Project Details

Project Name: Tampa

Location: 5305 Garden Ln, Tampa, FL 33610, USA

Unique ID: 5P-19.75-6TOP-HD-57-L-4Hx17W-27FL

Dealer: ______________________________

Date: Wed Jul 23 2025

Number of Modules: 68

Number of Poles: 5

Date Sold: ______________________________

Array Dimensions N/S	15.05 ft
Array Dimensions E/W	97.45 ft
Winter Tilt Angle	5
Front Edge Clearance	10 ft

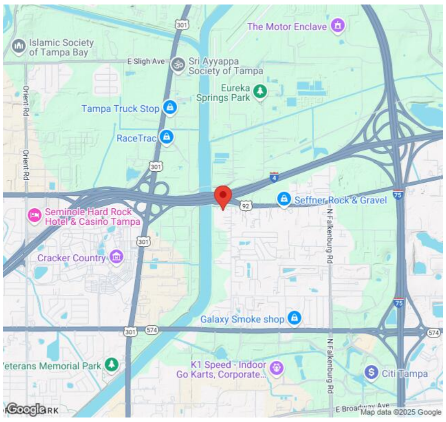
MT Solar Bill of Materials (5P-19.75-6TOP-HD-57-L-4Hx17W-27FL)

Part	Short Description	BOM Qty
MTS-PC-6	6IN Pole Cap Assembly	5
MTS-HF-HD	H-Frame Assembly-HD	5
MTS-HD-Wing-57	57IN HD Wing	4
MTS-HD-Splice-90	90IN HD Splice	8
MTS-HD-Splice-57	57IN HD Splice	8
MTS-CLAMP-HOOK-4PK	Hook Clamp	17

Rail Bill of Materials

Part	Qty
Rails (181in)	34
Rail Attachment	68
Module Mid Clamp	102
Module End Clamp	68
Ground Lug	17

Site Details:



Site Address: 5305 Garden Ln, Tampa, FL 33610, USA

Array Specification

Duty Classification:	HD
Module Width:	44.65 in
Module Length:	67.79in
Number of Rows:	4
Number of Columns:	17
Total Number of Modules:	68
Winter Tilt Angle:	5
Front Edge Clearance:	10
Total Array Height at Tilt:	11.31 ft
Total Frame Length:	96.00 ft
Module Info/Notes:	JKM430N-54HL4-B
Array Dimensions N/S:	15.05 ft
Array Dimensions E/W:	97.45 ft
Rail Length:	180.60 in
Rail Spacing:	2.87 ft

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	10.66 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: 5.50 ft Pile 2: 5.50 ft Pile 3: 5.50 ft Pile 4: 5.50 ft Pile 5: 5.50 ft
Foundation Volume:	16.296 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	5305 Garden Ln, Tampa, FL 33610, USA
Wind Speed:	130 mph

Snow Load:	0 psf

Design Disclaimer

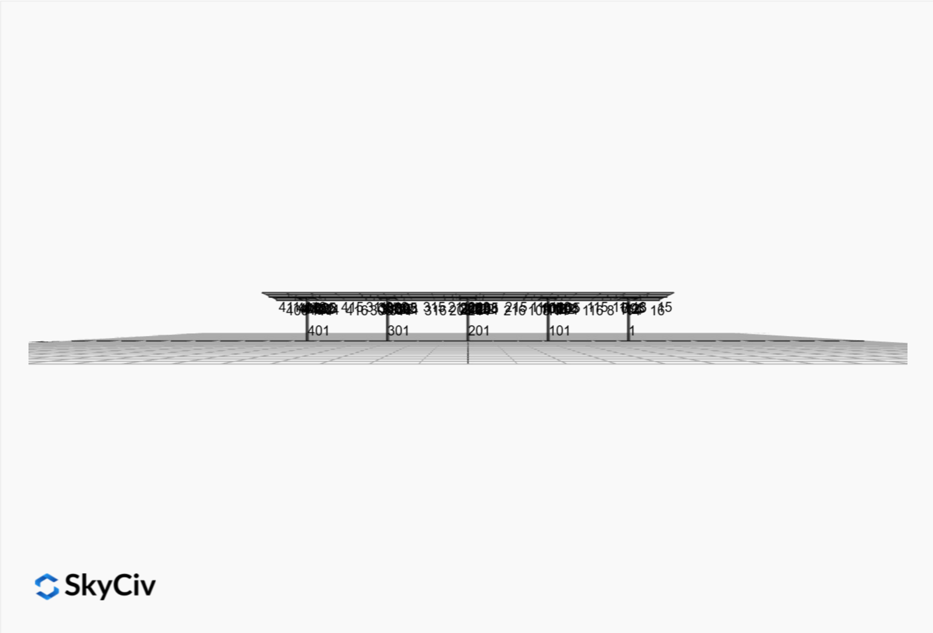
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

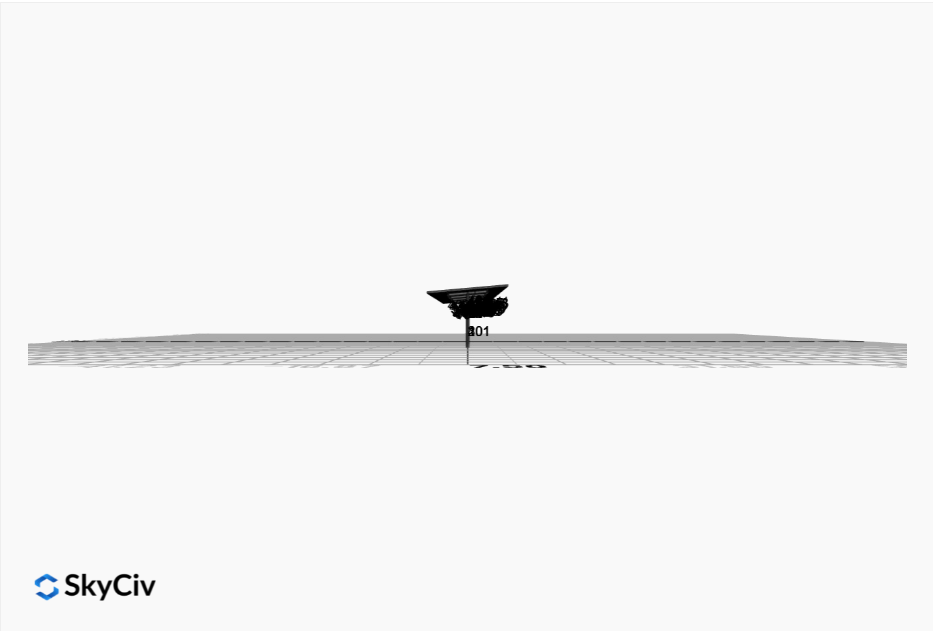
AutoDesigner Input

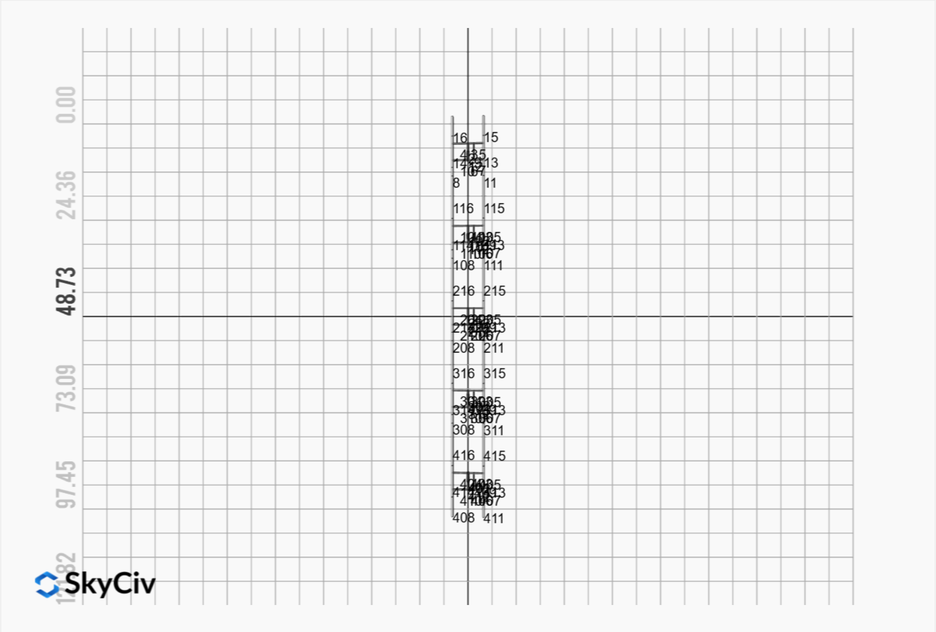
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","designer_name":"Jaime","designer_email":"jaime@gosolarpower.com","designer_phone":"5614031089","project_id":"Tampa","site_address":"5305 Garden Ln, Tampa, FL 33610, USA","module_info":"JKM430N-54HL4-B","module_width":44.65,"module_length":67.79,"number_rows":"4","number_columns":17,"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":10,"risk_category":"I","exposure_category":"C","frame_duty_override":"HD","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}

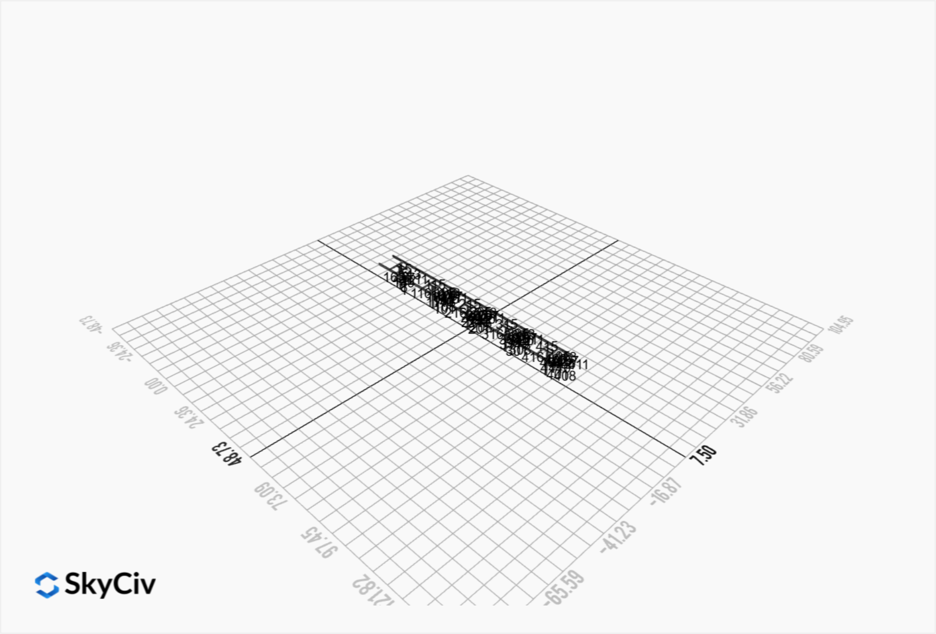
Design Notes:

