Your Project Calculations

Project Name: Beaverdam Carport

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

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=TDcXjAJGSaamXoR7ejPhyqx1j0cSiWWEH3n6xZVkuRRoLDpAzWEUdTEgwzXSsgTL

Array Specification

Product:	Beam
Unique ID:	5P-19.75-6TOP-SD-45-L-4Hx13W-7A13
Duty Classification:	SD
Module Width:	41.10 in
Module Length:	87.20in
Number of Rows:	4
Number of Columns:	13
Total Number of Modules:	52
Desired Tilt Angle:	5
Front Edge Clearance:	8
Total Array Height at Tilt:	9.20 ft
Total Frame Length:	94.00 ft
Frame Weight:	3272 lbs
Array Dimensions N/S:	13.87 ft
Array Dimensions E/W:	95.55 ft
Rail Length:	166.40 in
Rail Spacing:	3.63 ft
Rail Check:	Not Checked

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	8.60 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 4.50 ft Pile 2: 4.50 ft Pile 3: 4.50 ft Pile 4: 4.50 ft Pile 5: 4.50 ft
Foundation Volume:	13.333 y^3
Foundation Result:	PASSED
Mount Twist:	0.037662 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	54 Clubside Dr, Asheville, NC 28804, USA
Wind Speed:	99 mph
Snow Load:	15 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.009072 ksf

Design Disclaimer

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

AutoDesigner Input


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{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"product_type":"Beam","project_id":"Beaverdam Carport","site_address":"54 Clubside Dr, Asheville, NC 28804, USA","module_width":41.1,"module_length":87.2,"number_rows":"4","number_columns":13,"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":5,"ground_clearance":8,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}
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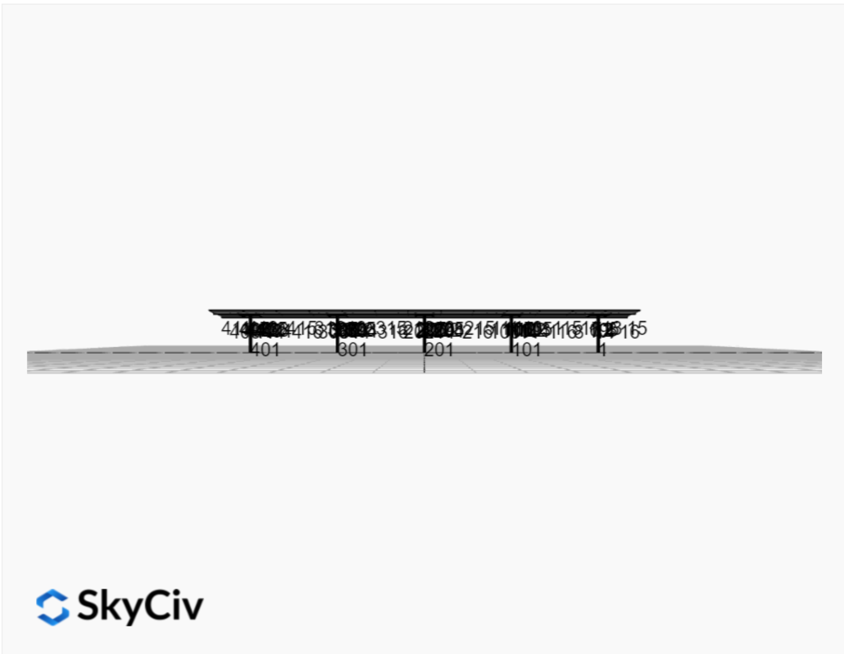
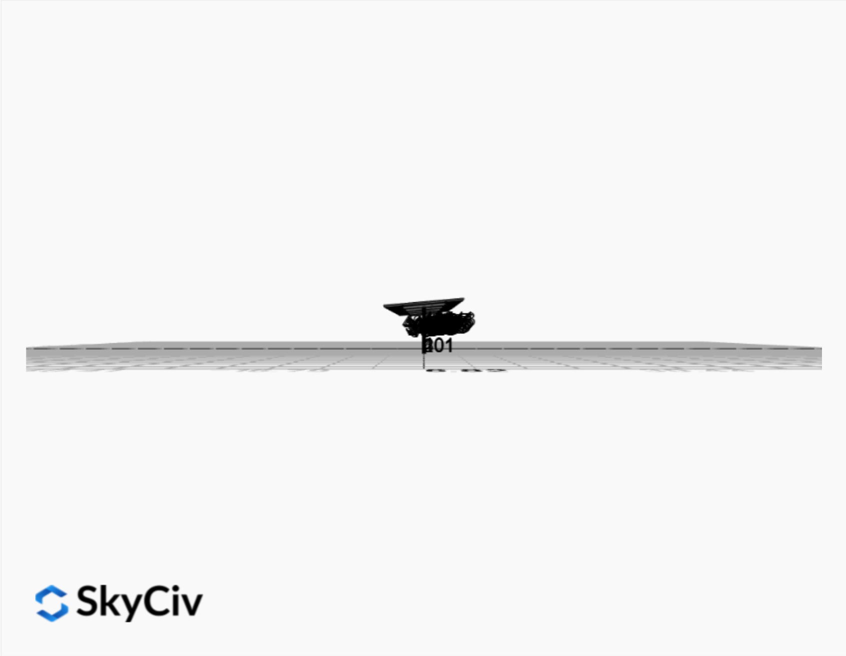
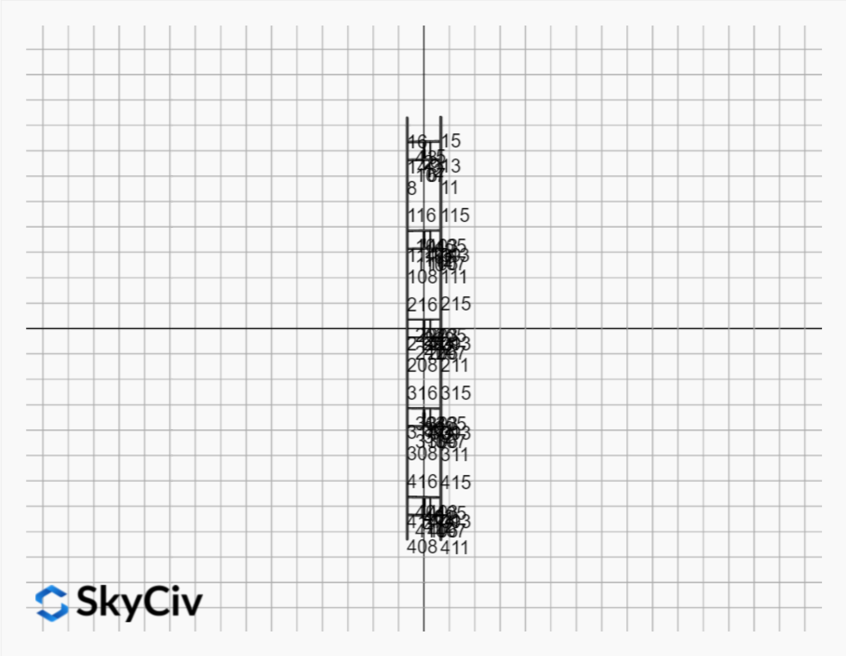
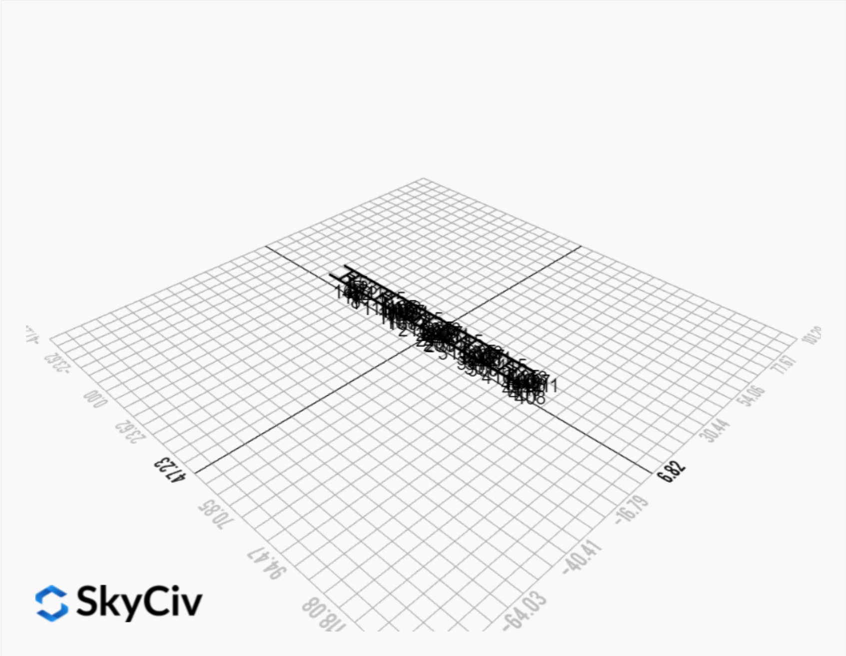
Design Notes:

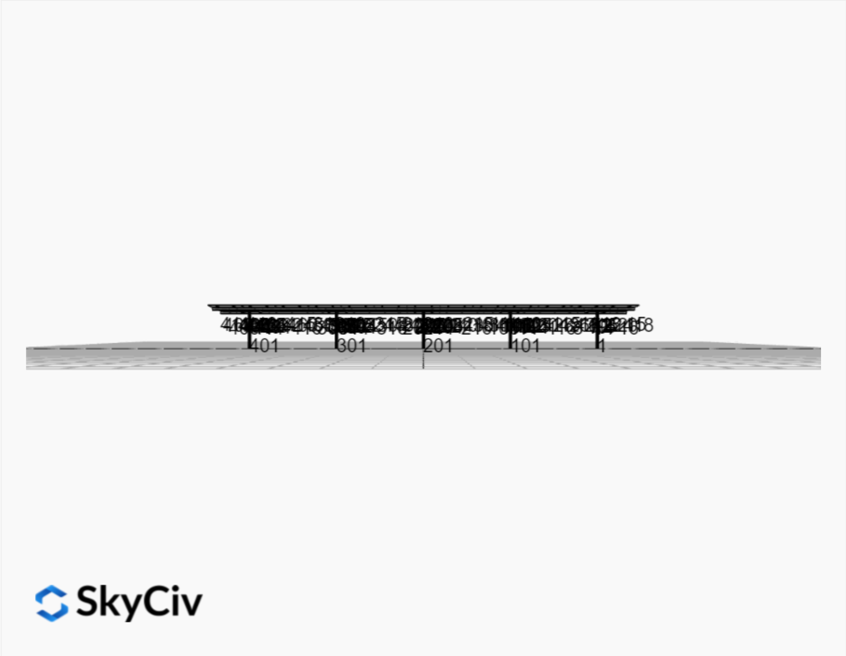
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only



