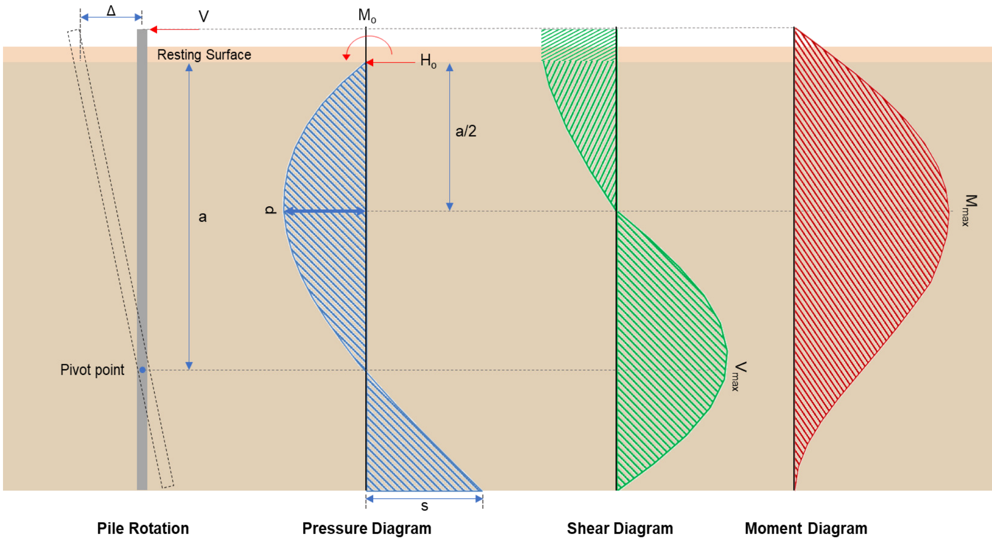
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.022959\ \mathrm{kip/ft^2})}{(1.3125\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.017492$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.115\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.705\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(47.284\ \mathrm{kipft}) + ((-5.115\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 15.761\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.761\ \mathrm{kipft/ft})}{(-1.705\ \mathrm{kip/ft})}$$

$$E = 9.2442\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.761 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (-1.705 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (15.761 \text{ kipft/ft})) + (4 \times (-1.705 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.1154 \text{ ft}$$

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

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

$$V_{max} = ((-1.705 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.2442 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.1154 \text{ ft})}{(8.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.2442 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.1154 \text{ ft})}{(8.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 12.939 \text{ kip}$$

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

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

$$M_{max} = ((-1.705 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(9.2442 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.1154 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (9.2442 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.1154 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.2442 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.1154 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 52.573 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.066 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.022 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.152 \text{ kipft}) + ((0.066 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.050667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.050667 \text{ kipft/ft})}{(0.022 \text{ kip/ft})}$$

$$E = 2.303 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.050667 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (0.022 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (0.050667 \text{ kipft/ft})) + (4 \times (0.022 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.3561 \text{ ft}$$

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

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

$$V_{max} = ((0.022\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.303\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.3561\ \text{ft})}{(8.75\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.303\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.3561\ \text{ft})}{(8.75\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.075145\ \text{kip}$$

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

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

$$M_{max} = ((0.022\ \text{kip/ft}) \times (36\ \text{in}) \times (8.75\ \text{ft})) \times \left[\left(\frac{(2.303\ \text{ft})}{(8.75\ \text{ft})} + \frac{(6.3561\ \text{ft})}{2 \times (8.75\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.303\ \text{ft})}{(8.75\ \text{ft})} + 3\right) \times \left(\frac{(6.3561\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.303\ \text{ft})}{(8.75\ \text{ft})} + 2\right) \times \left(\frac{(6.3561\ \text{ft})}{2 \times (8.75\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.27765\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,
$f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.837\ \text{kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5\ \text{ksi}) \times (1017.9\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (1017.9\ \text{in}^2))\right]$$

$$A_{st,required} = -36.972\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-36.972\ \text{in}^2), (0.0018 \times (1017.9\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

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

$$Ratio = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

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

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

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(12.837 \text{ kip})}{(1253.9 \text{ kip})}$$

$$Ratio = 0.010238$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 12.837 \text{ kip} \rightarrow 12837 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(12837 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)}\right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.617 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09 \text{ kip}), (76.617 \text{ kip}), (204.04 \text{ kip})\right]$$

$$V_c = 76.617 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((76.617 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 74.612 \text{ kip}$$

Considering x-direction:

$V_{max} = 12.939 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(12.939\ \text{kip})}{(74.612\ \text{kip})}$$ $$Ratio = 0.17342$$	Status: **PASS** Ratio: **0.170**
	Considering z-direction: $V_{max} = 0.075145\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.075145\ \text{kip})}{(74.612\ \text{kip})}$$ $$Ratio = 0.0010072$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{\pi\, D^3}{32}$$ $$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$ $$S_m = 4580.4\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 62.027kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 527.23\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$ $$\phi M_n = 62.027\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 52.573\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(52.573\ \text{kipft})}{(62.027\ \text{kipft})}$$ $$Ratio = 0.84759$$	Status: **PASS** Ratio: **0.850**
	Considering z-direction: $M_{max} = 0.27765\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{}$$	

	$$Ratio = \frac{}{\phi M_n}$$ $$Ratio = \frac{(0.27765 \text{ kipft})}{(62.027 \text{ kipft})}$$ $$Ratio = 0.0044762$$	Status: **PASS** Ratio: **0.000**