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

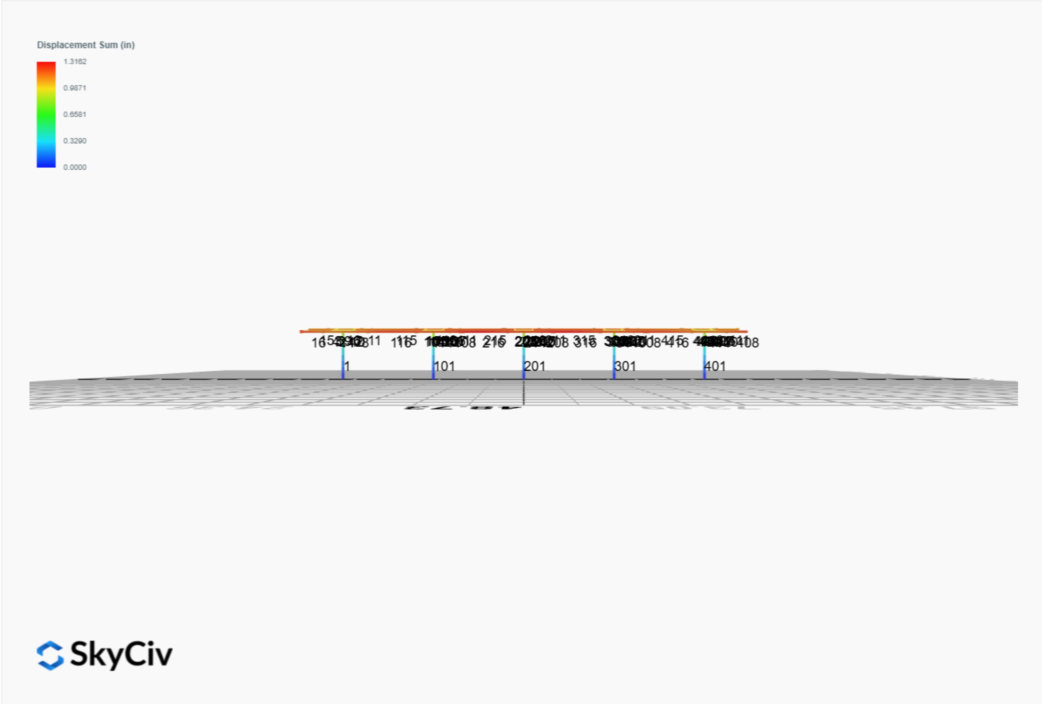


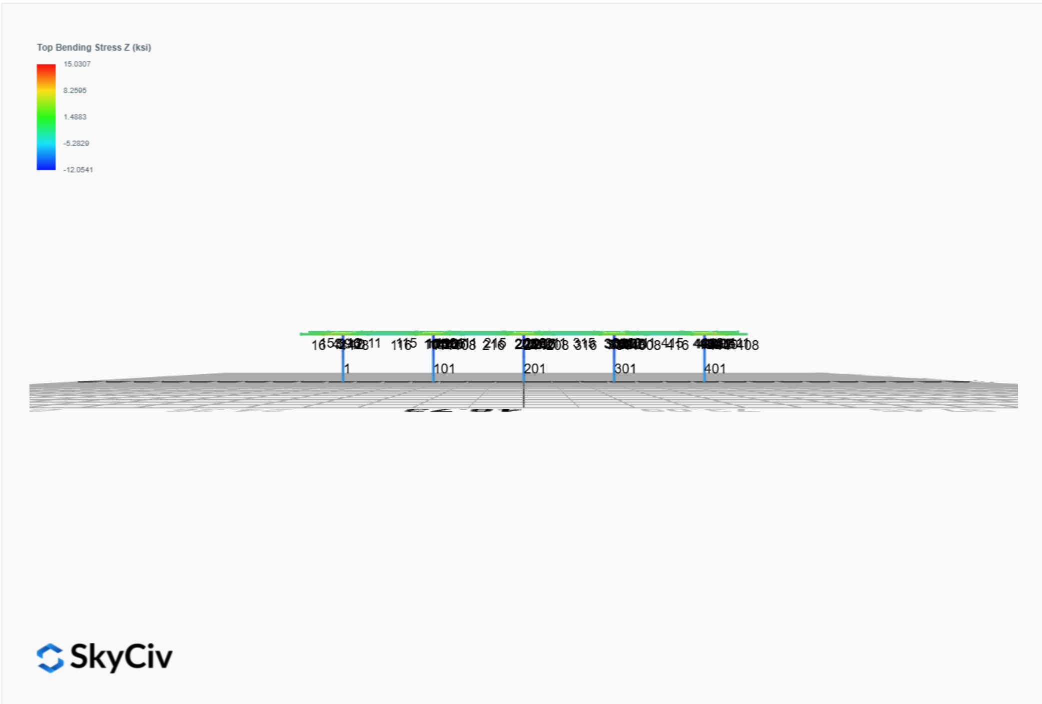


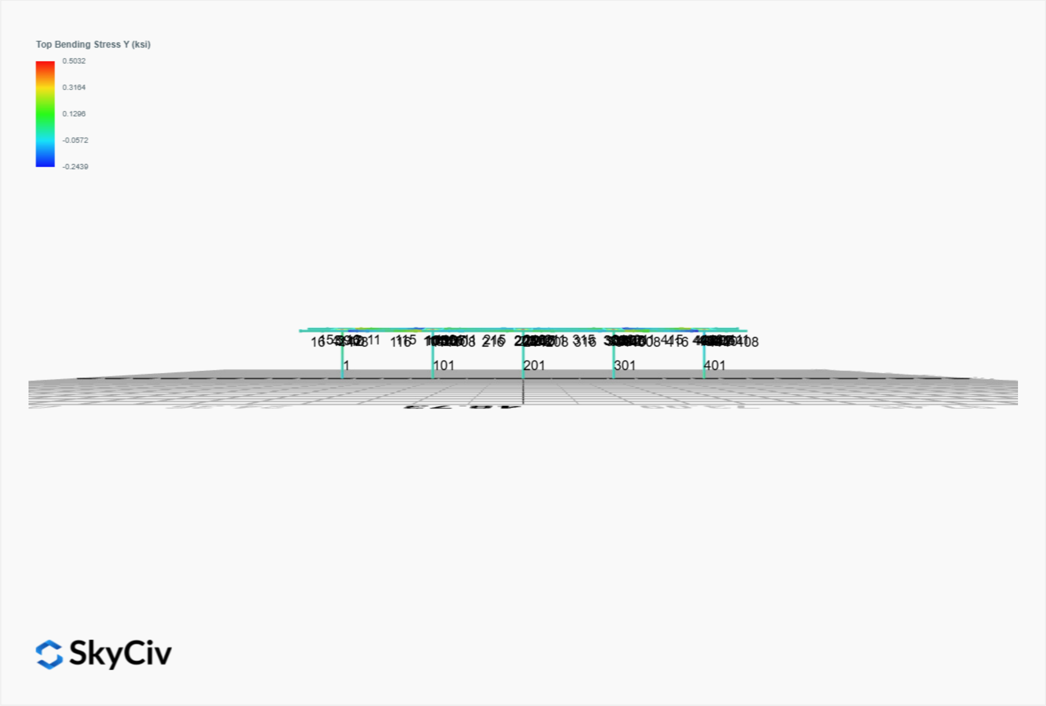


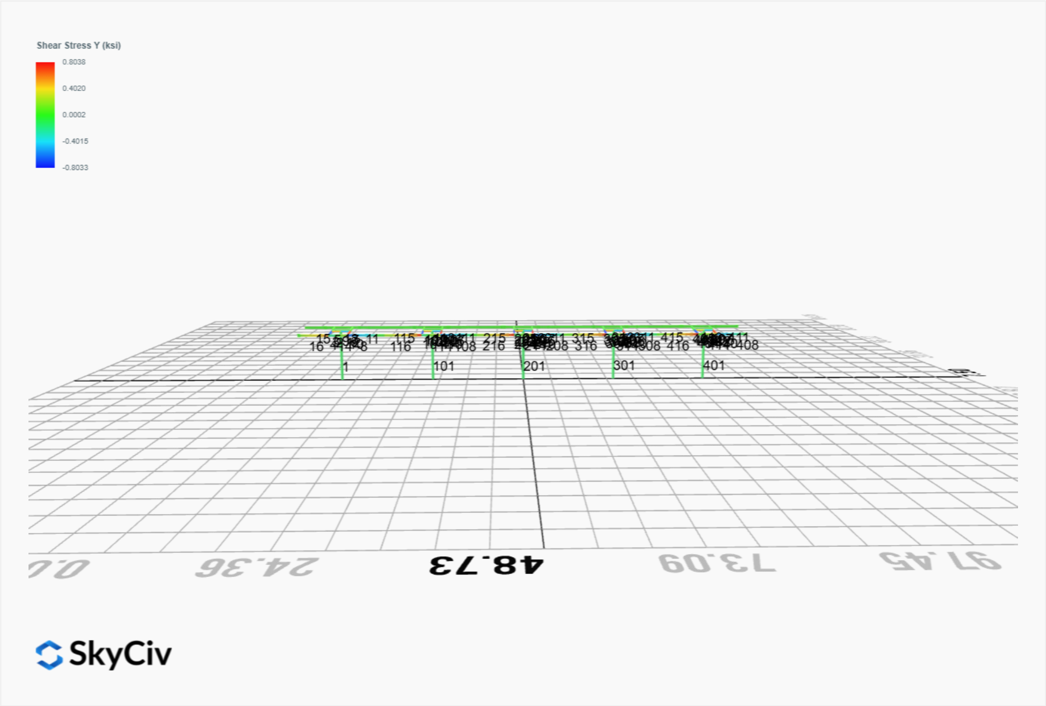


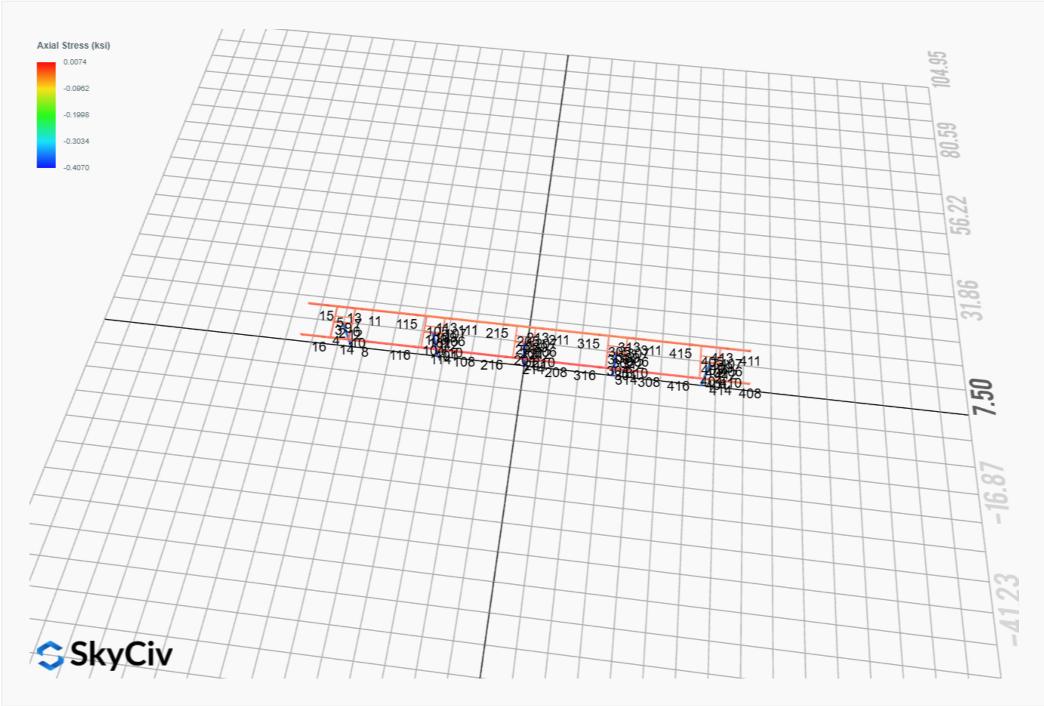
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
0.5032
0.3164
0.1296
-0.0572
-0.2439
1
101
201
301
401
SkyCiv