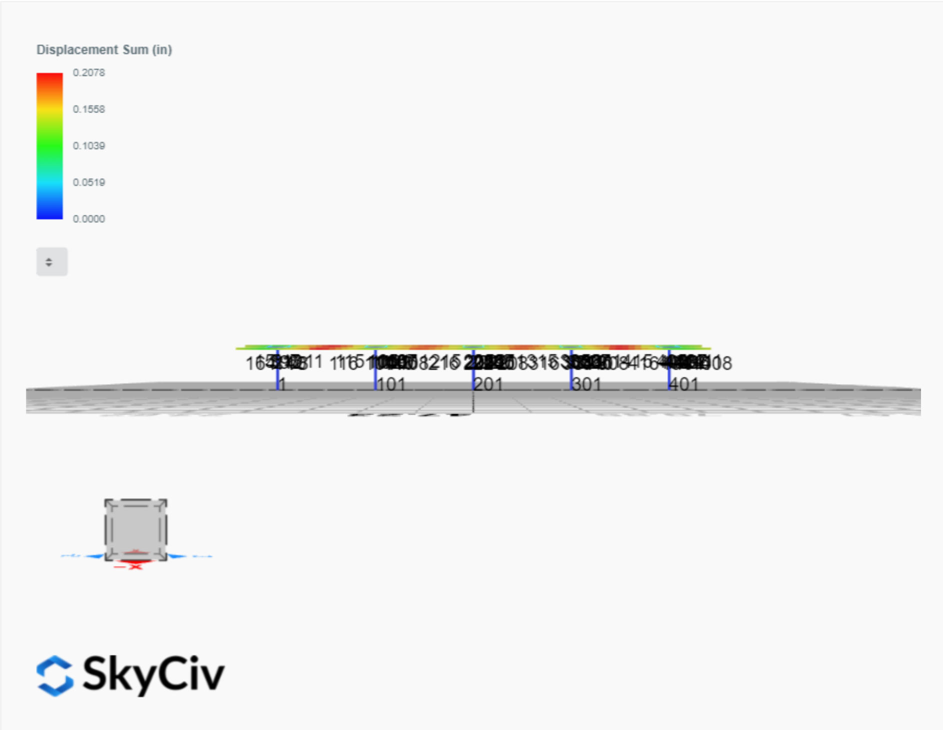


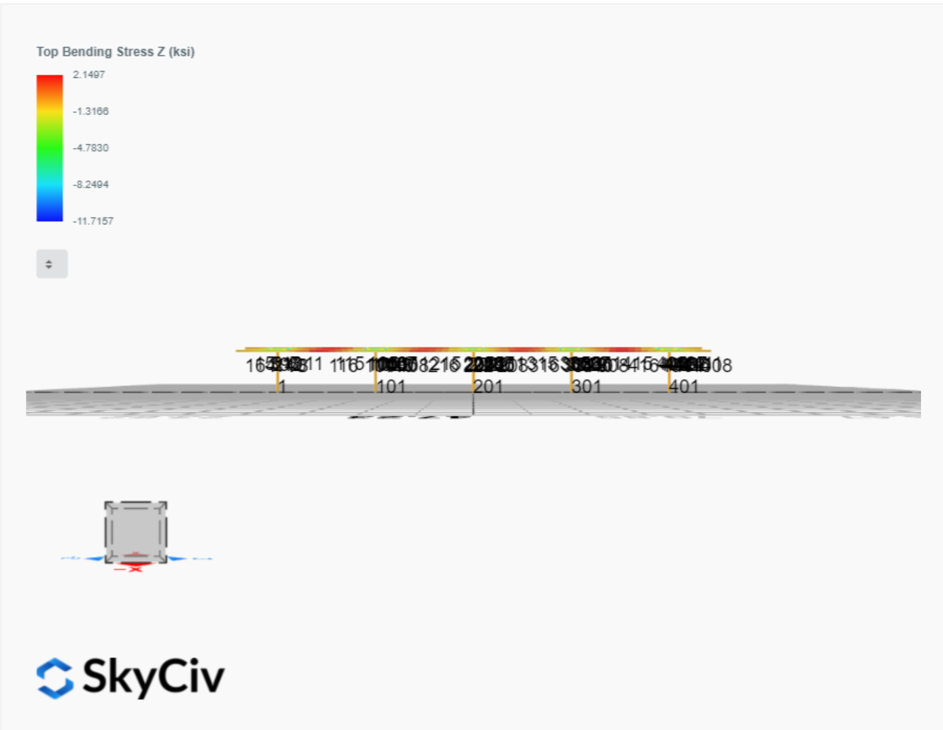


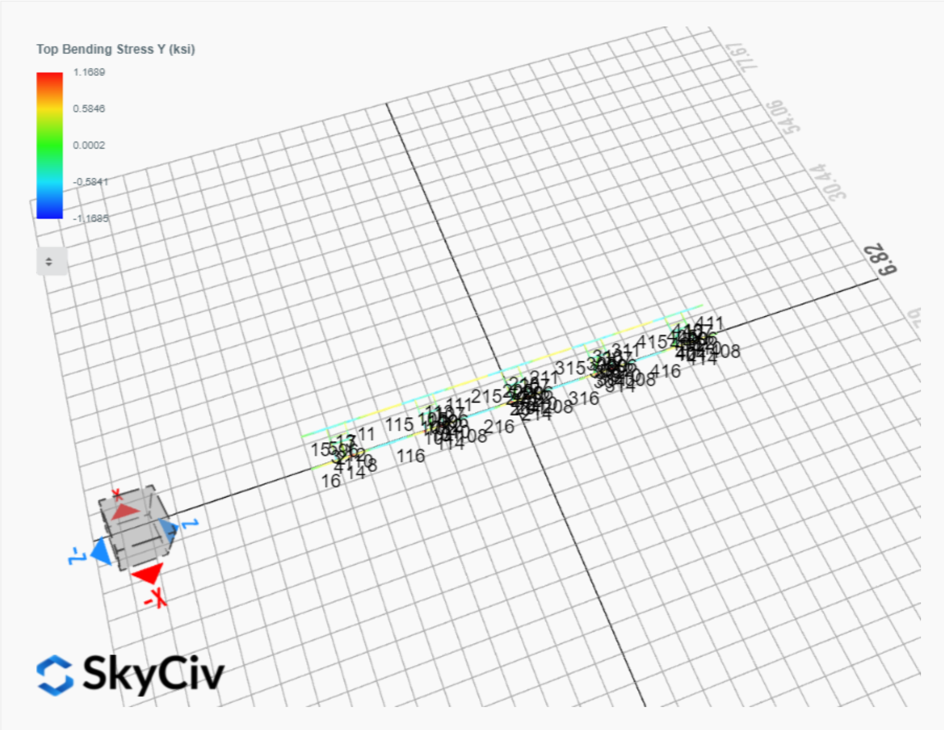


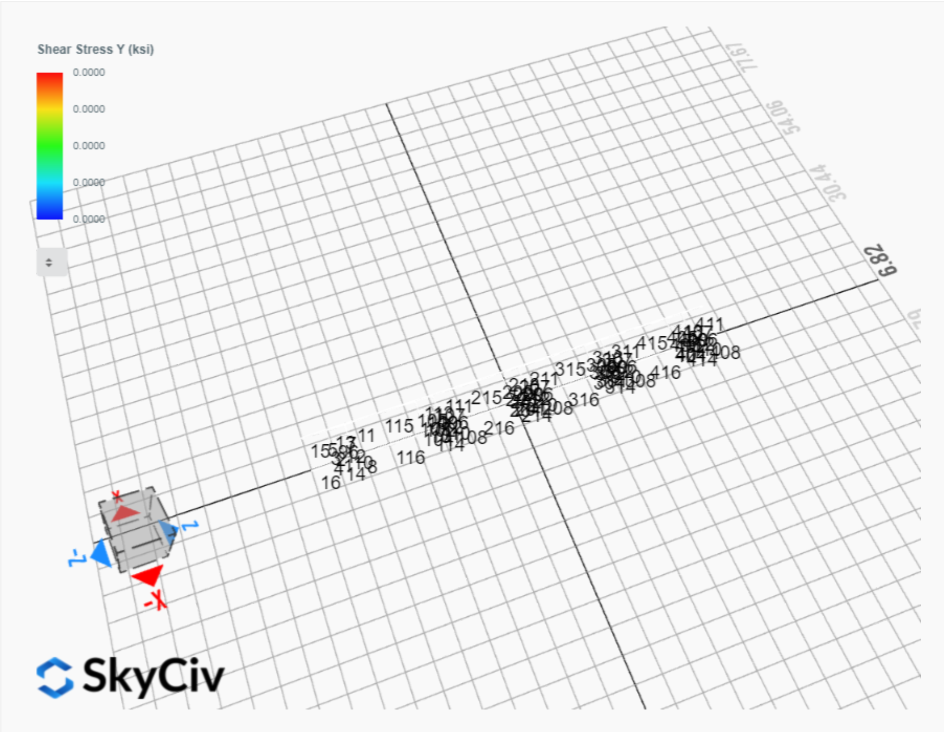

401
301
201
101
1

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
1.1689
0.5846
0.0002
-0.5841
-1.1685
6.82
SkyCiv


Shear Stress Y (ksi)
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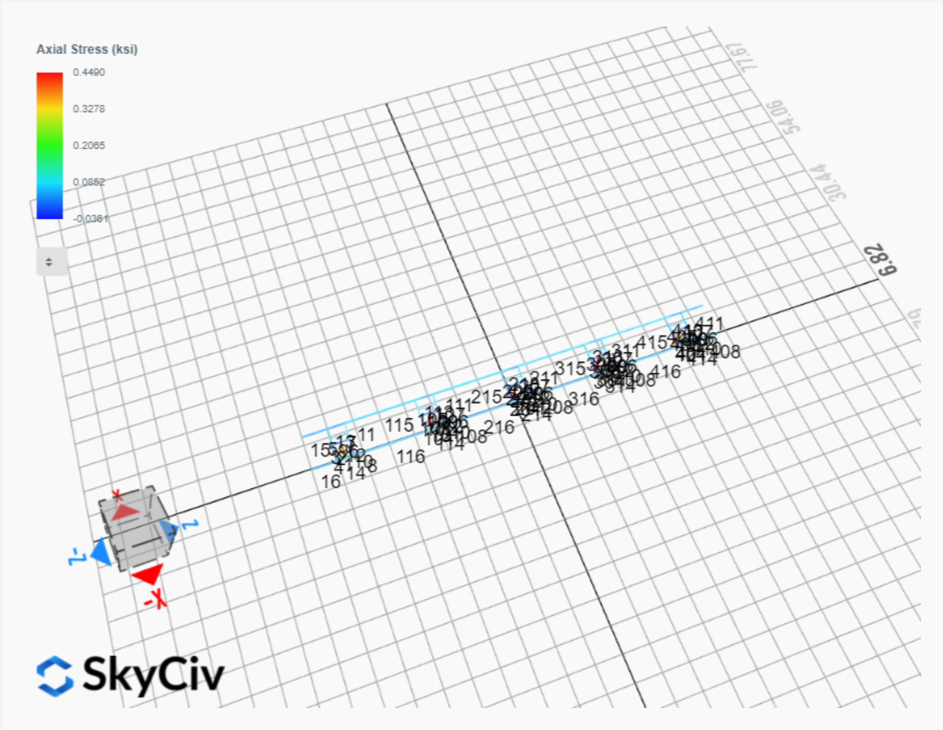
0.0000
0.0000
0.0000
0.0000
6.82
SkyCiv


Axial Stress (ksi)
0.4490
0.3278
0.2065
0.0852
-0.0361
6.82
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	0.0014	1.7344	0.0346	0.0838	-0.0035	0.0103
ULS: 2. D + L	0.0014	1.7344	0.0346	0.0838	-0.0035	0.0103
ULS: 3. D + (S or Lr or R)	0.0034	3.8847	0.0871	0.2113	-0.0087	-0.0046
ULS: 3. D + (S or Lr or R)	0.0014	1.7344	0.0346	0.0838	-0.0035	0.0103
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0029	3.3472	0.0739	0.1794	-0.0074	-0.0009
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0014	1.7344	0.0346	0.0838	-0.0035	0.0103
ULS: 5b. D + 0.7E	0.0014	1.7344	0.0346	0.0838	-0.0035	0.0103
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0029	3.3472	0.0739	0.1794	-0.0074	-0.0009
ULS: 8. 0.6D + 0.7E	0.0008	1.0407	0.0207	0.0503	-0.0021	0.0062
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2109	4.1259	0.0935	0.2255	-0.0218	2.3243
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2109	4.1259	0.0935	0.2255	-0.0218	2.3243
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0543	1.0895	0.0198	0.0480	-0.0021	2.0016
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1445	0.2154	-0.0047	-0.0096	0.0151	-6.6309
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1563	5.1408	0.1181	0.2856	-0.0212	1.7346
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1563	5.1408	0.1181	0.2856	-0.0212	1.7346
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0426	2.8634	0.0629	0.1526	-0.0064	1.4925
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1102	2.2079	0.0445	0.1093	0.0065	-4.9818
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1578	3.5280	0.0788	0.1901	-0.0172	1.7458
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1578	3.5280	0.0788	0.1901	-0.0172	1.7458
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0411	1.2507	0.0235	0.0570	-0.0024	1.5037
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1087	0.5952	0.0051	0.0138	0.0105	-4.9706
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2114	3.4321	0.0797	0.1919	-0.0205	2.3202
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2114	3.4321	0.0797	0.1919	-0.0205	2.3202
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0538	0.3957	0.0060	0.0145	-0.0007	1.9974
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1439	-0.4784	-0.0185	-0.0431	0.0165	-6.6350

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.5146
Shear X	-0.3537
Shear Z	0.1753
Moment X	0.4248
Moment Y (Twist)	0.0376
Moment Z	11.2870

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.1408
Shear X	-0.2114
Shear Z	0.1181
Moment X	0.2856
Moment Y (Twist)	0.0218
Moment Z	6.6350

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	-0.0015	1.9697	-0.0043	-0.0111	0.0011	0.0326
ULS: 2. D + L	-0.0015	1.9697	-0.0043	-0.0111	0.0011	0.0326
ULS: 3. D + (S or Lr or R)	-0.0038	4.4759	-0.0109	-0.0279	0.0028	0.0516
ULS: 3. D + (S or Lr or R)	-0.0015	1.9697	-0.0043	-0.0111	0.0011	0.0326
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0032	3.8493	-0.0093	-0.0237	0.0024	0.0468
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0015	1.9697	-0.0043	-0.0111	0.0011	0.0326
ULS: 5b. D + 0.7E	-0.0015	1.9697	-0.0043	-0.0111	0.0011	0.0326

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0032	3.8493	-0.0093	-0.0237	0.0024	0.0468
ULS: 8. 0.6D + 0.7E	-0.0009	1.1818	-0.0026	-0.0066	0.0007	0.0195
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2426	4.7572	-0.0115	-0.0296	0.0006	2.6448
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2426	4.7572	-0.0115	-0.0296	0.0006	2.6448
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0673	1.2169	-0.0019	-0.0053	-0.0024	2.2090
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1443	0.2010	-0.0007	-0.0007	0.0085	-7.3072
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1840	5.9400	-0.0146	-0.0376	0.0020	2.0060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1840	5.9400	-0.0146	-0.0376	0.0020	2.0060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0484	3.2848	-0.0075	-0.0194	-0.0003	1.6792
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1062	2.5228	-0.0065	-0.0159	0.0079	-5.4579
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1823	4.0603	-0.0097	-0.0250	0.0007	1.9917
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1823	4.0603	-0.0097	-0.0250	0.0007	1.9917
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0501	1.4051	-0.0025	-0.0067	-0.0015	1.6649
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1079	0.6432	-0.0016	-0.0033	0.0067	-5.4722
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2420	3.9693	-0.0097	-0.0252	0.0001	2.6318
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2420	3.9693	-0.0097	-0.0252	0.0001	2.6318
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0679	0.4291	-0.0002	-0.0008	-0.0029	2.1959
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1449	-0.5869	0.0011	0.0038	0.0081	-7.3202

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	8.6966
Shear X	-0.4046
Shear Z	-0.0218
Moment X	-0.0561
Moment Y (Twist)	0.0150
Moment Z	12.4534

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.9400
Shear X	-0.2426
Shear Z	-0.0146
Moment X	-0.0376
Moment Y (Twist)	0.0085
Moment Z	7.3202

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	0.0003	1.9440	-0.0000	0.0000	0.0000	0.0205
ULS: 2. D + L	0.0003	1.9440	-0.0000	0.0000	0.0000	0.0205
ULS: 3. D + (S or Lr or R)	0.0007	4.4110	-0.0000	-0.0000	0.0000	0.0213
ULS: 3. D + (S or Lr or R)	0.0003	1.9440	-0.0000	0.0000	0.0000	0.0205
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0006	3.7942	-0.0000	0.0000	0.0000	0.0211
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0003	1.9440	-0.0000	0.0000	0.0000	0.0205
ULS: 5b. D + 0.7E	0.0003	1.9440	-0.0000	0.0000	0.0000	0.0205
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0006	3.7942	-0.0000	0.0000	0.0000	0.0211
ULS: 8. 0.6D + 0.7E	0.0002	1.1664	-0.0000	0.0000	0.0000	0.0123
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2394	4.6880	-0.0000	-0.0000	0.0000	2.6411
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2394	4.6880	-0.0000	-0.0000	0.0000	2.6411
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0661	1.2040	-0.0000	0.0000	0.0000	2.2438
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1502	0.2007	-0.0000	0.0000	0.0000	-7.4210
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1792	5.8523	-0.0000	-0.0000	0.0000	1.9865
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1792	5.8523	-0.0000	-0.0000	0.0000	1.9865
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0500	3.2392	-0.0000	0.0000	0.0000	1.6886
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1130	2.4868	-0.0000	-0.0000	0.0000	-5.5600

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	-0.1795	4.0020	-0.0000	-0.0000	0.0000	1.9860
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1795	4.0020	-0.0000	-0.0000	0.0000	1.9860
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0497	1.3890	-0.0000	0.0000	0.0000	1.6880
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1127	0.6365	-0.0000	0.0000	0.0000	-5.5606
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2395	3.9105	-0.0000	-0.0000	0.0000	2.6329
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2395	3.9105	-0.0000	-0.0000	0.0000	2.6329
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0660	0.4264	-0.0000	0.0000	0.0000	2.2356
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1501	-0.5769	-0.0000	0.0000	0.0000	-7.4292

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	8.5667
Shear X	-0.3995
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	12.6525

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.8523
Shear X	-0.2395
Shear Z	-0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	7.4292

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	-0.0015	1.9697	0.0043	0.0111	-0.0011	0.0326
ULS: 2. D + L	-0.0015	1.9697	0.0043	0.0111	-0.0011	0.0326
ULS: 3. D + (S or Lr or R)	-0.0038	4.4759	0.0109	0.0279	-0.0028	0.0516
ULS: 3. D + (S or Lr or R)	-0.0015	1.9697	0.0043	0.0111	-0.0011	0.0326
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0032	3.8493	0.0093	0.0237	-0.0024	0.0468
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0015	1.9697	0.0043	0.0111	-0.0011	0.0326
ULS: 5b. D + 0.7E	-0.0015	1.9697	0.0043	0.0111	-0.0011	0.0326
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0032	3.8493	0.0093	0.0237	-0.0024	0.0468
ULS: 8. 0.6D + 0.7E	-0.0009	1.1818	0.0026	0.0066	-0.0007	0.0195
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2426	4.7572	0.0115	0.0296	-0.0006	2.6448
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2426	4.7572	0.0115	0.0296	-0.0006	2.6448
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0673	1.2169	0.0019	0.0053	0.0024	2.2090
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1443	0.2010	0.0007	0.0007	-0.0085	-7.3072
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1840	5.9400	0.0146	0.0376	-0.0020	2.0060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1840	5.9400	0.0146	0.0376	-0.0020	2.0060
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0484	3.2848	0.0075	0.0194	0.0003	1.6792
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1062	2.5228	0.0065	0.0159	-0.0079	-5.4579
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1823	4.0603	0.0097	0.0250	-0.0007	1.9917
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1823	4.0603	0.0097	0.0250	-0.0007	1.9917
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0501	1.4051	0.0025	0.0067	0.0015	1.6649
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1079	0.6432	0.0016	0.0033	-0.0067	-5.4722
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2420	3.9693	0.0097	0.0252	-0.0001	2.6318
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2420	3.9693	0.0097	0.0252	-0.0001	2.6318
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0679	0.4291	0.0002	0.0008	0.0029	2.1959
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1449	-0.5869	-0.0011	-0.0038	-0.0081	-7.3202

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.6966
Shear X	-0.4046
Shear Z	0.0218
Moment X	0.0561
Moment Y (Twist)	0.0150
Moment Z	12.4534

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

Result	Value (kip, kip-ft)
Axial	5.9400
Shear X	-0.2426
Shear Z	0.0146
Moment X	0.0376
Moment Y (Twist)	0.0085
Moment Z	7.3202

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	0.0014	1.7344	-0.0346	-0.0838	0.0035	0.0103
ULS: 2. D + L	0.0014	1.7344	-0.0346	-0.0838	0.0035	0.0103
ULS: 3. D + (S or Lr or R)	0.0034	3.8847	-0.0871	-0.2113	0.0087	-0.0046
ULS: 3. D + (S or Lr or R)	0.0014	1.7344	-0.0346	-0.0838	0.0035	0.0103
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0029	3.3472	-0.0739	-0.1794	0.0074	-0.0009
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0014	1.7344	-0.0346	-0.0838	0.0035	0.0103
ULS: 5b. D + 0.7E	0.0014	1.7344	-0.0346	-0.0838	0.0035	0.0103
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0029	3.3472	-0.0739	-0.1794	0.0074	-0.0009
ULS: 8. 0.6D + 0.7E	0.0008	1.0407	-0.0207	-0.0503	0.0021	0.0062
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2109	4.1259	-0.0935	-0.2255	0.0218	2.3243
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2109	4.1259	-0.0935	-0.2255	0.0218	2.3243
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0543	1.0895	-0.0198	-0.0480	0.0021	2.0016
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1445	0.2154	0.0047	0.0096	-0.0151	-6.6309
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1563	5.1408	-0.1181	-0.2856	0.0212	1.7346
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1563	5.1408	-0.1181	-0.2856	0.0212	1.7346
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0426	2.8634	-0.0629	-0.1526	0.0064	1.4925
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1102	2.2079	-0.0445	-0.1093	-0.0065	-4.9818
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1578	3.5280	-0.0788	-0.1901	0.0172	1.7458
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1578	3.5280	-0.0788	-0.1901	0.0172	1.7458
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0411	1.2507	-0.0235	-0.0570	0.0024	1.5037
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1087	0.5952	-0.0051	-0.0138	-0.0105	-4.9706
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2114	3.4321	-0.0797	-0.1919	0.0205	2.3202
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2114	3.4321	-0.0797	-0.1919	0.0205	2.3202
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0538	0.3957	-0.0060	-0.0145	0.0007	1.9974
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1439	-0.4784	0.0185	0.0431	-0.0165	-6.6350

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.5146
Shear X	-0.3537
Shear Z	-0.1753
Moment X	-0.4248
Moment Y (Twist)	0.0377
Moment Z	11.2870

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.1408
Shear X	-0.2114
Shear Z	-0.1181
Moment X	-0.2856
Moment Y (Twist)	0.0218
Moment Z	6.6350

Project Details

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

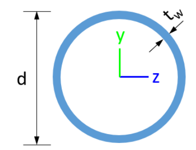
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

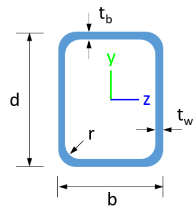
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

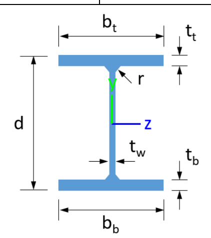
Section Dimensions



ID	Name	d (in)	t_w (in)					
1	2in Pipe Sch 40	2.38	0.15					
4	4in Pipe Sch 40	4.50	0.24					
7	6in Pipe Sch 40	6.63	0.28					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
15	HSS5x3x1/8	5.00	3.00	0.12	0.12	0.12		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
18	W6x9	5.90	0.17	3.94	3.94	0.21	0.21	0.25