Shear Stress Y (ksi)
0.8038
0.4020
0.0002
-0.4015
-0.8033
1
101
201
301
401
SkyCiv


Axial Stress (ksi)
0.0074
-0.0962
-0.1998
-0.3034
-0.4070
104.95
80.59
56.22
31.86
7.50
-16.87
-41.23

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	-0.0008	2.1141	-0.0052	-0.0172	0.0018	0.0355
ULS: 2. D + L	-0.0008	2.1141	-0.0052	-0.0172	0.0018	0.0355
ULS: 3. D + (S or Lr or R)	-0.0008	2.1141	-0.0052	-0.0172	0.0018	0.0355
ULS: 3. D + (S or Lr or R)	-0.0008	2.1141	-0.0052	-0.0172	0.0018	0.0355
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0008	2.1141	-0.0052	-0.0172	0.0018	0.0355
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0008	2.1141	-0.0052	-0.0172	0.0018	0.0355
ULS: 5b. D + 0.7E	-0.0008	2.1141	-0.0052	-0.0172	0.0018	0.0355
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0008	2.1141	-0.0052	-0.0172	0.0018	0.0355
ULS: 8. 0.6D + 0.7E	-0.0005	1.2685	-0.0031	-0.0103	0.0011	0.0213
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4162	6.8181	-0.0185	-0.0624	0.0033	5.6413
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4162	6.8181	-0.0185	-0.0624	0.0033	5.6413
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1070	0.8451	-0.0007	-0.0023	-0.0009	3.6094
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2708	-0.8731	0.0018	0.0065	0.0049	-13.0026
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3123	5.6421	-0.0152	-0.0511	0.0029	4.2399
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3123	5.6421	-0.0152	-0.0511	0.0029	4.2399
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0801	1.1624	-0.0018	-0.0060	-0.0003	2.7159
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2029	-0.1263	0.0000	0.0006	0.0042	-9.7431
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3123	5.6421	-0.0152	-0.0511	0.0029	4.2399
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3123	5.6421	-0.0152	-0.0511	0.0029	4.2399
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0801	1.1624	-0.0018	-0.0060	-0.0003	2.7159
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2029	-0.1263	0.0000	0.0006	0.0042	-9.7431
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4159	5.9725	-0.0165	-0.0555	0.0025	5.6271
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4159	5.9725	-0.0165	-0.0555	0.0025	5.6271
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1073	-0.0005	0.0014	0.0046	-0.0016	3.5952
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2711	-1.7187	0.0038	0.0134	0.0042	-13.0168

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.3769
Shear X	-0.6935
Shear Z	-0.0285
Moment X	-0.0962
Moment Y (Twist)	0.0077
Moment Z	22.2046

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.8181
Shear X	-0.4162
Shear Z	-0.0185
Moment X	-0.0624
Moment Y (Twist)	0.0049
Moment Z	13.0168

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	0.0011	2.2120	0.0025	0.0082	-0.0011	0.0203
ULS: 2. D + L	0.0011	2.2120	0.0025	0.0082	-0.0011	0.0203
ULS: 3. D + (S or Lr or R)	0.0011	2.2120	0.0025	0.0082	-0.0011	0.0203
ULS: 3. D + (S or Lr or R)	0.0011	2.2120	0.0025	0.0082	-0.0011	0.0203
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0011	2.2120	0.0025	0.0082	-0.0011	0.0203

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0011	2.2120	0.0025	0.0082	-0.0011	0.0203
ULS: 5b. D + 0.7E	0.0011	2.2120	0.0025	0.0082	-0.0011	0.0203
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0011	2.2120	0.0025	0.0082	-0.0011	0.0203
ULS: 8. 0.6D + 0.7E	0.0007	1.3272	0.0015	0.0049	-0.0007	0.0122
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4317	7.1862	0.0101	0.0328	-0.0054	5.8665
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4317	7.1862	0.0101	0.0328	-0.0054	5.8665
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1205	0.8694	0.0013	0.0040	-0.0029	3.6976
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2711	-0.9458	-0.0035	-0.0107	0.0067	-13.4559
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3235	5.9426	0.0082	0.0267	-0.0044	4.4050
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3235	5.9426	0.0082	0.0267	-0.0044	4.4050
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0907	1.2050	0.0016	0.0051	-0.0024	2.7783
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2036	-0.1564	-0.0020	-0.0060	0.0047	-10.0869
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3235	5.9426	0.0082	0.0267	-0.0044	4.4050
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3235	5.9426	0.0082	0.0267	-0.0044	4.4050
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0907	1.2050	0.0016	0.0051	-0.0024	2.7783
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2036	-0.1564	-0.0020	-0.0060	0.0047	-10.0869
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4321	6.3014	0.0091	0.0295	-0.0050	5.8584
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4321	6.3014	0.0091	0.0295	-0.0050	5.8584
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1201	-0.0154	0.0002	0.0007	-0.0024	3.6895
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2707	-1.8306	-0.0045	-0.0140	0.0071	-13.4641

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.9447
Shear X	-0.7213
Shear Z	0.0157
Moment X	0.0512
Moment Y (Twist)	0.0130
Moment Z	22.9822

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.1862
Shear X	-0.4321
Shear Z	0.0101
Moment X	0.0328
Moment Y (Twist)	0.0071
Moment Z	13.4641

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	-0.0007	2.2393	0.0001	-0.0000	-0.0001	0.0338
ULS: 2. D + L	-0.0007	2.2393	0.0001	-0.0000	-0.0001	0.0338
ULS: 3. D + (S or Lr or R)	-0.0007	2.2393	0.0001	-0.0000	-0.0001	0.0338
ULS: 3. D + (S or Lr or R)	-0.0007	2.2393	0.0001	-0.0000	-0.0001	0.0338
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0007	2.2393	0.0001	-0.0000	-0.0001	0.0338
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0007	2.2393	0.0001	-0.0000	-0.0001	0.0338
ULS: 5b. D + 0.7E	-0.0007	2.2393	0.0001	-0.0000	-0.0001	0.0338
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0007	2.2393	0.0001	-0.0000	-0.0001	0.0338
ULS: 8. 0.6D + 0.7E	-0.0004	1.3436	0.0000	-0.0000	-0.0000	0.0203
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4397	7.2899	0.0002	-0.0001	-0.0002	5.9698
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4397	7.2899	0.0002	-0.0001	-0.0002	5.9698
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1212	0.8763	0.0000	0.0000	-0.0001	3.7606
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2720	-0.9674	-0.0001	-0.0000	0.0002	-13.6252

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	-0.3299	6.0272	0.0002	-0.0000	-0.0002	4.4858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3299	6.0272	0.0002	-0.0000	-0.0002	4.4858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0907	1.2171	0.0000	0.0000	-0.0001	2.8289
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2038	-0.1657	-0.0000	-0.0000	0.0001	-10.2105
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3299	6.0272	0.0002	-0.0000	-0.0002	4.4858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3299	6.0272	0.0002	-0.0000	-0.0002	4.4858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0907	1.2171	0.0000	0.0000	-0.0001	2.8289
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2038	-0.1657	-0.0000	-0.0000	0.0001	-10.2105
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4394	6.3942	0.0002	-0.0001	-0.0002	5.9562
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4394	6.3942	0.0002	-0.0001	-0.0002	5.9562
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1215	-0.0194	-0.0000	0.0000	-0.0001	3.7471
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2723	-1.8631	-0.0001	-0.0000	0.0002	-13.6387

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	11.1048
Shear X	-0.7322
Shear Z	0.0004
Moment X	-0.0001
Moment Y (Twist)	0.0004
Moment Z	23.2833

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.2899
Shear X	-0.4397
Shear Z	0.0002
Moment X	-0.0001
Moment Y (Twist)	0.0002
Moment Z	13.6387

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	0.0011	2.2119	-0.0027	-0.0094	0.0013	0.0203
ULS: 2. D + L	0.0011	2.2119	-0.0027	-0.0094	0.0013	0.0203
ULS: 3. D + (S or Lr or R)	0.0011	2.2119	-0.0027	-0.0094	0.0013	0.0203
ULS: 3. D + (S or Lr or R)	0.0011	2.2119	-0.0027	-0.0094	0.0013	0.0203
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0011	2.2119	-0.0027	-0.0094	0.0013	0.0203
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0011	2.2119	-0.0027	-0.0094	0.0013	0.0203
ULS: 5b. D + 0.7E	0.0011	2.2119	-0.0027	-0.0094	0.0013	0.0203
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0011	2.2119	-0.0027	-0.0094	0.0013	0.0203
ULS: 8. 0.6D + 0.7E	0.0007	1.3271	-0.0016	-0.0056	0.0008	0.0122
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4316	7.1860	-0.0109	-0.0373	0.0056	5.8665
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4316	7.1860	-0.0109	-0.0373	0.0056	5.8665
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1205	0.8694	-0.0013	-0.0043	0.0029	3.6979
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2711	-0.9458	0.0036	0.0116	-0.0063	-13.4565
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3235	5.9425	-0.0089	-0.0303	0.0045	4.4049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3235	5.9425	-0.0089	-0.0303	0.0045	4.4049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0907	1.2050	-0.0017	-0.0056	0.0025	2.7785
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2036	-0.1564	0.0020	0.0063	-0.0044	-10.0873
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3235	5.9425	-0.0089	-0.0303	0.0045	4.4049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3235	5.9425	-0.0089	-0.0303	0.0045	4.4049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0907	1.2050	-0.0017	-0.0056	0.0025	2.7785
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2036	-0.1564	0.0020	0.0063	-0.0044	-10.0873

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4321	6.3013	-0.0098	-0.0335	0.0051	5.8584
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4321	6.3013	-0.0098	-0.0335	0.0051	5.8584
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1201	-0.0154	-0.0002	-0.0005	0.0024	3.6898
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2707	-1.8306	0.0047	0.0153	-0.0068	-13.4646

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.9445
Shear X	-0.7212
Shear Z	-0.0170
Moment X	-0.0581
Moment Y (Twist)	0.0126
Moment Z	22.9832