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)
1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28

15	HSS5x3x1/8	1.77	6.02	2.75	6.03	152.35	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	18.07	18.07	8.60	-	300	200	1
2	4	4.20	4.20	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.18,1.18,1.18,1.17	300	200	1
4	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.68,1.67,1.67,1.60,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.68,1.67,1.67,1.64,1.68	300	200	1
5	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.64,1.67,1.67,1.68,1.66	300	200	1
6	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.18,1.18,1.19,1.18	300	200	1
7	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.67,1.67,1.68,1.66	300	200	1
8	18	1.33	1.33	2.05	1.74,1.74,1.74,1.74,1.74,1.74,1.73,1.73,1.46,2.05,1.73,1.73,2.11,2.08,1.74,1.74,1.71,1.81,1.73,1.73,1.58,1.97,1.73,1.73,2.06,2.10	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.61,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
11	18	1.33	1.33	2.05	1.76,1.76,1.76,1.76,1.76,1.76,1.78,1.78,1.87,2.07,1.78,1.78,1.96,2.03,1.77,1.77,1.79,1.65,1.78,1.78,1.85,2.09,1.78,1.78,2.04,1.99	300	200	1
12	4	1.30	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.15,1.11,1.11,1.12,1.12,1.11,1.11,1.11,1.10,1.11,1.11,1.11,1.25,1.11,1.11,1.12,1.12	300	200	1
14	18	4.88	4.00	7.50	1.10,1.11,1.10,1.11,1.11,1.10,1.11,1.11,1.06,1.13,1.10,1.10,1.45,1.21,1.11,1.11,1.10,1.11,1.10,1.10,1.08,1.13,1.10,1.10,1.17,1.33	300	200	1
15	18	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	18	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	7	18.07	18.07	8.60	-	300	200	1
102	4	1.30	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.18	300	200	1
104	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.61,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66	300	200	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.19,1.18	300	200	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66	300	200	1

108	18	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.12,2.08,2.09,2.09,2.07,2.07,2.09,2.09,2.10,2.09,2.09,2.09,2.10,2.08,2.10,2.10,2.08,2.06	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.61,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
111	18	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.07,2.09,2.09,2.08,2.08,2.09,2.09,2.09,2.11,2.09,2.09,2.09,2.07,2.09,2.09,2.08,2.08	300	200	1
112	4	4.20	4.20	2.00	-	300	200	1
113	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.17,1.04,1.04,1.07,1.10,1.04,1.04,1.04,1.03,1.04,1.04,1.05,1.29,1.04,1.04,1.11,1.08	300	200	1
114	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.11,1.04,1.04,1.57,1.24,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.07,1.04,1.04,1.19,1.41	300	200	1
115	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.13,1.16,1.16,1.15,1.14,1.16,1.16,1.16,1.17,1.16,1.16,1.15,1.12,1.16,1.16,1.14,1.14	300	200	1
116	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.19,1.14,1.16,1.16,1.12,1.13,1.16,1.16,1.16,1.15,1.16,1.16,1.17,1.14,1.16,1.16,1.14,1.12	300	200	1
201	7	18.07	18.07	8.60	-	300	200	1
202	4	1.30	1.30	2.00	-	300	200	1
203	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.18	300	200	1
204	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.62,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
205	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66	300	200	1
206	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.18	300	200	1
207	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66	300	200	1
208	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.06,2.09,2.08,2.08,2.16,2.10,2.08,2.08,2.08,2.08,2.08,2.08,2.07,2.09,2.08,2.08,2.10,2.11	300	200	1
209	1	2.60	2.60	4.00	-	300	200	1
210	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.62,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
211	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.09,2.10,2.08,2.08,2.09,2.09,2.08,2.08,2.09,2.08,2.08,2.08,2.09,2.10,2.08,2.08,2.09,2.09	300	200	1
212	4	1.30	1.30	2.00	-	300	200	1
213	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.12,1.04,1.04,1.05,1.07,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.20,1.04,1.04,1.08,1.06	300	200	1
214	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.08,1.04,1.04,1.37,1.17,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.05,1.04,1.04,1.15,1.27	300	200	1
215	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.16	300	200	1
216	18	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.15,1.14,1.16,1.15,1.15,1.17,1.16,1.15,1.15,1.15,1.16,1.15,1.15,1.15,1.16,1.15,1.15,1.16,1.17	300	200	1
301	7	18.07	18.07	8.60	-	300	200	1

302	4	4.20	4.20	2.00	-	300	200	1
303	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.19,1.18	300	200	1
304	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.61,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
305	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66	300	200	1
306	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.18	300	200	1
307	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66	300	200	1
308	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.30,2.03,2.09,2.09,1.75,1.85,2.08,2.08,2.09,2.07,2.08,2.08,2.11,2.06,2.09,2.09,1.99,1.72	300	200	1
309	1	2.60	2.60	4.00	-	300	200	1
310	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.61,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
311	18	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.08,2.07,1.92,2.08,2.08,2.06,2.06,2.08,2.08,2.08,2.10,2.08,2.08,2.07,1.79,2.08,2.08,2.05,2.06	300	200	1
312	4	1.30	1.30	2.00	-	300	200	1
313	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.05,1.17,1.04,1.04,1.07,1.10,1.04,1.04,1.04,1.03,1.04,1.04,1.05,1.29,1.04,1.04,1.11,1.08	300	200	1
314	18	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.11,1.04,1.04,1.57,1.24,1.04,1.04,1.04,1.04,1.04,1.04,1.03,1.07,1.04,1.04,1.19,1.41	300	200	1
315	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.17,1.16,1.16,1.16,1.15,1.16,1.16,1.15,1.15	300	200	1
316	18	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.15,1.16,1.16,1.15,1.15,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.15,1.16,1.16,1.15,1.14	300	200	1
401	7	18.07	18.07	8.60	-	300	200	1
402	4	1.30	1.30	2.00	-	300	200	1
403	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.18,1.18,1.19,1.18	300	200	1
404	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.70,1.68,1.67,1.67,1.61,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	300	200	1
405	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.67,1.67,1.68,1.66	300	200	1
406	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.18,1.18,1.18,1.17	300	200	1
407	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.64,1.67,1.67,1.68,1.66	300	200	1
408	18	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	1	2.60	2.60	4.00	-	300	200	1
410	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.71,1.68,1.67,1.67,1.60,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.68,1.67,1.67,1.64,1.68	300	200	1
411	18	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1

412	4	4.20	4.20	2.00	-	00	00	1
413	18	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.15,1.11,1.11,1.12,1.12,1.11,1.11,1.11,1.10,1.11,1.11,1.11,1.25,1.11,1.11,1.12,1.12	300	200	1
414	18	4.88	4.00	7.50	1.10,1.11,1.10,1.11,1.11,1.10,1.11,1.11,1.06,1.13,1.10,1.10,1.45,1.21,1.11,1.11,1.10,1.11,1.10,1.10,1.08,1.13,1.10,1.10,1.17,1.33	300	200	1
415	18	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.15,1.13,1.13,1.14,1.14,1.12,1.12,1.13,1.11,1.12,1.12,1.13,1.16,1.13,1.13,1.14,1.14	300	200	1
416	18	6.63	6.63	10.20	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.14,1.12,1.12,1.17,1.16,1.12,1.12,1.12,1.13,1.12,1.12,1.11,1.14,1.12,1.12,1.15,1.17	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	251.16	127.02	42.30	42.30	75.35	75.35
2	142.83	131.65	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	4.60	29.14	16.61
4	79.65	72.01	10.99	4.60	29.14	16.61
5	79.65	73.44	10.99	4.60	29.14	16.61
6	79.65	74.02	10.99	4.60	29.14	16.61
7	79.65	73.44	10.99	4.60	29.14	16.61
8	120.60	117.88	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	4.60	29.14	16.61
11	120.60	117.88	23.36	6.45	30.09	45.74
12	142.83	141.72	16.17	16.17	42.85	42.85
13	120.60	98.23	19.37	6.45	30.09	45.74
14	120.60	98.23	18.66	6.45	30.09	45.74
15	120.60	54.44	23.36	6.45	30.09	45.74
16	120.60	54.44	23.36	6.45	30.09	45.74
101	251.16	127.02	42.30	42.30	75.35	75.35
102	142.83	141.72	16.17	16.17	42.85	42.85
103	79.65	74.02	10.99	4.60	29.14	16.61
104	79.65	72.01	10.99	4.60	29.14	16.61
105	79.65	73.44	10.99	4.60	29.14	16.61
106	79.65	74.02	10.99	4.60	29.14	16.61
107	79.65	73.44	10.99	4.60	29.14	16.61
108	120.60	117.88	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	4.60	29.14	16.61
111	120.60	117.88	23.36	6.45	30.09	45.74
112	142.83	131.65	16.17	16.17	42.85	42.85
113	120.60	98.23	18.13	6.45	30.09	45.74
114	120.60	98.23	18.13	6.45	30.09	45.74
115	120.60	68.63	15.30	6.45	30.09	45.74
116	120.60	68.63	15.30	6.45	30.09	45.74
201	251.16	127.02	42.30	42.30	75.35	75.35
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	4.60	29.14	16.61
204	79.65	72.01	10.99	4.60	29.14	16.61
205	79.65	73.44	10.99	4.60	29.14	16.61
206	79.65	74.02	10.99	4.60	29.14	16.61
207	79.65	73.44	10.99	4.60	29.14	16.61

208	120.60	117.88	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	4.60	29.14	16.61
211	120.60	117.88	23.36	6.45	30.09	45.74
212	142.83	141.72	16.17	16.17	42.85	42.85
213	120.60	98.23	18.31	6.45	30.09	45.74
214	120.60	98.23	18.13	6.45	30.09	45.74
215	120.60	68.63	15.71	6.45	30.09	45.74
216	120.60	68.63	15.57	6.45	30.09	45.74
301	251.16	127.02	42.30	42.30	75.35	75.35
302	142.83	131.65	16.17	16.17	42.85	42.85
303	79.65	74.02	10.99	4.60	29.14	16.61
304	79.65	72.01	10.99	4.60	29.14	16.61
305	79.65	73.44	10.99	4.60	29.14	16.61
306	79.65	74.02	10.99	4.60	29.14	16.61
307	79.65	73.44	10.99	4.60	29.14	16.61
308	120.60	117.88	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.01	10.99	4.60	29.14	16.61
311	120.60	117.88	23.36	6.45	30.09	45.74
312	142.83	141.72	16.17	16.17	42.85	42.85
313	120.60	98.23	18.13	6.45	30.09	45.74
314	120.60	98.23	18.13	6.45	30.09	45.74
315	120.60	68.63	15.71	6.45	30.09	45.74
316	120.60	68.63	15.57	6.45	30.09	45.74
401	251.16	127.02	42.30	42.30	75.35	75.35
402	142.83	141.72	16.17	16.17	42.85	42.85
403	79.65	74.02	10.99	4.60	29.14	16.61
404	79.65	72.01	10.99	4.60	29.14	16.61
405	79.65	73.44	10.99	4.60	29.14	16.61
406	79.65	74.02	10.99	4.60	29.14	16.61
407	79.65	73.44	10.99	4.60	29.14	16.61
408	120.60	54.44	23.36	6.45	30.09	45.74
409	48.35	43.11	2.85	2.85	14.51	14.51
410	79.65	72.01	10.99	4.60	29.14	16.61
411	120.60	54.44	23.36	6.45	30.09	45.74
412	142.83	131.65	16.17	16.17	42.85	42.85
413	120.60	98.23	19.37	6.45	30.09	45.74
414	120.60	98.23	18.66	6.45	30.09	45.74
415	120.60	68.63	15.16	6.45	30.09	45.74
416	120.60	68.63	15.16	6.45	30.09	45.74