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	7.1860
Shear X	-0.4321
Shear Z	-0.0109
Moment X	-0.0373
Moment Y (Twist)	0.0068
Moment Z	13.4646

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	-0.0008	2.1141	0.0053	0.0172	-0.0020	0.0355
ULS: 2. D + L	-0.0008	2.1141	0.0053	0.0172	-0.0020	0.0355
ULS: 3. D + (S or Lr or R)	-0.0008	2.1141	0.0053	0.0172	-0.0020	0.0355
ULS: 3. D + (S or Lr or R)	-0.0008	2.1141	0.0053	0.0172	-0.0020	0.0355
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0008	2.1141	0.0053	0.0172	-0.0020	0.0355
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0008	2.1141	0.0053	0.0172	-0.0020	0.0355
ULS: 5b. D + 0.7E	-0.0008	2.1141	0.0053	0.0172	-0.0020	0.0355
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0008	2.1141	0.0053	0.0172	-0.0020	0.0355
ULS: 8. 0.6D + 0.7E	-0.0005	1.2685	0.0032	0.0103	-0.0012	0.0213
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.4162	6.8181	0.0191	0.0625	-0.0036	5.6414
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.4162	6.8181	0.0191	0.0625	-0.0036	5.6414
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.1070	0.8451	0.0007	0.0023	0.0008	3.6100
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.2708	-0.8731	-0.0019	-0.0066	-0.0050	-13.0040
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3123	5.6421	0.0157	0.0512	-0.0032	4.2399
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3123	5.6421	0.0157	0.0512	-0.0032	4.2399
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0801	1.1624	0.0019	0.0061	0.0001	2.7164
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2029	-0.1263	-0.0001	-0.0007	-0.0042	-9.7441
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.3123	5.6421	0.0157	0.0512	-0.0032	4.2399
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.3123	5.6421	0.0157	0.0512	-0.0032	4.2399
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0801	1.1624	0.0019	0.0061	0.0001	2.7164
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.2029	-0.1263	-0.0001	-0.0007	-0.0042	-9.7441
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.4159	5.9724	0.0170	0.0556	-0.0028	5.6272
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.4159	5.9724	0.0170	0.0556	-0.0028	5.6272
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.1073	-0.0005	-0.0014	-0.0046	0.0016	3.5958
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.2711	-1.7187	-0.0040	-0.0135	-0.0042	-13.0181

Worst Case Reactions LRFD

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

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.3769
Shear X	-0.6935
Shear Z	0.0294
Moment X	0.0964
Moment Y (Twist)	0.0076
Moment Z	22.2070

Result	Value (kip, kip-ft)
Axial	6.8181
Shear X	-0.4162
Shear Z	0.0191
Moment X	0.0625
Moment Y (Twist)	0.0050
Moment Z	13.0181

Project Details

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

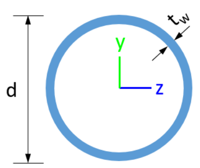
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

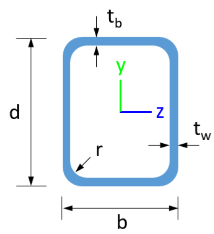
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

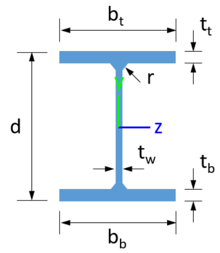
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
7	6in Pipe Sch 40	6.63	0.28					



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



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

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

2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	22.38	22.38	10.66	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
4	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.13,1.69,1.67,1.67,1.13,1.69,1.67,1.67,1.66,1.69	300	200	1
5	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
7	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
8	19	1.33	1.33	2.05	2.12,2.12,2.12,2.12,2.12,2.12,2.11,2.11,2.38,2.27,2.11,2.11,2.38,2.27,2.11,2.11,1.53,2.35,2.11,2.11,1.53,2.35,2.11,2.11,2.37,2.23	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.13,1.68,1.67,1.67,1.13,1.68,1.67,1.67,1.66,1.69	300	200	1
11	19	1.33	1.33	2.05	2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.12,2.37,2.36,2.12,2.12,2.37,2.36,2.12,2.12,2.28,2.37,2.12,2.12,2.28,2.37,2.12,2.12,2.34,2.34	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.09,1.13,1.10,1.09,1.09,1.13,1.10,1.09,1.09,1.10,1.12,1.09,1.09,1.10,1.12,1.09,1.09,1.16,1.10	300	200	1
14	19	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.14,1.30,1.09,1.09,1.14,1.30,1.09,1.09,2.20,1.14,1.09,1.09,2.20,1.14,1.09,1.09,1.11,1.50	300	200	1
15	19	9.97	9.97	4.75	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	19	9.97	9.97	4.75	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	22.38	22.38	10.66	-	300	200	1
102	5	4.20	4.20	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.11,1.68,1.67,1.67,1.11,1.68,1.67,1.67,1.65,1.69	300	200	1
105	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.66,1.67,1.66,1.66,1.66,1.67,1.66,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.65,1.66,1.66,1.67,1.66	300	200	1
106	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
108	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.08,2.08,2.07,2.07,2.08,2.08,2.07,2.07,2.24,2.07,2.07,2.07,2.24,2.07,2.07,2.07,2.07,2.09	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.12,1.68,1.67,1.67,1.12,1.68,1.67,1.67,1.66,1.69	300	200	1
111	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.08,2.07	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1

113	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.12,1.06,1.04,1.04,1.12,1.06,1.04,1.04,1.05,1.11,1.04,1.04,1.05,1.11,1.04,1.04,1.19,1.06	300	200	1
114	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.12,1.52,1.04,1.04,1.12,1.52,1.04,1.04,1.11,1.15,1.04,1.04,1.11,1.15,1.04,1.04,1.08,1.97	300	200	1
115	19	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
116	19	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.16,1.18,1.18,1.17,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.17,1.16	300	200	1
201	7	22.38	22.38	10.66	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
204	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.11,1.68,1.67,1.67,1.11,1.68,1.67,1.67,1.66,1.69	300	200	1
205	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66	300	200	1
206	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
207	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
208	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.07,2.09,2.09,2.09,2.07,2.09,2.09,2.08,2.08,2.09,2.09,2.08,2.08,2.09,2.09,2.09,2.07	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.11,1.68,1.67,1.67,1.11,1.68,1.67,1.67,1.66,1.69	300	200	1
211	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.08,2.08,2.09,2.09,2.08,2.08,2.09,2.09,2.08,2.08,2.09,2.09,2.08,2.08,2.09,2.09,2.08,2.08	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.09,1.04,1.04,1.04,1.09,1.04,1.04,1.04,1.04,1.07,1.04,1.04,1.04,1.07,1.04,1.04,1.14,1.04	300	200	1
214	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.09,1.42,1.04,1.04,1.09,1.42,1.04,1.04,1.04,1.11,1.04,1.04,1.04,1.11,1.04,1.04,1.06,1.80	300	200	1
215	19	10.20	10.20	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16	300	200	1
216	19	10.20	10.20	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.17,1.17,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.16,1.16,1.17,1.17,1.17,1.16	300	200	1
301	7	22.38	22.38	10.66	-	300	200	1
302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.12,1.68,1.67,1.67,1.12,1.68,1.67,1.67,1.65,1.68	300	200	1
305	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.66,1.67,1.66,1.66,1.66,1.67,1.66,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.65,1.66,1.66,1.67,1.66	300	200	1
306	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
307	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
308	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.06,2.01,2.07,2.07,2.06,2.01,2.07,2.07,2.02,2.06,2.07,2.07,2.02,2.06,2.07,2.07,2.07,1.92	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.11,1.68,1.67,1.67,1.11,1.68,1.67,1.67,1.66,1.69	300	200	1
311	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.07,2.06,2.06,2.07,2.07,2.06,2.06,2.07,2.07,2.07,2.06,2.07,2.07,2.07,2.06,2.07,2.07,2.06,2.06	300	200	1
312	5	4.20	4.20	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.12,1.06,1.04,1.04,1.12,1.06,1.04,1.04,1.05,1.11,1.04,1.04,1.05,1.11,1.04,1.04,1.19,1.06	300	200	1
314	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.12,1.52,1.04,1.04,1.12,1.52,1.04,1.04,1.11,1.15,1.04,1.04,1.11,1.15,1.04,1.04,1.08,1.97	300	200	1

315	19	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16	300	200	1
316	19	10.20	10.20	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.22,1.16,1.16,1.16,1.22,1.16,1.16,1.16,1.16,1.17	300	200	1
401	7	22.38	22.38	10.66	-	300	200	1
402	5	1.30	1.30	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
404	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.13,1.68,1.67,1.67,1.13,1.68,1.67,1.67,1.65,1.69	300	200	1
405	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
406	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.17,1.18,1.18,1.19,1.18	300	200	1
407	16	1.52	1.52	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.68,1.66	300	200	1
408	19	9.97	9.97	4.75	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	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.67,1.65,1.69,1.67,1.67,1.65,1.69,1.67,1.67,1.13,1.69,1.67,1.67,1.13,1.69,1.67,1.67,1.66,1.69	300	200	1
411	19	9.97	9.97	4.75	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	5	1.30	1.30	2.00	-	300	200	1
413	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.13,1.10,1.10,1.10,1.13,1.10,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.12,1.10,1.10,1.16,1.10	300	200	1
414	19	4.88	4.00	7.50	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.14,1.30,1.09,1.09,1.14,1.30,1.09,1.09,2.18,1.14,1.09,1.09,2.18,1.14,1.09,1.09,1.11,1.50	300	200	1
415	19	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.18,1.18,1.19,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.19,1.19	300	200	1
416	19	10.20	10.20	10.20	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.22,1.18,1.18,1.19,1.22,1.18,1.18,1.89,1.19,1.18,1.18,1.89,1.19,1.18,1.18,1.19,1.24	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	88.17	42.30	42.30	75.35	75.35
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	123.95	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	123.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	25.09	6.12	40.24	43.62
14	133.20	85.85	25.06	6.12	40.24	43.62
15	133.20	32.95	32.87	6.12	40.24	43.62
16	133.20	32.95	32.87	6.12	40.24	43.62
101	251.16	88.17	42.30	42.30	75.35	75.35
102	198.33	182.14	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28

104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	123.95	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	123.95	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	85.85	23.87	6.12	40.24	43.62
114	133.20	85.85	23.86	6.12	40.24	43.62
115	133.20	31.52	18.11	6.12	40.24	43.62
116	133.20	31.52	17.94	6.12	40.24	43.62
201	251.16	88.17	42.30	42.30	75.35	75.35
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	123.95	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	123.95	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	23.76	6.12	40.24	43.62
214	133.20	85.85	23.74	6.12	40.24	43.62
215	133.20	31.52	17.98	6.12	40.24	43.62
216	133.20	31.52	17.92	6.12	40.24	43.62
301	251.16	88.17	42.30	42.30	75.35	75.35
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	123.95	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	123.95	32.87	6.12	40.24	43.62
312	198.33	182.14	21.95	21.95	59.50	59.50
313	133.20	85.85	23.86	6.12	40.24	43.62
314	133.20	85.85	23.85	6.12	40.24	43.62
315	133.20	31.52	17.97	6.12	40.24	43.62
316	133.20	31.52	17.95	6.12	40.24	43.62
401	251.16	88.17	42.30	42.30	75.35	75.35
402	198.33	196.72	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28
407	116.10	114.23	15.79	11.10	42.08	23.28

407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	32.95	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	32.95	32.87	6.12	40.24	43.62
412	198.33	196.72	21.95	21.95	59.50	59.50
413	133.20	85.85	25.10	6.12	40.24	43.62
414	133.20	85.85	25.07	6.12	40.24	43.62
415	133.20	31.52	18.25	6.12	40.24	43.62
416	133.20	31.52	18.23	6.12	40.24	43.62

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.118	0.525	0.005	0.009	0.000	0.530	#16	0.598	Not Required	Pass
2	0.000	0.417	0.031	0.086	0.006	0.447	#13	0.053	Not Required	Pass
3	0.000	0.620	0.004	0.063	0.001	0.624	#13	0.045	Not Required	Pass
4	0.000	0.575	0.008	0.058	0.002	0.578	#13	0.080	Not Required	Pass
5	0.000	0.384	0.008	0.062	0.002	0.386	#13	0.074	Not Required	Pass
6	0.001	0.614	0.004	0.062	0.001	0.615	#13	0.045	Not Required	Pass
7	0.001	0.381	0.012	0.061	0.003	0.382	#13	0.074	Not Required	Pass
8	0.000	0.043	0.015	0.040	0.001	0.048	#13	0.095	Not Required	Pass
9	0.001	0.070	0.007	0.001	0.000	0.078	#13	0.204	Not Required	Pass
10	0.001	0.566	0.011	0.057	0.002	0.571	#13	0.080	Not Required	Pass
11	0.000	0.045	0.015	0.043	0.001	0.053	#32	0.095	Not Required	Pass
12	0.000	0.407	0.031	0.085	0.006	0.438	#13	0.035	Not Required	Pass
13	0.000	0.247	0.027	0.055	0.001	0.250	#13	0.286	Not Required	Pass
14	0.000	0.234	0.027	0.051	0.001	0.240	#13	0.190	Not Required	Pass
15	0.000	0.095	0.010	0.033	0.001	0.104	#13	Not Required	Not Required	Pass
16	0.000	0.088	0.010	0.030	0.001	0.097	#13	Not Required	Not Required	Pass
101	0.124	0.543	0.003	0.010	0.000	0.549	#16	0.598	Not Required	Pass
102	0.000	0.429	0.032	0.090	0.006	0.461	#13	0.114	Not Required	Pass
103	0.001	0.649	0.003	0.065	0.001	0.652	#13	0.045	Not Required	Pass
104	0.001	0.602	0.009	0.061	0.002	0.609	#13	0.080	Not Required	Pass
105	0.001	0.402	0.008	0.065	0.002	0.404	#13	0.074	Not Required	Pass
106	0.001	0.655	0.004	0.066	0.001	0.658	#13	0.045	Not Required	Pass
107	0.001	0.406	0.008	0.066	0.002	0.408	#13	0.074	Not Required	Pass
108	0.000	0.053	0.009	0.039	0.001	0.056	#13	0.095	Not Required	Pass
109	0.001	0.069	0.006	0.001	0.000	0.076	#13	0.204	Not Required	Pass
110	0.001	0.606	0.008	0.061	0.002	0.609	#13	0.080	Not Required	Pass
111	0.000	0.057	0.009	0.042	0.001	0.060	#13	0.095	Not Required	Pass
112	0.000	0.434	0.032	0.090	0.006	0.467	#13	0.035	Not Required	Pass
113	0.001	0.200	0.020	0.054	0.001	0.205	#13	0.286	Not Required	Pass
114	0.001	0.192	0.020	0.050	0.001	0.196	#13	0.286	Not Required	Pass
115	0.001	0.218	0.010	0.041	0.001	0.226	#13	0.728	Not Required	Pass
116	0.000	0.202	0.010	0.038	0.001	0.211	#13	0.728	Not Required	Pass
201	0.126	0.550	0.000	0.010	0.000	0.556	#16	0.598	Not Required	Pass
202	0.000	0.438	0.032	0.091	0.006	0.470	#13	0.035	Not Required	Pass
203	0.001	0.661	0.003	0.067	0.001	0.664	#13	0.045	Not Required	Pass
204	0.001	0.613	0.008	0.062	0.002	0.618	#13	0.080	Not Required	Pass
205	0.001	0.410	0.008	0.066	0.002	0.412	#13	0.074	Not Required	Pass

206	0.001	0.661	0.003	0.067	0.001	0.664	#13	0.045	Not Required	Pass
207	0.001	0.410	0.008	0.066	0.002	0.412	#13	0.074	Not Required	Pass
208	0.000	0.049	0.007	0.040	0.001	0.050	#13	0.095	Not Required	Pass
209	0.001	0.069	0.006	0.001	0.000	0.076	#13	0.204	Not Required	Pass
210	0.001	0.613	0.008	0.062	0.002	0.618	#13	0.080	Not Required	Pass
211	0.000	0.053	0.007	0.043	0.001	0.054	#13	0.095	Not Required	Pass
212	0.000	0.438	0.032	0.091	0.006	0.470	#13	0.035	Not Required	Pass
213	0.001	0.212	0.018	0.055	0.001	0.216	#13	0.286	Not Required	Pass
214	0.001	0.204	0.018	0.051	0.001	0.208	#13	0.286	Not Required	Pass
215	0.002	0.228	0.010	0.043	0.001	0.236	#13	0.728	Not Required	Pass
216	0.001	0.211	0.010	0.040	0.001	0.220	#13	0.728	Not Required	Pass
301	0.124	0.543	0.003	0.010	0.000	0.549	#16	0.598	Not Required	Pass
302	0.000	0.435	0.032	0.090	0.006	0.467	#13	0.035	Not Required	Pass
303	0.001	0.656	0.004	0.066	0.001	0.659	#13	0.045	Not Required	Pass
304	0.001	0.606	0.008	0.061	0.002	0.610	#13	0.080	Not Required	Pass
305	0.001	0.407	0.008	0.065	0.002	0.409	#13	0.074	Not Required	Pass
306	0.001	0.648	0.003	0.065	0.001	0.651	#13	0.045	Not Required	Pass
307	0.001	0.402	0.008	0.065	0.002	0.403	#13	0.074	Not Required	Pass
308	0.000	0.051	0.009	0.038	0.001	0.051	#13	0.095	Not Required	Pass
309	0.001	0.069	0.006	0.001	0.000	0.076	#13	0.204	Not Required	Pass
310	0.001	0.602	0.009	0.061	0.002	0.608	#13	0.080	Not Required	Pass
311	0.000	0.055	0.009	0.041	0.001	0.055	#13	0.095	Not Required	Pass
312	0.000	0.429	0.032	0.090	0.006	0.461	#13	0.114	Not Required	Pass
313	0.001	0.200	0.020	0.054	0.001	0.205	#13	0.286	Not Required	Pass
314	0.001	0.192	0.020	0.050	0.001	0.196	#13	0.286	Not Required	Pass
315	0.002	0.226	0.010	0.042	0.001	0.235	#13	0.728	Not Required	Pass
316	0.001	0.209	0.010	0.039	0.001	0.218	#13	0.728	Not Required	Pass
401	0.118	0.525	0.005	0.009	0.000	0.530	#16	0.598	Not Required	Pass
402	0.000	0.407	0.031	0.084	0.006	0.438	#13	0.035	Not Required	Pass
403	0.001	0.614	0.004	0.062	0.001	0.615	#13	0.045	Not Required	Pass
404	0.001	0.566	0.011	0.057	0.002	0.572	#13	0.080	Not Required	Pass
405	0.001	0.381	0.012	0.061	0.003	0.382	#13	0.074	Not Required	Pass
406	0.000	0.620	0.004	0.063	0.001	0.624	#13	0.045	Not Required	Pass
407	0.000	0.384	0.008	0.062	0.002	0.386	#13	0.074	Not Required	Pass
408	0.000	0.088	0.010	0.030	0.001	0.097	#13	Not Required	Not Required	Pass
409	0.001	0.070	0.007	0.001	0.000	0.078	#13	0.204	Not Required	Pass
410	0.000	0.575	0.008	0.058	0.002	0.578	#13	0.080	Not Required	Pass
411	0.000	0.095	0.010	0.033	0.001	0.104	#13	Not Required	Not Required	Pass
412	0.000	0.417	0.031	0.086	0.006	0.448	#13	0.053	Not Required	Pass
413	0.000	0.247	0.027	0.055	0.001	0.250	#13	0.190	Not Required	Pass
414	0.000	0.234	0.027	0.051	0.001	0.240	#13	0.286	Not Required	Pass
415	0.001	0.215	0.015	0.043	0.001	0.224	#13	0.728	Not Required	Pass
416	0.000	0.201	0.015	0.040	0.001	0.210	#13	0.728	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength

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

REFERENCES	CALCULATIONS	RESULTS

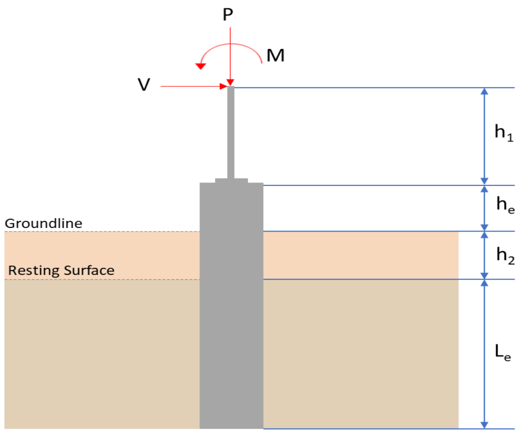
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 5.5$ 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)	6.818	10.377
V_x (kip)	-0.416	-0.694
V_z (kip)	-0.019	-0.028
M_x (kipft)	-0.062	-0.096
M_z (kipft)	13.017	22.205

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,

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

$$H_o = \frac{(-0.416 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.066242 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(13.017 \text{ kipft}) + ((-0.416 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.0728 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.2529 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.019 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0030255 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.062 \text{ kipft}) + ((-0.019 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0098726 \text{ kipft/ft}$$

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:
$L_{e,z} = 0.85883 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.2529 \text{ ft}), (0.85883 \text{ ft})]$$

$$L_{e,req} = 5.253 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.253 \text{ ft})}{(5.5 \text{ ft})}$$

$$Ratio = 0.95509$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.818 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.42612 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.42612 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.21306$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.066242 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 2.0728 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.0728 \text{ kipft/ft}) \times (5.5 \text{ ft})) + \left(3 \times (-0.066242 \text{ kip/ft}) \times (5.5 \text{ ft})^2\right)}{(6 \times (2.0728 \text{ kipft/ft})) + (4 \times (-0.066242 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7147 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.0728 \text{ kipft/ft})) + (3 \times (-0.066242 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.0728 \text{ kipft/ft})) + (2 \times (-0.066242 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.23401 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.0728 \text{ kipft/ft})) + ((-0.066242 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.75 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7147 \text{ ft})}{2}$$

$$p_a = 0.27861 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23401\ \mathrm{kip/ft^2}\right)}{\left(0.27861\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.83992$$