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	0.059	0.267	0.026	0.005	0.002	0.269	#16	0.483	Not Required	Pass
2	0.001	0.374	0.023	0.080	0.004	0.391	#21	0.111	Not Required	Pass
3	0.002	0.588	0.008	0.059	0.002	0.593	#21	0.044	Not Required	Pass
4	0.001	0.571	0.043	0.058	0.006	0.612	#21	0.078	Not Required	Pass
5	0.002	0.364	0.024	0.059	0.003	0.367	#21	0.073	Not Required	Pass
6	0.002	0.658	0.036	0.067	0.005	0.695	#21	0.044	Not Required	Pass
7	0.002	0.407	0.053	0.066	0.008	0.426	#21	0.073	Not Required	Pass
8	0.001	0.075	0.018	0.040	0.002	0.084	#21	0.088	Not Required	Pass

9	0.002	0.079	0.018	0.002	0.001	0.097	#21	0.198	Not Required	Pass
10	0.002	0.638	0.037	0.065	0.004	0.644	#21	0.078	Not Required	Pass
11	0.001	0.076	0.020	0.041	0.002	0.083	#21	0.088	Not Required	Pass
12	0.000	0.441	0.025	0.090	0.004	0.460	#21	0.052	Not Required	Pass
13	0.001	0.178	0.046	0.054	0.002	0.196	#21	0.265	Not Required	Pass
14	0.001	0.178	0.044	0.052	0.002	0.189	#21	0.177	Not Required	Pass
15	0.000	0.063	0.014	0.026	0.001	0.078	#21	Not Required	Not Required	Pass
16	0.000	0.062	0.014	0.026	0.001	0.076	#21	Not Required	Not Required	Pass
101	0.068	0.294	0.003	0.005	0.000	0.297	#16	0.483	Not Required	Pass
102	0.000	0.478	0.028	0.100	0.005	0.499	#21	0.052	Not Required	Pass
103	0.002	0.728	0.020	0.074	0.002	0.749	#21	0.044	Not Required	Pass
104	0.002	0.709	0.040	0.072	0.005	0.735	#21	0.078	Not Required	Pass
105	0.002	0.451	0.044	0.073	0.006	0.463	#21	0.073	Not Required	Pass
106	0.002	0.720	0.018	0.073	0.002	0.736	#21	0.044	Not Required	Pass
107	0.002	0.447	0.040	0.072	0.006	0.456	#21	0.073	Not Required	Pass
108	0.001	0.052	0.016	0.042	0.002	0.059	#21	0.088	Not Required	Pass
109	0.002	0.081	0.010	0.001	0.000	0.091	#21	0.198	Not Required	Pass
110	0.002	0.700	0.041	0.071	0.005	0.731	#21	0.078	Not Required	Pass
111	0.001	0.054	0.016	0.043	0.002	0.060	#21	0.088	Not Required	Pass
112	0.000	0.470	0.028	0.099	0.005	0.491	#21	0.167	Not Required	Pass
113	0.001	0.207	0.042	0.057	0.002	0.235	#21	0.265	Not Required	Pass
114	0.002	0.208	0.042	0.055	0.002	0.231	#21	0.265	Not Required	Pass
115	0.002	0.211	0.023	0.044	0.002	0.234	#21	0.439	Not Required	Pass
116	0.001	0.207	0.024	0.043	0.002	0.231	#21	0.439	Not Required	Pass
201	0.067	0.299	0.000	0.005	0.000	0.302	#16	0.483	Not Required	Pass
202	0.000	0.466	0.028	0.098	0.005	0.487	#21	0.034	Not Required	Pass
203	0.002	0.714	0.018	0.072	0.002	0.732	#21	0.044	Not Required	Pass
204	0.002	0.693	0.039	0.070	0.005	0.721	#21	0.078	Not Required	Pass
205	0.002	0.442	0.041	0.072	0.006	0.452	#21	0.073	Not Required	Pass
206	0.002	0.714	0.018	0.072	0.002	0.732	#21	0.044	Not Required	Pass
207	0.002	0.442	0.041	0.072	0.006	0.452	#21	0.073	Not Required	Pass
208	0.001	0.055	0.015	0.041	0.002	0.062	#21	0.088	Not Required	Pass
209	0.002	0.078	0.008	0.001	0.000	0.087	#21	0.198	Not Required	Pass
210	0.002	0.693	0.039	0.070	0.005	0.721	#21	0.078	Not Required	Pass
211	0.001	0.056	0.015	0.043	0.002	0.062	#21	0.088	Not Required	Pass
212	0.000	0.466	0.028	0.098	0.005	0.487	#21	0.034	Not Required	Pass
213	0.001	0.202	0.040	0.055	0.002	0.229	#21	0.265	Not Required	Pass
214	0.001	0.200	0.040	0.053	0.002	0.222	#21	0.265	Not Required	Pass
215	0.001	0.190	0.023	0.043	0.002	0.214	#21	0.439	Not Required	Pass
216	0.001	0.188	0.023	0.041	0.002	0.211	#21	0.439	Not Required	Pass
301	0.068	0.294	0.003	0.005	0.000	0.297	#16	0.483	Not Required	Pass
302	0.000	0.470	0.028	0.099	0.005	0.491	#21	0.167	Not Required	Pass
303	0.002	0.720	0.018	0.073	0.002	0.736	#21	0.044	Not Required	Pass
304	0.002	0.700	0.041	0.071	0.005	0.731	#21	0.078	Not Required	Pass
305	0.002	0.447	0.040	0.072	0.006	0.456	#21	0.073	Not Required	Pass
306	0.002	0.728	0.020	0.074	0.002	0.749	#21	0.044	Not Required	Pass
307	0.002	0.451	0.044	0.073	0.006	0.463	#21	0.073	Not Required	Pass
308	0.001	0.059	0.017	0.043	0.002	0.064	#21	0.088	Not Required	Pass
309	0.002	0.081	0.010	0.001	0.000	0.091	#21	0.198	Not Required	Pass
310	0.002	0.709	0.040	0.072	0.005	0.735	#21	0.078	Not Required	Pass
311	0.001	0.061	0.017	0.044	0.002	0.066	#21	0.088	Not Required	Pass
312	0.000	0.478	0.028	0.100	0.005	0.499	#21	0.052	Not Required	Pass
313	0.001	0.207	0.042	0.057	0.002	0.235	#21	0.265	Not Required	Pass
314	0.002	0.208	0.042	0.055	0.002	0.231	#21	0.265	Not Required	Pass

315	0.001	0.191	0.023	0.043	0.002	0.214	#21	0.439	Not Required	Pass
316	0.001	0.186	0.023	0.042	0.002	0.210	#21	0.439	Not Required	Pass
401	0.059	0.267	0.026	0.005	0.002	0.269	#16	0.483	Not Required	Pass
402	0.000	0.441	0.025	0.090	0.004	0.460	#21	0.052	Not Required	Pass
403	0.002	0.658	0.036	0.067	0.005	0.695	#21	0.044	Not Required	Pass
404	0.002	0.638	0.037	0.065	0.004	0.644	#21	0.078	Not Required	Pass
405	0.002	0.407	0.053	0.066	0.008	0.426	#21	0.073	Not Required	Pass
406	0.002	0.588	0.008	0.059	0.002	0.593	#21	0.044	Not Required	Pass
407	0.002	0.364	0.024	0.059	0.003	0.367	#21	0.073	Not Required	Pass
408	0.000	0.062	0.014	0.026	0.001	0.076	#21	Not Required	Not Required	Pass
409	0.002	0.079	0.018	0.002	0.001	0.097	#21	0.198	Not Required	Pass
410	0.001	0.571	0.043	0.058	0.006	0.612	#21	0.078	Not Required	Pass
411	0.000	0.063	0.014	0.026	0.001	0.078	#21	Not Required	Not Required	Pass
412	0.001	0.374	0.023	0.080	0.004	0.391	#21	0.111	Not Required	Pass
413	0.001	0.178	0.046	0.054	0.002	0.196	#21	0.177	Not Required	Pass
414	0.001	0.178	0.044	0.052	0.002	0.189	#21	0.265	Not Required	Pass
415	0.002	0.217	0.023	0.041	0.002	0.241	#21	0.439	Not Required	Pass
416	0.001	0.212	0.024	0.040	0.002	0.236	#21	0.439	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/comresssion)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

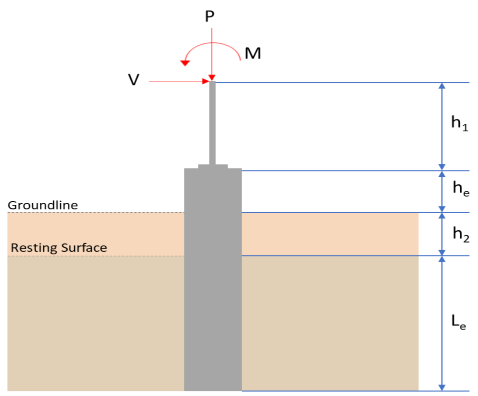
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4.5\ \mathrm{ft}$ - 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)	5.141	7.515
V_x (kip)	-0.211	-0.354
V_z (kip)	0.118	0.175
M_x (kipft)	0.286	0.425
M_z (kipft)	6.635	11.287

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.211\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.033599\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(6.635\ \mathrm{kipft}) + ((-0.211\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 1.0565\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 4.2355\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.118\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.01879\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.286\ \mathrm{kipft}) + ((0.118\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.045541\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.7812\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.2355\ \mathrm{ft}), (1.7812\ \mathrm{ft})]$$

$$L_{e,req} = 4.236\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 4.5\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.236\ \mathrm{ft})}{(4.5\ \mathrm{ft})}$$

$$Ratio = 0.94133$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.141\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.32131\ \mathrm{kip/ft}^2$$

$$q = 0.32131\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.32131\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.16066$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.033599\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.0565\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.0565\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (1.0565\ \mathrm{kipft/ft})) + (4 \times (-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0327\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.0565\ \mathrm{kipft/ft})) + (3 \times (-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^{\ 2}}{(4.5\ \mathrm{ft})^2 \times [(3 \times (1.0565\ \mathrm{kipft/ft})) + (2 \times (-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 0.18384\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.0565\ \mathrm{kipft/ft})) + ((-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.58129\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.0327\ \mathrm{ft})}{2}$$

$$p_a = 0.22745\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18384\ \mathrm{kip/ft^2}\right)}{\left(0.22745\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.80828$$

Status: **PASS**
Ratio: **0.810**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.58129\ \mathrm{kip/ft^2}\right)}{\left(0.675\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.86117$$

Status: **PASS**
Ratio: **0.860**

Considering z-direction:

$H_o = 0.01879\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.045541\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.045541\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (0.045541\ \mathrm{kipft/ft})) + (4 \times (0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.2074\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.045541\ \mathrm{kipft/ft})) + (3 \times (0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^2}{(4.5\ \mathrm{ft})^2 \times [(3 \times (0.045541\ \mathrm{kipft/ft})) + (2 \times (0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 0.02301\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.045541\ \mathrm{kipft/ft})) + ((0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.052041\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.2074\ \mathrm{ft})}{2}$$

$$p_a = 0.24056\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.02301\ \mathrm{kip/ft^2}\right)}{\left(0.24056\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.095655$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