Status: **PASS**
Ratio: **0.840**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.75\ \mathrm{kip/ft^2}\right)}{\left(0.825\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90908$$

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

Considering z-direction:

$H_o = -0.0030255\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0098726\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0098726\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{(6 \times (0.0098726\ \mathrm{kipft/ft})) + (4 \times (-0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.9092\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0098726\ \mathrm{kipft/ft})) + (3 \times (-0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]^{\,2}}{(5.5\ \mathrm{ft})^2 \times [(3 \times (0.0098726\ \mathrm{kipft/ft})) + (2 \times (-0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}$$

$$p = -0.00073643\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0098726\ \mathrm{kipft/ft})) + ((-0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}{(5.5\ \mathrm{ft})^2}$$

$$s = 0.00061589\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.9092\ \mathrm{ft})}{2}$$

$$p_a = 0.29319\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00073643\ \mathrm{kip/ft^2}\right)}{\left(0.29319\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0025118$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (5.5\text{ ft})$$

$$p_s = 0.825\text{ kip/ft}^2$$

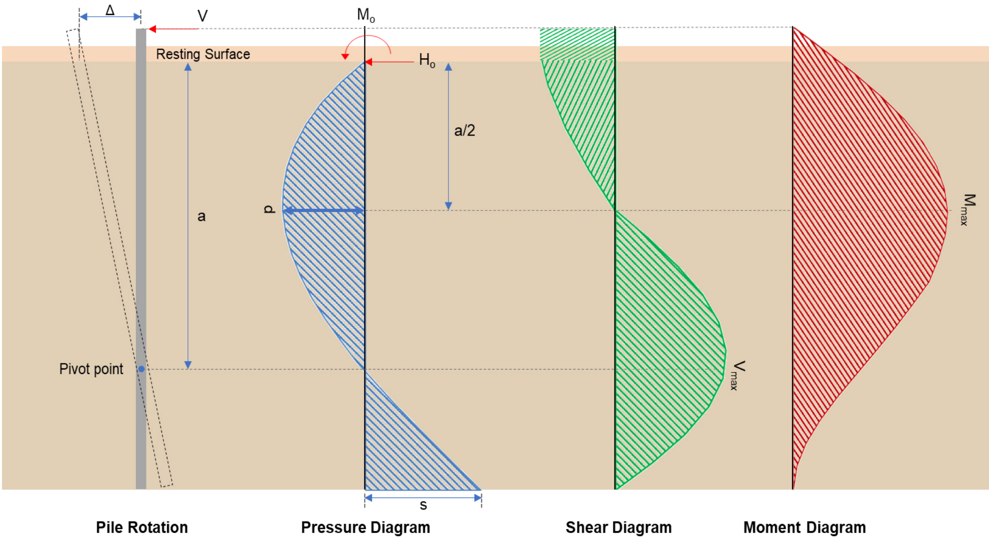
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00061589\text{ kip/ft}^2)}{(0.825\text{ kip/ft}^2)}$$

$$Ratio = 0.00074653$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.694\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.11051\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.205\text{ kipft}) + ((-0.694\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 3.5358\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.5358\text{ kipft/ft})}{(-0.11051\text{ kip/ft})}$$

$$E = 31.996\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.5358\text{ kipft/ft}) \times (5.5\text{ ft})) + \left(3 \times (-0.11051\text{ kip/ft}) \times (5.5\text{ ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (3.5358\ \text{kipft/ft})) + (4 \times (-0.11051\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.7138\ \text{ft}$$

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

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

$$V_{max} = ((-0.11051\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.996\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.7138\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.996\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.7138\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.8524\ \text{kip}$$

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

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

$$M_{max} = ((-0.11051\ \text{kip/ft}) \times (48\ \text{in}) \times (5.5\ \text{ft})) \times \left[\left(\frac{(31.996\ \text{ft})}{(5.5\ \text{ft})} + \frac{(3.7138\ \text{ft})}{2 \times (5.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (31.996\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.7138\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (31.996\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.7138\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 13.121\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.028\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0044586\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.096\ \text{kipft}) + ((-0.028\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.015287\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.015287\ \text{kipft/ft})}{(-0.0044586\ \text{kip/ft})}$$

$$E = 3.4286\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015287\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (-0.0044586\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (0.015287\ \text{kipft/ft})) + (4 \times (-0.0044586\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.9035\ \text{ft}$$

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

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

$$V_{max} = ((-0.0044586 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4286 \text{ ft})}{(5.5 \text{ ft})} + 3\right) \times \left(\frac{(3.9035 \text{ ft})}{(5.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4286 \text{ ft})}{(5.5 \text{ ft})} + 2\right) \times \left(\frac{(3.9035 \text{ ft})}{(5.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.031517 \text{ kip}$$

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

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

$$M_{max} = ((-0.0044586 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(3.4286 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9035 \text{ ft})}{2 \times (5.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.4286 \text{ ft})}{(5.5 \text{ ft})} + 3\right) \times \left(\frac{(3.9035 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4286 \text{ ft})}{(5.5 \text{ ft})} + 2\right) \times \left(\frac{(3.9035 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.077895 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.377 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.251 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-84.251 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3	s_{rebar} - Minimum spacing of reinforcement,	

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.377 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.003879$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,$P = 10.377\ \text{kip} \rightarrow 10377\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(10377\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.87\ \text{kip}$$

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.87\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.87\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.87\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111\ \text{kip}$$

Considering x-direction:

$V_{max} = 4.8524\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.8524\ \text{kip})}{(111\ \text{kip})}$$

$$Ratio = 0.043717$$

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

Considering z-direction:

$V_{max} = 0.031517\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.031517\ \text{kip})}{(111\ \text{kip})}$$

$$Ratio = 0.00028394$$

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:

$M_{max} = 13.121\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.121\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.052567$$

Status: **PASS**
Ratio: **0.050**

Considering z-direction:

$M_{max} = 0.077895\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.077895 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00031208$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

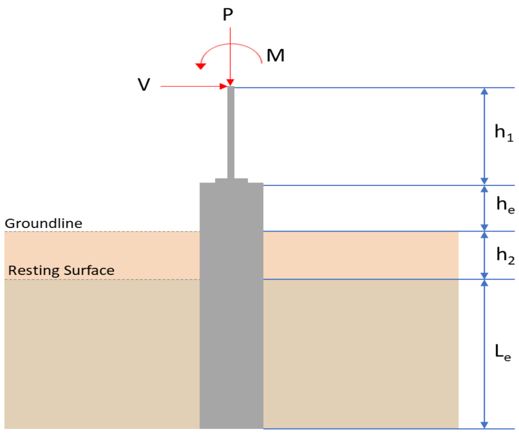
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 5.5$ 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)	7.186	10.945
V_x (kip)	-0.432	-0.721
V_z (kip)	0.010	0.016
M_x (kipft)	0.033	0.051
M_z (kipft)	13.464	22.982

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,

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

$$H_o = \frac{(-0.432\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.06879\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(13.464\ \text{kipft}) + ((-0.432\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 2.1439\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.3086\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.01\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0015924\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.033\ \text{kipft}) + ((0.01\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0052548\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.79131\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.3086\ \text{ft}), (0.79131\ \text{ft})]$$

$$L_{e,req} = 5.309\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.309\ \text{ft})}{(5.5\ \text{ft})}$$

$$Ratio = 0.96527$$

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

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

$$q = \frac{(7.186\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.44912\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.44912\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.22456$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.06879\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.1439\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.1439\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (-0.06879\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (2.1439\ \text{kipft/ft})) + (4 \times (-0.06879\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.7149\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.1439\ \text{kipft/ft})) + (3 \times (-0.06879\ \text{kip/ft}) \times (5.5\ \text{ft}))]^{\ 2}}{(5.5\ \text{ft})^2 \times [(3 \times (2.1439\ \text{kipft/ft})) + (2 \times (-0.06879\ \text{kip/ft}) \times (5.5\ \text{ft}))]}$$

$$p = 0.24188\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.1439\ \text{kipft/ft})) + ((-0.06879\ \text{kip/ft}) \times (5.5\ \text{ft}))]}{(5.5\ \text{ft})^2}$$

$$s = 0.77545\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.7149\ \text{ft})}{2}$$

$$p_a = 0.27862\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24188 \text{ kip/ft}^2\right)}{\left(0.27862 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.86813$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$$

$$p_s = 0.825 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.77545 \text{ kip/ft}^2\right)}{\left(0.825 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.93994$$

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

Considering z-direction:

$H_o = 0.0015924 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0052548 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0052548 \text{ kipft/ft}) \times (5.5 \text{ ft})) + \left(3 \times (0.0015924 \text{ kip/ft}) \times (5.5 \text{ ft})^2\right)}{(6 \times (0.0052548 \text{ kipft/ft})) + (4 \times (0.0015924 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9079 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0052548 \text{ kipft/ft})) + (3 \times (0.0015924 \text{ kip/ft}) \times (5.5 \text{ ft}))]^{\,2}}{(5.5 \text{ ft})^2 \times [(3 \times (0.0052548 \text{ kipft/ft})) + (2 \times (0.0015924 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.0016663 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0052548 \text{ kipft/ft})) + ((0.0015924 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.0038217 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9079 \text{ ft})}{2}$$

$$p_a = 0.29309 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0016663 \text{ kip/ft}^2\right)}{\left(0.29309 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.0056851$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

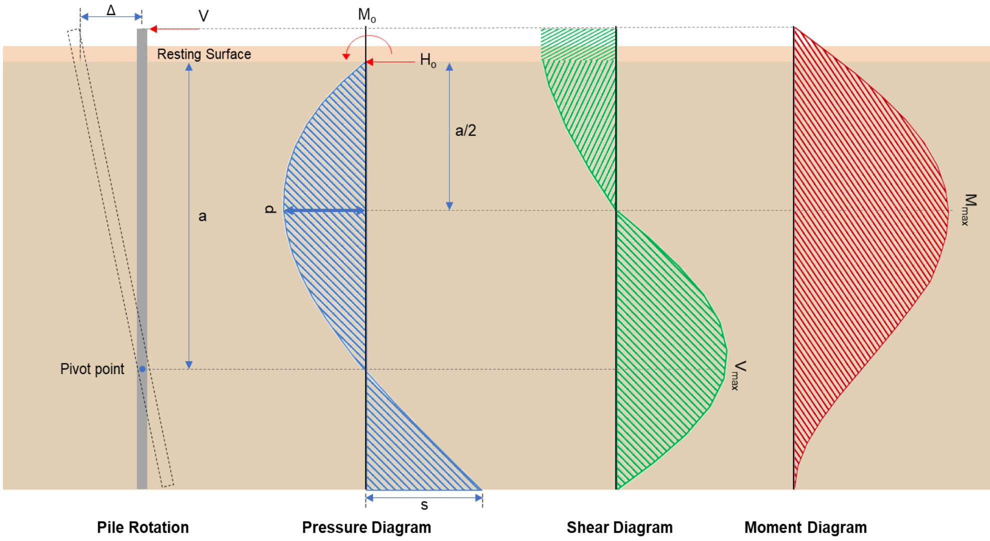
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0038217\ \mathrm{kip/ft^2}\right)}{\left(0.825\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0046323$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.721\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.11481\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.982\ \mathrm{kipft}) + ((-0.721\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 3.6596\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.6596\ \mathrm{kipft/ft})}{(-0.11481\ \mathrm{kip/ft})}$$

$$E = 31.875\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.6596\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.11481\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (3.6596\ \text{kipft/ft})) + (4 \times (-0.11481\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.714\ \text{ft}$$