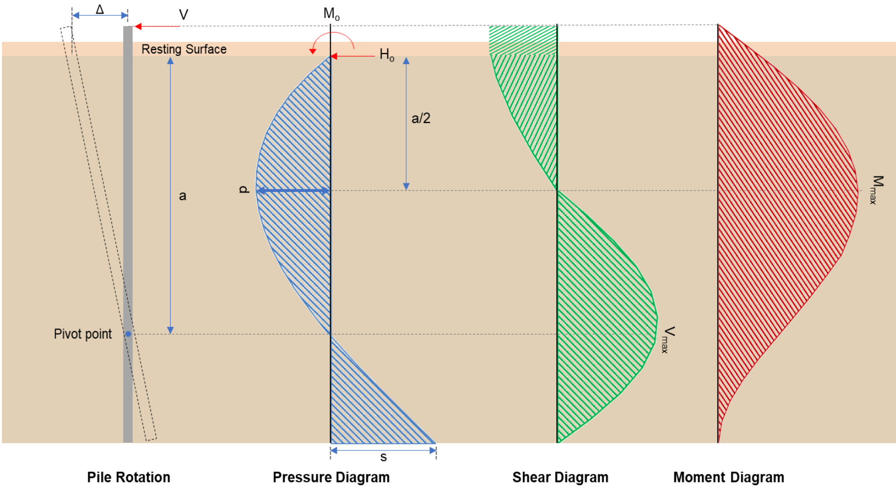
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.052041\ \mathrm{kip/ft^2})}{(0.675\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.077097$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.354\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.056369\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(11.287\ \mathrm{kipft}) + ((-0.354\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 1.7973\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.7973\ \mathrm{kipft/ft})}{(-0.056369\ \mathrm{kip/ft})}$$

$$E = 31.884\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.7973\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.056369\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (1.7973\ \mathrm{kipft/ft})) + (4 \times (-0.056369\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0322\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.056369\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.884\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0322\ \mathrm{ft})}{(4.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.884\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0322\ \mathrm{ft})}{(4.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 2.9832\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.056369\text{ kip/ft}) \times (48\text{ in}) \times (4.5\text{ ft})) \times \left[\left(\frac{(31.884\text{ ft})}{(4.5\text{ ft})} + \frac{(3.0322\text{ ft})}{2 \times (4.5\text{ ft})}\right) - \left[\left(\frac{4 \times (31.884\text{ ft})}{(4.5\text{ ft})} + 3\right) \times \left(\frac{(3.0322\text{ ft})}{2 \times (4.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (31.884\text{ ft})}{(4.5\text{ ft})} + 2\right) \times \left(\frac{(3.0322\text{ ft})}{2 \times (4.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 6.6189\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.175\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.027866\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.425\text{ kipft}) + ((0.175\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.067675\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.067675\text{ kipft/ft})}{(0.027866\text{ kip/ft})}$$

$$E = 2.4286\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.067675\text{ kipft/ft}) \times (4.5\text{ ft})) + \left(3 \times (0.027866\text{ kip/ft}) \times (4.5\text{ ft})^2\right)}{(6 \times (0.067675\text{ kipft/ft})) + (4 \times (0.027866\text{ kip/ft}) \times (4.5\text{ ft}))}$$

$$a = 3.2072\text{ ft}$$

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

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

$$V_{max} = ((0.027866\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4286\text{ ft})}{(4.5\text{ ft})} + 3\right) \times \left(\frac{(3.2072\text{ ft})}{(4.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.4286\text{ ft})}{(4.5\text{ ft})} + 2\right) \times \left(\frac{(3.2072\text{ ft})}{(4.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.18063\text{ kip}$$

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

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

$$M_{max} = ((0.027866\text{ kip/ft}) \times (48\text{ in}) \times (4.5\text{ ft})) \times \left[\left(\frac{(2.4286\text{ ft})}{(4.5\text{ ft})} + \frac{(3.2072\text{ ft})}{2 \times (4.5\text{ ft})}\right) - \left[\left(\frac{4 \times (2.4286\text{ ft})}{(4.5\text{ ft})} + 3\right) \times \left(\frac{(3.2072\text{ ft})}{2 \times (4.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.4286\text{ ft})}{(4.5\text{ ft})} + 2\right) \times \left(\frac{(3.2072\text{ ft})}{2 \times (4.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.36162 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.515 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.346 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.346 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.515\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0028092$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 7.515\ \text{kip} \rightarrow 7515\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(7515\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.49\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.49\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.49\ \text{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 737.28\ \text{kip}$$	
	A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$	
	V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((119.49\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 110.75\ \text{kip}$$	
	Considering x-direction: $V_{max} = 2.9832\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(2.9832\ \text{kip})}{(110.75\ \text{kip})}$$ $$Ratio = 0.026937$$	Status: **PASS** Ratio: **0.030**
	Considering z-direction: $V_{max} = 0.18063\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.18063\ \text{kip})}{(110.75\ \text{kip})}$$ $$Ratio = 0.001631$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\ D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$	

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 6.6189\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(6.6189\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.026518$$	Status: **PASS** Ratio: **0.030**
	Considering z-direction: $M_{max} = 0.36162\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.36162\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.0014488$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

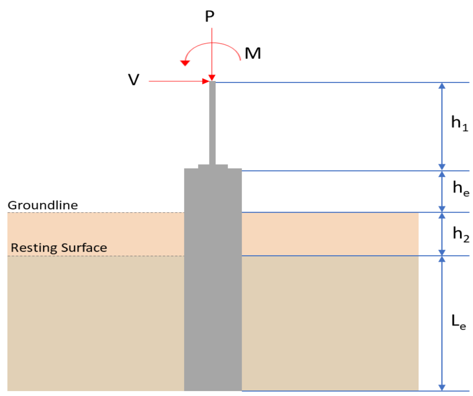
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4.5\ \mathrm{ft}$ - 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)	5.940	8.697
V_x (kip)	-0.243	-0.405
V_z (kip)	-0.015	-0.022
M_x (kipft)	-0.038	-0.056
M_z (kipft)	7.320	12.453

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.243\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.038694\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.32\ \text{kipft}) + ((-0.243\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.1656\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.3641\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.015\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0023885\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.038\ \text{kipft}) + ((-0.015\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.006051\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.72439\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.3641\ \text{ft}), (0.72439\ \text{ft})]$$

$$L_{e,req} = 4.364\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.364\ \text{ft})}{(4.5\ \text{ft})}$$

$$Ratio = 0.96978$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.94\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.37125\ \text{kip/ft}^2$$

$$q = 0.37125\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.37125\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.18563$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.038694\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.1656\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.1656\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.038694\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (1.1656\ \mathrm{kipft/ft})) + (4 \times (-0.038694\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.034\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.1656\ \mathrm{kipft/ft})) + (3 \times (-0.038694\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^{\ 2}}{(4.5\ \mathrm{ft})^2 \times [(3 \times (1.1656\ \mathrm{kipft/ft})) + (2 \times (-0.038694\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 0.20162\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.1656\ \mathrm{kipft/ft})) + ((-0.038694\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.63914\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.034\ \mathrm{ft})}{2}$$

$$p_a = 0.22755\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.20162\ \mathrm{kip/ft^2}\right)}{\left(0.22755\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.88606$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.63914\ \mathrm{kip/ft^2}\right)}{\left(0.675\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94687$$

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

Considering z-direction:

$H_o = -0.0023885\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.006051\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.006051\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (0.006051\ \mathrm{kipft/ft})) + (4 \times (-0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.2033\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.006051\ \mathrm{kipft/ft})) + (3 \times (-0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^2}{(4.5\ \mathrm{ft})^2 \times [(3 \times (0.006051\ \mathrm{kipft/ft})) + (2 \times (-0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = -0.00071621\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.006051\ \mathrm{kipft/ft})) + ((-0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.00040104\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.2033\ \mathrm{ft})}{2}$$

$$p_a = 0.24025\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00071621\ \mathrm{kip/ft^2}\right)}{\left(0.24025\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0029811$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

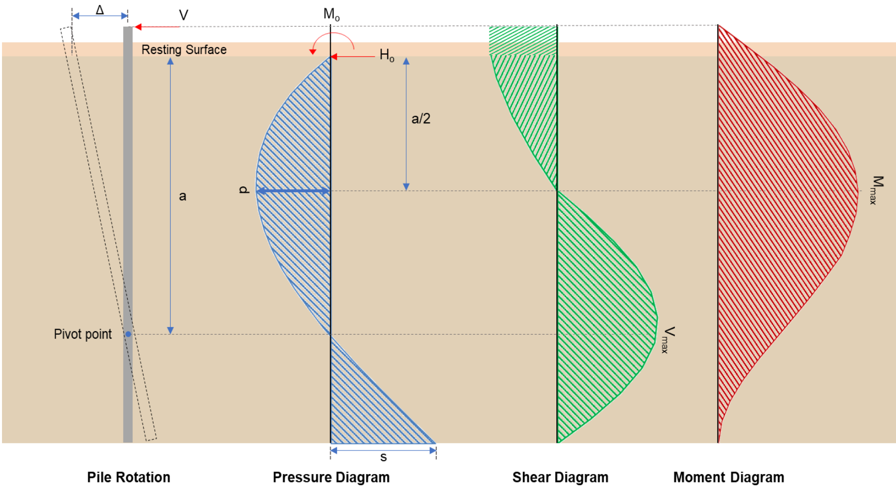
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00040104 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.00059413$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.405 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.06449 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.453 \text{ kipft}) + ((-0.405 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.983 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.983 \text{ kipft/ft})}{(-0.06449 \text{ kip/ft})}$$

$$E = 30.748 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.983 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (-0.06449 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (1.983 \text{ kipft/ft})) + (4 \times (-0.06449 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0333 \text{ ft}$$

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

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

$$V_{max} = ((-0.06449 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (30.748 \text{ ft})}{(4.5 \text{ ft})} + 3\right) \times \left(\frac{(3.0333 \text{ ft})}{(4.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (30.748 \text{ ft})}{(4.5 \text{ ft})} + 2\right) \times \left(\frac{(3.0333 \text{ ft})}{(4.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 3.2973 \text{ kip}$$

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

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

$$M_{max} = ((-0.06449 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(30.748 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0333 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (30.748 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0333 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (30.748 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0333 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 7.3121 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.022 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0035032 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.056 \text{ kipft}) + ((-0.022 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0089172 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0089172 \text{ kipft/ft})}{(-0.0035032 \text{ kip/ft})}$$

$$E = 2.5455 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0089172 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (-0.0035032 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (0.0089172 \text{ kipft/ft})) + (4 \times (-0.0035032 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.2029 \text{ ft}$$

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

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

$$V_{max} = ((-0.0035032 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.5455 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.2029 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.5455 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.2029 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.023345 \text{ kip}$$

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

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

$$M_{max} = ((-0.0035032 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(2.5455 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.2029 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.5455 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.2029 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.5455 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.2029 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.046892\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(8.697\ \text{kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\ \text{ksi}) \times \left(2304\ \text{in}^2\right)\right)}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, \left(0.08 \times \left(2304\ \text{in}^2\right)\right)\right]$$

$$A_{st,required} = -84.307\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.307\ \text{in}^2\right), \left(0.0018 \times \left(2304\ \text{in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(8.697\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.003251$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,$P = 8.697\ \mathrm{kip} \rightarrow 8697\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(8697\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.64\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.64\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.64\ \mathrm{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{s,a} = 737.28\ \mathrm{kip}$$	
	A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \mathrm{in})^2}{4}$$ $$A_v = 0.11045\ \mathrm{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \mathrm{in}^2\right) \times (60\ \mathrm{ksi}) \times (38.4\ \mathrm{in})}{(10\ \mathrm{in})}$$ $$V_{s,b} = 50.894\ \mathrm{kip}$$	
	V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \mathrm{kip}), (50.894\ \mathrm{kip})\right]$$ $$V_s = 50.894\ \mathrm{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((119.64\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$ $$\phi V_n = 110.85\ \mathrm{kip}$$	
	Considering x-direction: $V_{max} = 3.2973\ \mathrm{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(3.2973\ \mathrm{kip})}{(110.85\ \mathrm{kip})}$$ $$Ratio = 0.029745$$	Status: **PASS** Ratio: **0.030**
	Considering z-direction: $V_{max} = 0.023345\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.023345\ \mathrm{kip})}{(110.85\ \mathrm{kip})}$$ $$Ratio = 0.0002106$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\ D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$	

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi \, 0.85 \, f_{ck}' \, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 7.3121 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(7.3121 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.029295$$	Status: **PASS** Ratio: **0.030**
	Considering z-direction: $M_{max} = 0.046892 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.046892 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00018787$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

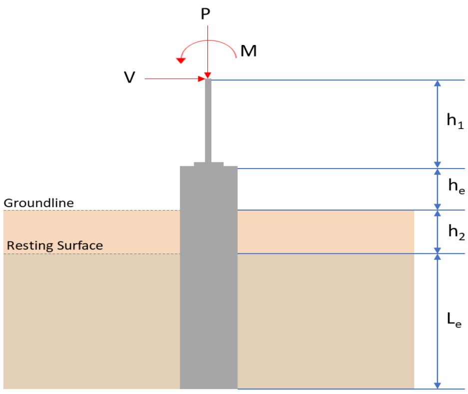
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4.5\ \mathrm{ft}$ - 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)	5.852	8.567
V_x (kip)	-0.240	-0.400
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	7.429	12.653

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.24\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.038217\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.429\ \text{kipft}) + ((-0.24\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.183\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.3894\ \text{ft}$ - 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,

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

$$L_{e,req} = MAX[(4.3894\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 4.389\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.389\ \text{ft})}{(4.5\ \text{ft})}$$

$$Ratio = 0.97533$$

Status: PASS
Ratio: 0.980

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.852\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.36575\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.36575\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.18288$$

Status: PASS
Ratio: 0.180

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.038217\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.183\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.183\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.038217\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (1.183\ \mathrm{kipft/ft})) + (4 \times (-0.038217\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0331\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.183\ \mathrm{kipft/ft})) + (3 \times (-0.038217\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^2}{(4.5\ \mathrm{ft})^2 \times [(3 \times (1.183\ \mathrm{kipft/ft})) + (2 \times (-0.038217\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 0.2054\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.183\ \mathrm{kipft/ft})) + ((-0.038217\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.65006\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.0331\ \mathrm{ft})}{2}$$

$$p_a = 0.22748\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.2054\ \mathrm{kip/ft^2}\right)}{\left(0.22748\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90292$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

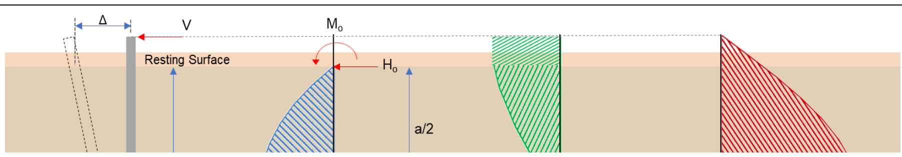
$Ratio$ - Lateral soil capacity

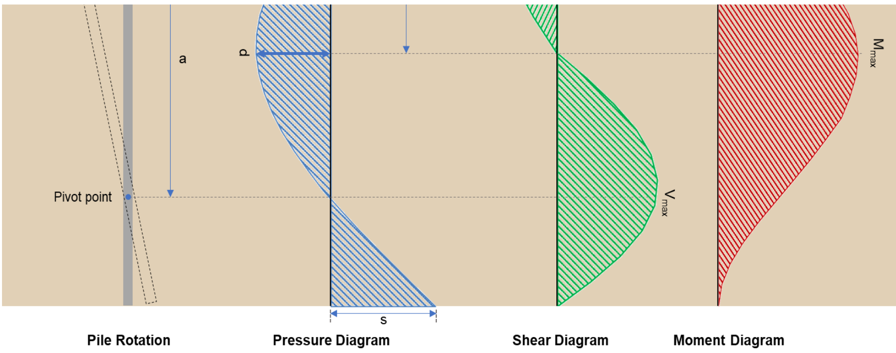
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(0.65006\ \mathrm{kip/ft^2}\right)}{\left(0.675\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96305$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.4\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.063694\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.653\text{ kipft}) + ((-0.4\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 2.0148\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.0148\text{ kipft/ft})}{(-0.063694\text{ kip/ft})}$$

$$E = 31.632\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.0148\text{ kipft/ft}) \times (4.5\text{ ft})) + \left(3 \times (-0.063694\text{ kip/ft}) \times (4.5\text{ ft})^2\right)}{(6 \times (2.0148\text{ kipft/ft})) + (4 \times (-0.063694\text{ kip/ft}) \times (4.5\text{ ft}))}$$

$$a = 3.0325\text{ ft}$$

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

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

$$V_{max} = ((-0.063694\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.632\text{ ft})}{(4.5\text{ ft})} + 3\right) \times \left(\frac{(3.0325\text{ ft})}{(4.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.632\text{ ft})}{(4.5\text{ ft})} + 2\right) \times \left(\frac{(3.0325\text{ ft})}{(4.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 3.3455\text{ kip}$$

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

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

$$M_{max} = ((-0.063694\text{ kip/ft}) \times (48\text{ in}) \times (4.5\text{ ft})) \times \left[\left(\frac{(31.632\text{ ft})}{(4.5\text{ ft})} + \frac{(3.0325\text{ ft})}{2 \times (4.5\text{ ft})}\right) - \left[\left(\frac{4 \times (31.632\text{ ft})}{(4.5\text{ ft})} + 3\right) \times \left(\frac{(3.0325\text{ ft})}{2 \times (4.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (31.632\text{ ft})}{(4.5\text{ ft})} + 2\right) \times \left(\frac{(3.0325\text{ ft})}{2 \times (4.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 7.422 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(8.567 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.311 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.311 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

	Ties: **#3(0.375 in) - 10 in**	

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(8.567\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0032024$$	Status: **PASS** Ratio: **0.000**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 48\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,max} = 296.21\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 8.567\ \text{kip} \rightarrow 8567\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(8567\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 119.63\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,b} = 348.89\ \text{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \text{kip}), (119.63\ \text{kip}), (348.89\ \text{kip})\right]$$ $$V_c = 119.63\ \text{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.63\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 110.84\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 3.3455\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(3.3455\ \mathrm{kip})}{(110.84\ \mathrm{kip})}$$

$$Ratio = 0.030184$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 7.422\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.422\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.029736$$

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

REFERENCES	CALCULATIONS	RESULTS

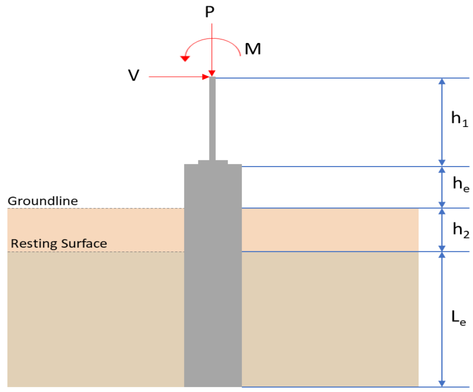
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 4.5$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.940	8.697
V_x (kip)	-0.243	-0.405
V_z (kip)	0.015	0.022
M_x (kipft)	0.038	0.056
M_z (kipft)	7.320	12.453

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.243 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.038694 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.32\ \text{kipft}) + ((-0.243\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.1656\ \text{kipft/ft}$$

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:
$L_{e,x} = 4.3641\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.015\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0023885\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.038\ \text{kipft}) + ((0.015\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.006051\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.84591\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.3641\ \text{ft}), (0.84591\ \text{ft})]$$

$$L_{e,req} = 4.364\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.364\ \text{ft})}{(4.5\ \text{ft})}$$

$$Ratio = 0.96978$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.94\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.37125\ \text{kip/ft}^2$$

$$q = 0.37125 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.37125 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.18563$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.038694 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 1.1656 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.1656 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (-0.038694 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (1.1656 \text{ kipft/ft})) + (4 \times (-0.038694 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.034 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.1656 \text{ kipft/ft})) + (3 \times (-0.038694 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.1656 \text{ kipft/ft})) + (2 \times (-0.038694 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.20162 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.1656 \text{ kipft/ft})) + ((-0.038694 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.63914 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.034 \text{ ft})}{2}$$

$$p_a = 0.22755 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.20162 \text{ kip/ft}^2\right)}{\left(0.22755 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.88606$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.63914\ \mathrm{kip/ft^2}\right)}{\left(0.675\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94687$$

Status: PASS
Ratio: 0.950

Considering z-direction:

$H_o = 0.0023885\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.006051\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.006051\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (0.006051\ \mathrm{kipft/ft})) + (4 \times (0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.2033\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.006051\ \mathrm{kipft/ft})) + (3 \times (0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^{\ 2}}{(4.5\ \mathrm{ft})^2 \times [(3 \times (0.006051\ \mathrm{kipft/ft})) + (2 \times (0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 0.0029765\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.006051\ \mathrm{kipft/ft})) + ((0.0023885\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.0067705\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.2033\ \mathrm{ft})}{2}$$

$$p_a = 0.24025\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0029765\ \mathrm{kip/ft^2}\right)}{\left(0.24025\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.012389$$

Status: PASS
Ratio: 0.010

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

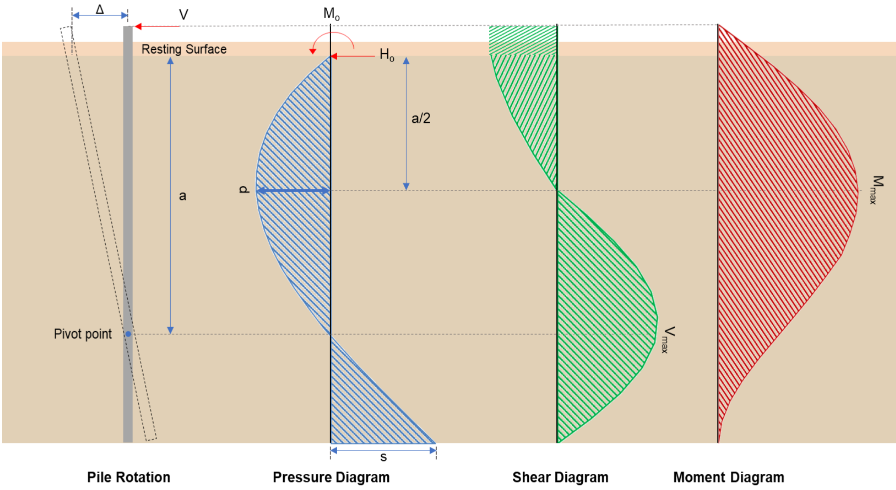
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0067705\ \mathrm{kip/ft^2})}{(0.675\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.01003$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.405\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.06449\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.453\ \mathrm{kipft}) + ((-0.405\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 1.983\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.983\ \mathrm{kipft/ft})}{(-0.06449\ \mathrm{kip/ft})}$$

$$E = 30.748\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.983\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.06449\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (1.983\ \mathrm{kipft/ft})) + (4 \times (-0.06449\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0333\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.06449\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (30.748\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.0333\ \mathrm{ft})}{(4.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (30.748\ \mathrm{ft})}{(4.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.0333\ \mathrm{ft})}{(4.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 3.2973\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.06449\text{ kip/ft}) \times (48\text{ in}) \times (4.5\text{ ft})) \times \left[\left(\frac{(30.748\text{ ft})}{(4.5\text{ ft})} + \frac{(3.0333\text{ ft})}{2 \times (4.5\text{ ft})}\right) - \left[\left(\frac{4 \times (30.748\text{ ft})}{(4.5\text{ ft})} + 3\right) \times \left(\frac{(3.0333\text{ ft})}{2 \times (4.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (30.748\text{ ft})}{(4.5\text{ ft})} + 2\right) \times \left(\frac{(3.0333\text{ ft})}{2 \times (4.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 7.3121\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.022\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.0035032\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.056\text{ kipft}) + ((0.022\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.0089172\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0089172\text{ kipft/ft})}{(0.0035032\text{ kip/ft})}$$

$$E = 2.5455\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0089172\text{ kipft/ft}) \times (4.5\text{ ft})) + \left(3 \times (0.0035032\text{ kip/ft}) \times (4.5\text{ ft})^2\right)}{(6 \times (0.0089172\text{ kipft/ft})) + (4 \times (0.0035032\text{ kip/ft}) \times (4.5\text{ ft}))}$$

$$a = 3.2029\text{ ft}$$

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

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

$$V_{max} = ((0.0035032\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.5455\text{ ft})}{(4.5\text{ ft})} + 3\right) \times \left(\frac{(3.2029\text{ ft})}{(4.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.5455\text{ ft})}{(4.5\text{ ft})} + 2\right) \times \left(\frac{(3.2029\text{ ft})}{(4.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.023345\text{ kip}$$

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

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

$$M_{max} = ((0.0035032\text{ kip/ft}) \times (48\text{ in}) \times (4.5\text{ ft})) \times \left[\left(\frac{(2.5455\text{ ft})}{(4.5\text{ ft})} + \frac{(3.2029\text{ ft})}{2 \times (4.5\text{ ft})}\right) - \left[\left(\frac{4 \times (2.5455\text{ ft})}{(4.5\text{ ft})} + 3\right) \times \left(\frac{(3.2029\text{ ft})}{2 \times (4.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.5455\text{ ft})}{(4.5\text{ ft})} + 2\right) \times \left(\frac{(3.2029\text{ ft})}{2 \times (4.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.046892 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(8.697 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.307 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.307 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

Ties: **#3(0.375 in) - 10 in**

	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, [A_g - A_{st}]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(8.697\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.003251$$	Status: **PASS** Ratio: **0.000**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 48\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,max} = 296.21\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 8.697\ \text{kip} \rightarrow 8697\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(8697\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 119.64\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,b} = 348.89\ \text{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \text{kip}), (119.64\ \text{kip}), (348.89\ \text{kip})\right]$$ $$V_c = 119.64\ \text{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.64 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.85 \text{ kip}$$

Considering x-direction:

$V_{max} = 3.2973 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(3.2973 \text{ kip})}{(110.85 \text{ kip})}$$

$$Ratio = 0.029745$$

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

Considering z-direction:

$V_{max} = 0.023345 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.023345 \text{ kip})}{(110.85 \text{ kip})}$$

$$Ratio = 0.0002106$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 7.3121 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(7.3121 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.029295$$	Status: **PASS** Ratio: **0.030**
	Considering z-direction: $M_{max} = 0.046892 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.046892 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00018787$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

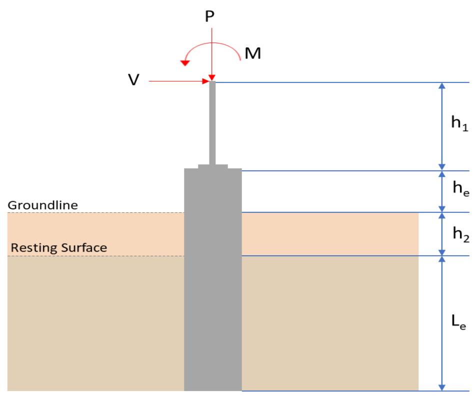
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4.5\ \mathrm{ft}$ - 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)	5.141	7.515
V_x (kip)	-0.211	-0.354
V_z (kip)	-0.118	-0.175
M_x (kipft)	-0.286	-0.425
M_z (kipft)	6.635	11.287

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.211\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.033599\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(6.635 \text{ kipft}) + ((-0.211 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.0565 \text{ kipft/ft}$$

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:
$L_{e,x} = 4.2355 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.118 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.01879 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.286 \text{ kipft}) + ((-0.118 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.045541 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.2969 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.2355 \text{ ft}), (1.2969 \text{ ft})]$$

$$L_{e,req} = 4.236 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(4.236 \text{ ft})}{(4.5 \text{ ft})}$$

$$Ratio = 0.94133$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.141 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.32131 \text{ kip/ft}^2$$

$q = 0.32131\ \mathrm{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.32131\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.16066$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.125$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.033599\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 1.0565\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.0565\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (1.0565\ \mathrm{kipft/ft})) + (4 \times (-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.0327\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.0565\ \mathrm{kipft/ft})) + (3 \times (-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^{\ 2}}{(4.5\ \mathrm{ft})^2 \times [(3 \times (1.0565\ \mathrm{kipft/ft})) + (2 \times (-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = 0.18384\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (1.0565\ \mathrm{kipft/ft})) + ((-0.033599\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.58129\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.0327\ \mathrm{ft})}{2}$$

$$p_a = 0.22745\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18384\ \mathrm{kip/ft}^2\right)}{\left(0.22745\ \mathrm{kip/ft}^2\right)}$$

$$Ratio = 0.80828$$

Status: **PASS**
Ratio: **0.810**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.58129\ \mathrm{kip/ft^2}\right)}{\left(0.675\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.86117$$

Status: **PASS**
Ratio: **0.860**

Considering z-direction:

$H_o = -0.01879\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.045541\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.045541\ \mathrm{kipft/ft}) \times (4.5\ \mathrm{ft})) + \left(3 \times (-0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft})^2\right)}{(6 \times (0.045541\ \mathrm{kipft/ft})) + (4 \times (-0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))}$$

$$a = 3.2074\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.045541\ \mathrm{kipft/ft})) + (3 \times (-0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]^{\ 2}}{(4.5\ \mathrm{ft})^2 \times [(3 \times (0.045541\ \mathrm{kipft/ft})) + (2 \times (-0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}$$

$$p = -0.0058283\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.045541\ \mathrm{kipft/ft})) + ((-0.01879\ \mathrm{kip/ft}) \times (4.5\ \mathrm{ft}))]}{(4.5\ \mathrm{ft})^2}$$

$$s = 0.0019344\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.2074\ \mathrm{ft})}{2}$$

$$p_a = 0.24056\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0058283\ \mathrm{kip/ft^2}\right)}{\left(0.24056\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.024228$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4.5\ \mathrm{ft})$$

$$p_s = 0.675\ \mathrm{kip/ft^2}$$

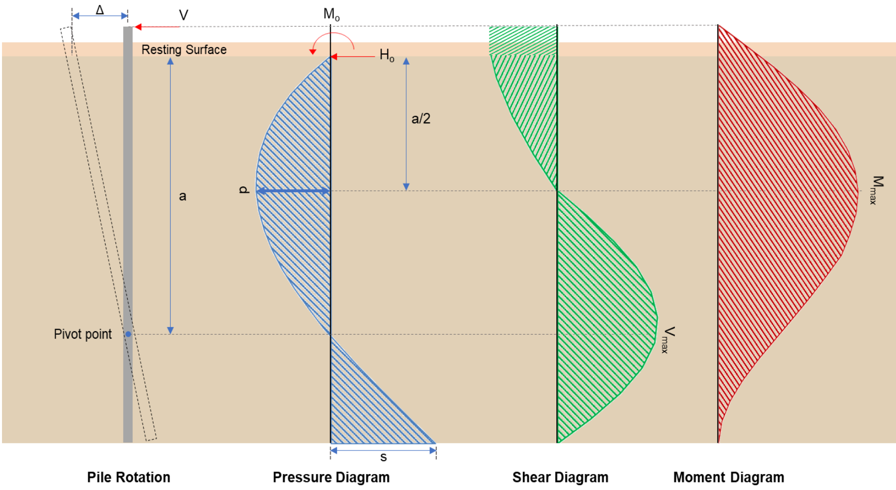
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0019344\ \text{kip/ft}^2)}{(0.675\ \text{kip/ft}^2)}$$

$$Ratio = 0.0028658$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.354\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.056369\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(11.287\ \text{kipft}) + ((-0.354\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 1.7973\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.7973\ \text{kipft/ft})}{(-0.056369\ \text{kip/ft})}$$

$$E = 31.884\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.7973\ \text{kipft/ft}) \times (4.5\ \text{ft})) + \left(3 \times (-0.056369\ \text{kip/ft}) \times (4.5\ \text{ft})^2\right)}{(6 \times (1.7973\ \text{kipft/ft})) + (4 \times (-0.056369\ \text{kip/ft}) \times (4.5\ \text{ft}))}$$

$$a = 3.0322\ \text{ft}$$

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

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

$$V_{max} = ((-0.056369\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.884\ \text{ft})}{(4.5\ \text{ft})} + 3\right) \times \left(\frac{(3.0322\ \text{ft})}{(4.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.884\ \text{ft})}{(4.5\ \text{ft})} + 2\right) \times \left(\frac{(3.0322\ \text{ft})}{(4.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 2.9832\ \text{kip}$$

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

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

$$M_{max} = ((-0.056369 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(31.884 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0322 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (31.884 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0322 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (31.884 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0322 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 6.6189 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.175 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.027866 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.425 \text{ kipft}) + ((-0.175 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.067675 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.067675 \text{ kipft/ft})}{(-0.027866 \text{ kip/ft})}$$

$$E = 2.4286 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.067675 \text{ kipft/ft}) \times (4.5 \text{ ft})) + \left(3 \times (-0.027866 \text{ kip/ft}) \times (4.5 \text{ ft})^2\right)}{(6 \times (0.067675 \text{ kipft/ft})) + (4 \times (-0.027866 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.2072 \text{ ft}$$

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

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

$$V_{max} = ((-0.027866 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4286 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.2072 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.4286 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.2072 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.18063 \text{ kip}$$

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

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

$$M_{max} = ((-0.027866 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(2.4286 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.2072 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.4286 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.2072 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.4286 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.2072 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

	$$M_{max} = 0.36162 \text{ kipft}$$		

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.515 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.346 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.346 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

Main reinforcement: **14 - #5 (0.625 in)**

	Ties: **#3(0.375 in) - 10 in**	

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.515\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.0028092$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 7.515\ \mathrm{kip} \rightarrow 7515\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(7515\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.49\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.49\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.49\ \mathrm{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\ b_w\ d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$ $$V_{s,a} = 737.28\ \mathrm{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\ d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \mathrm{in})^2}{4}$$ $$A_v = 0.11045\ \mathrm{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\ A_v\ f_{ywk}\ d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \mathrm{in}^2\right) \times (60\ \mathrm{ksi}) \times (38.4\ \mathrm{in})}{(10\ \mathrm{in})}$$ $$V_{s,b} = 50.894\ \mathrm{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \mathrm{kip}), (50.894\ \mathrm{kip})\right]$$ $$V_s = 50.894\ \mathrm{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((119.49\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$ $$\phi V_n = 110.75\ \mathrm{kip}$$ **Considering x-direction:** $V_{max} = 2.9832\ \mathrm{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(2.9832\ \mathrm{kip})}{(110.75\ \mathrm{kip})}$$ $$Ratio = 0.026937$$	Status: **PASS** Ratio: **0.030**
	Considering z-direction: $V_{max} = 0.18063\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.18063\ \mathrm{kip})}{(110.75\ \mathrm{kip})}$$ $$Ratio = 0.001631$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\ D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$	

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 6.6189 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(6.6189 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.026518$$	Status: **PASS** Ratio: **0.030**
	Considering z-direction: $M_{max} = 0.36162 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.36162 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0014488$$	Status: **PASS** Ratio: **0.000**