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

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

$$V_{max} = ((-0.11481\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.875\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.714\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.875\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.714\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 5.0233\ \text{kip}$$

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

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

$$M_{max} = ((-0.11481\ \text{kip/ft}) \times (48\ \text{in}) \times (5.5\ \text{ft})) \times \left[\left(\frac{(31.875\ \text{ft})}{(5.5\ \text{ft})} + \frac{(3.714\ \text{ft})}{2 \times (5.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (31.875\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.714\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (31.875\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.714\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 13.582\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.016\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0025478\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.051\ \text{kipft}) + ((0.016\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.008121\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.008121\ \text{kipft/ft})}{(0.0025478\ \text{kip/ft})}$$

$$E = 3.1875\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.008121\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (0.0025478\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (0.008121\ \text{kipft/ft})) + (4 \times (0.0025478\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.9119\ \text{ft}$$

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

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

$$V_{max} = ((0.0025478\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.1875\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.9119\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.1875\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.9119\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.017226\ \text{kip}$$

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

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

$$M_{max} = ((0.0025478\ \text{kip/ft}) \times (48\ \text{in}) \times (5.5\ \text{ft})) \times \left[\left(\frac{(3.1875\ \text{ft})}{(5.5\ \text{ft})} + \frac{(3.9119\ \text{ft})}{2 \times (5.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.1875\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.9119\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.1875\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.9119\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.042362\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(10.945\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.232\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.232\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.945\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0040913$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.945 \text{ kip} \rightarrow 10945 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(10945 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.94 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.94 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.94 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.94 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.05 \text{ kip}$$

Considering x-direction:

$V_{max} = 5.0233 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(5.0233\ \text{kip})}{(111.05\ \text{kip})}$$ $$Ratio = 0.045237$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $V_{max} = 0.017226\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.017226\ \text{kip})}{(111.05\ \text{kip})}$$ $$Ratio = 0.00015513$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 13.582\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(13.582\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.054415$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $M_{max} = 0.042362\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.042362 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00016972$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

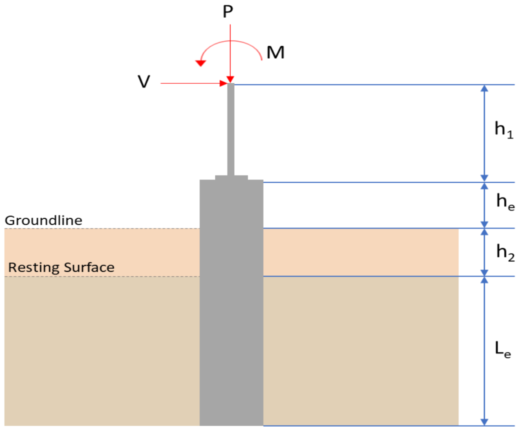
SkyCiv Foundation Design

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
$L = 5.5\ \mathrm{ft}$ - 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)	7.290	11.105
V_x (kip)	-0.440	-0.732
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	13.639	23.283

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,

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

$$H_o = \frac{(-0.44\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.070064\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(13.639\ \text{kipft}) + ((-0.44\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 2.1718\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.3291\ \text{ft}$ - 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,

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

$$L_{e,req} = MAX[(5.3291\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 5.329\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.329\ \text{ft})}{(5.5\ \text{ft})}$$

$$Ratio = 0.96891$$

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

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

$$q = \frac{(7.29\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.45563\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.45563\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.22781$$

Status: **PASS**
Ratio: **0.230**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.070064\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.1718\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.1718\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.070064\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{(6 \times (2.1718\ \mathrm{kipft/ft})) + (4 \times (-0.070064\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.7151\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.1718\ \mathrm{kipft/ft})) + (3 \times (-0.070064\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]^2}{(5.5\ \mathrm{ft})^2 \times [(3 \times (2.1718\ \mathrm{kipft/ft})) + (2 \times (-0.070064\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}$$

$$p = 0.24479\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.1718\ \mathrm{kipft/ft})) + ((-0.070064\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}{(5.5\ \mathrm{ft})^2}$$

$$s = 0.78511\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.7151\ \mathrm{ft})}{2}$$

$$p_a = 0.27864\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24479\ \mathrm{kip/ft^2}\right)}{\left(0.27864\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.87853$$

Status: **PASS**
Ratio: **0.880**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

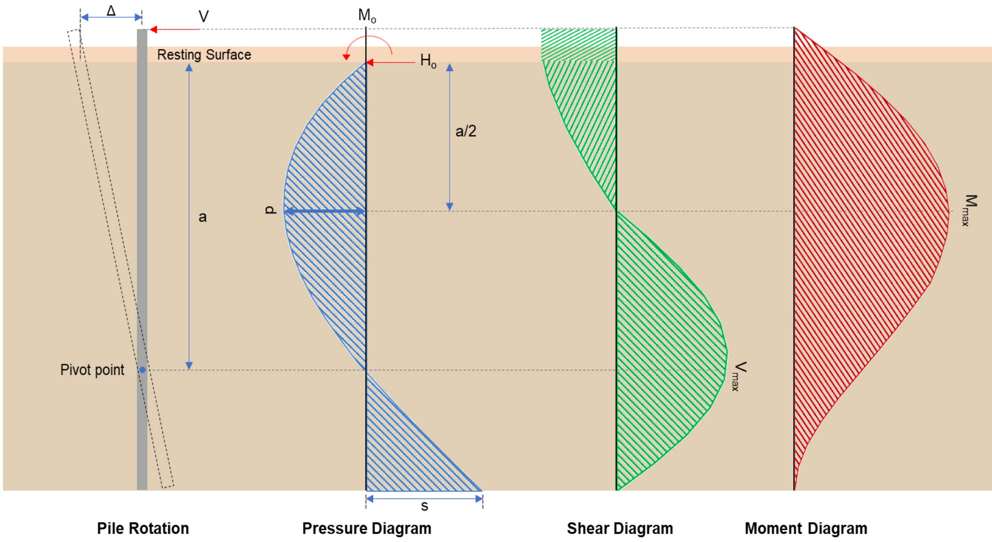
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.78511\ \mathrm{kip/ft^2}\right)}{\left(0.825\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.95165$$

Status: PASS
Ratio: 0.950



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.732\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.11656\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.283\text{ kipft}) + ((-0.732\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 3.7075\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.7075\text{ kipft/ft})}{(-0.11656\text{ kip/ft})}$$

$$E = 31.807\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.7075\text{ kipft/ft}) \times (5.5\text{ ft})) + \left(3 \times (-0.11656\text{ kip/ft}) \times (5.5\text{ ft})^2\right)}{(6 \times (3.7075\text{ kipft/ft})) + (4 \times (-0.11656\text{ kip/ft}) \times (5.5\text{ ft}))}$$

$$a = 3.714\text{ ft}$$

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

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

$$V_{max} = ((-0.11656\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.807\text{ ft})}{(5.5\text{ ft})} + 3\right) \times \left(\frac{(3.714\text{ ft})}{(5.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.807\text{ ft})}{(5.5\text{ ft})} + 2\right) \times \left(\frac{(3.714\text{ ft})}{(5.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 5.0808\text{ kip}$$

$V_{max} = 5.0898 \text{ kip}$

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

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

$$M_{max} = ((-0.11656 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(31.807 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.714 \text{ ft})}{2 \times (5.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (31.807 \text{ ft})}{(5.5 \text{ ft})} + 3\right) \times \left(\frac{(3.714 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (31.807 \text{ ft})}{(5.5 \text{ ft})} + 2\right) \times \left(\frac{(3.714 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 13.761 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.105 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.227 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\,[(-84.227 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.105\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0041511$$

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 $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 11.105\ \text{kip} \rightarrow 11105\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(11105\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.97\ \text{kip}$$

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

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.97\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.97\ \text{kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.97\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.06\ \text{kip}$$

Considering x-direction:

$V_{max} = 5.0898\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(5.0898\ \text{kip})}{(111.06\ \text{kip})}$$

$$Ratio = 0.045829$$

Status: **PASS**
Ratio: **0.050**

	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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 13.761\text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.761\text{ kipft})}{(249.6\text{ kipft})}$$

$$Ratio = 0.055133$$

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

REFERENCES	CALCULATIONS	RESULTS

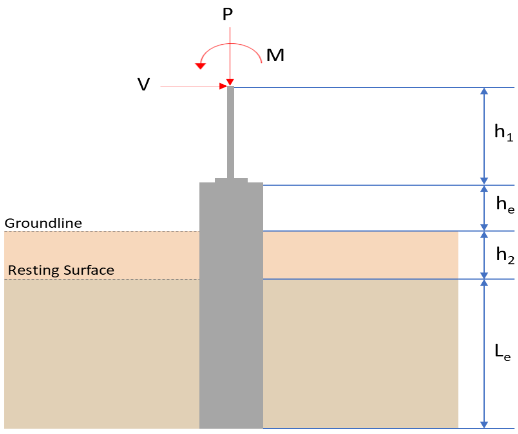
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 5.5$ 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)	7.186	10.944
V_x (kip)	-0.432	-0.721
V_z (kip)	-0.011	-0.017
M_x (kipft)	-0.037	-0.058
M_z (kipft)	13.465	22.983

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,

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

$$H_o = \frac{(-0.432\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.06879\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(13.465\ \text{kipft}) + ((-0.432\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 2.1441\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.3088\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.011\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0017516\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.037\ \text{kipft}) + ((-0.011\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0058917\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.73323\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.3088\ \text{ft}), (0.73323\ \text{ft})]$$

$$L_{e,req} = 5.309\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 5.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.309\ \text{ft})}{(5.5\ \text{ft})}$$

$$Ratio = 0.96527$$

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

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

$$q = \frac{(7.186\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.44912\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.44912\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.22456$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.06879\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.1441\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.1441\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.06879\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{(6 \times (2.1441\ \mathrm{kipft/ft})) + (4 \times (-0.06879\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.7149\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.1441\ \mathrm{kipft/ft})) + (3 \times (-0.06879\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]^2}{(5.5\ \mathrm{ft})^2 \times [(3 \times (2.1441\ \mathrm{kipft/ft})) + (2 \times (-0.06879\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}$$

$$p = 0.2419\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.1441\ \mathrm{kipft/ft})) + ((-0.06879\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}{(5.5\ \mathrm{ft})^2}$$

$$s = 0.77551\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.7149\ \mathrm{ft})}{2}$$

$$p_a = 0.27862\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.2419\ \mathrm{kip/ft^2}\right)}{\left(0.27862\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.8682$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.77551\ \mathrm{kip/ft^2}\right)}{\left(0.825\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94001$$

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

Considering z-direction:

$H_o = -0.0017516\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0058917\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0058917\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.0017516\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{(6 \times (0.0058917\ \mathrm{kipft/ft})) + (4 \times (-0.0017516\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.9057\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0058917\ \mathrm{kipft/ft})) + (3 \times (-0.0017516\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]^{\ 2}}{(5.5\ \mathrm{ft})^2 \times [(3 \times (0.0058917\ \mathrm{kipft/ft})) + (2 \times (-0.0017516\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}$$

$$p = -0.00044306\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0058917\ \mathrm{kipft/ft})) + ((-0.0017516\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}{(5.5\ \mathrm{ft})^2}$$

$$s = 0.00042638\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.9057\ \mathrm{ft})}{2}$$

$$p_a = 0.29293\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00044306\ \mathrm{kip/ft^2}\right)}{\left(0.29293\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0015125$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

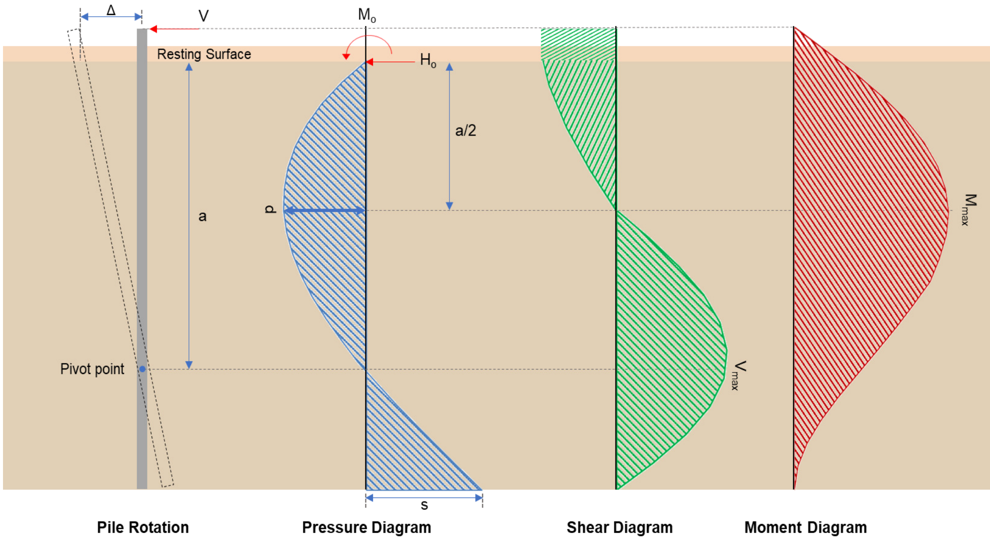
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00042638\ \mathrm{kip/ft^2})}{(0.825\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.00051683$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.721\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.11481\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.983\ \mathrm{kipft}) + ((-0.721\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 3.6597\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.6597\ \mathrm{kipft/ft})}{(-0.11481\ \mathrm{kip/ft})}$$

$$E = 31.877\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.6597\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (-0.11481\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (3.6597\ \text{kipft/ft})) + (4 \times (-0.11481\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.7139\ \text{ft}$$

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

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

$$V_{max} = ((-0.11481\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (31.877\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.7139\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (31.877\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.7139\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 5.0235\ \text{kip}$$

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

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

$$M_{max} = ((-0.11481\ \text{kip/ft}) \times (48\ \text{in}) \times (5.5\ \text{ft})) \times \left[\left(\frac{(31.877\ \text{ft})}{(5.5\ \text{ft})} + \frac{(3.7139\ \text{ft})}{2 \times (5.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (31.877\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.7139\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (31.877\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.7139\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 13.583\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.017\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.002707\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.058\ \text{kipft}) + ((-0.017\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0092357\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0092357\ \text{kipft/ft})}{(-0.002707\ \text{kip/ft})}$$

$$E = 3.4118\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0092357\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (-0.002707\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (0.0092357\ \text{kipft/ft})) + (4 \times (-0.002707\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.9041\ \text{ft}$$

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

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

$$V_{max} = ((-0.002707\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4118\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.9041\ \text{ft})}{(5.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4118\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.9041\ \text{ft})}{(5.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.019077\ \text{kip}$$

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

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

$$M_{max} = ((-0.002707\ \text{kip/ft}) \times (48\ \text{in}) \times (5.5\ \text{ft})) \times \left[\left(\frac{(3.4118\ \text{ft})}{(5.5\ \text{ft})} + \frac{(3.9041\ \text{ft})}{2 \times (5.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.4118\ \text{ft})}{(5.5\ \text{ft})} + 3\right) \times \left(\frac{(3.9041\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4118\ \text{ft})}{(5.5\ \text{ft})} + 2\right) \times \left(\frac{(3.9041\ \text{ft})}{2 \times (5.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.047134\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.944\ \text{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.232\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.232\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

25.7.2.2 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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.944\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0040909$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\,D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,$P = 10.944 \text{ kip} \rightarrow 10944 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(10944 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.94 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.94 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.94 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.94 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.04 \text{ kip}$$

Considering x-direction:

$V_{max} = 5.0235 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(5.0235\text{ kip})}{(111.04\text{ kip})}$$ $$Ratio = 0.045239$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $V_{max} = 0.019077\text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.019077\text{ kip})}{(111.04\text{ kip})}$$ $$Ratio = 0.0001718$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\text{ in}) \times (48\text{ in})^2}{6}$$ $$S_m = 18432\text{ in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 13.583\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(13.583\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.054418$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $M_{max} = 0.047134\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.047134 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00018884$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

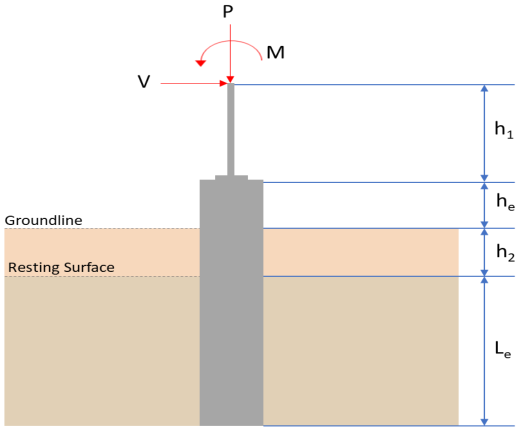
SkyCiv Foundation Design

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
$L = 5.5\ \mathrm{ft}$ - 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)	6.818	10.377
V_x (kip)	-0.416	-0.694
V_z (kip)	0.019	0.029
M_x (kipft)	0.063	0.096
M_z (kipft)	13.018	22.207

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,

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

$$H_o = \frac{(-0.416\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.066242\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(13.018 \text{ kipft}) + ((-0.416 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.0729 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.2531 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.019 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0030255 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.063 \text{ kipft}) + ((0.019 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.010032 \text{ kipft/ft}$$

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:
$L_{e,z} = 0.99436 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.2531 \text{ ft}), (0.99436 \text{ ft})]$$

$$L_{e,req} = 5.253 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 5.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.253 \text{ ft})}{(5.5 \text{ ft})}$$

$$Ratio = 0.95509$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.818\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.42612\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.42612\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.21306$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.066242\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.0729\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.0729\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (-0.066242\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (2.0729\ \text{kipft/ft})) + (4 \times (-0.066242\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.7147\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.0729\ \text{kipft/ft})) + (3 \times (-0.066242\ \text{kip/ft}) \times (5.5\ \text{ft}))]^{\ 2}}{(5.5\ \text{ft})^2 \times [(3 \times (2.0729\ \text{kipft/ft})) + (2 \times (-0.066242\ \text{kip/ft}) \times (5.5\ \text{ft}))]}$$

$$p = 0.23403\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.0729\ \text{kipft/ft})) + ((-0.066242\ \text{kip/ft}) \times (5.5\ \text{ft}))]}{(5.5\ \text{ft})^2}$$

$$s = 0.75006\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.7147\ \text{ft})}{2}$$

$$p_a = 0.27861\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23403\ \mathrm{kip/ft^2}\right)}{\left(0.27861\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.84$$

Status: **PASS**
Ratio: **0.840**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (5.5\ \mathrm{ft})$$

$$p_s = 0.825\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.75006\ \mathrm{kip/ft^2}\right)}{\left(0.825\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90916$$

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

Considering z-direction:

$H_o = 0.0030255\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.010032\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.010032\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{(6 \times (0.010032\ \mathrm{kipft/ft})) + (4 \times (0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.9073\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.010032\ \mathrm{kipft/ft})) + (3 \times (0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]^{\,2}}{(5.5\ \mathrm{ft})^2 \times [(3 \times (0.010032\ \mathrm{kipft/ft})) + (2 \times (0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}$$

$$p = 0.0031722\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.010032\ \mathrm{kipft/ft})) + ((0.0030255\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))]}{(5.5\ \mathrm{ft})^2}$$

$$s = 0.0072801\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(3.9073\ \mathrm{ft})}{2}$$

$$p_a = 0.29305\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0031722\ \mathrm{kip/ft^2}\right)}{\left(0.29305\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.010825$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (5.5\text{ ft})$$

$$p_s = 0.825\text{ kip/ft}^2$$

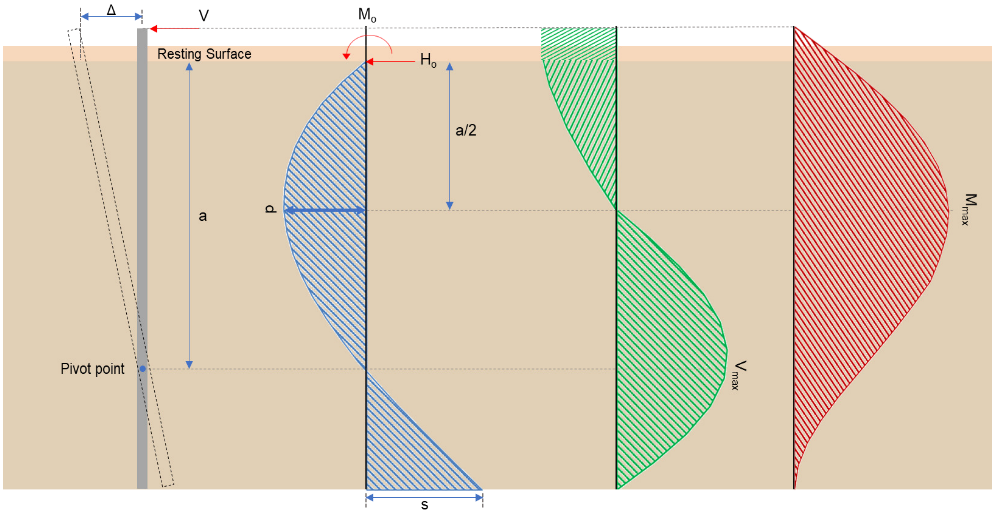
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0072801\text{ kip/ft}^2)}{(0.825\text{ kip/ft}^2)}$$

$$Ratio = 0.0088244$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.694\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.11051\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(22.207\text{ kipft}) + ((-0.694\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 3.5361\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(3.5361\text{ kipft/ft})}{(-0.11051\text{ kip/ft})}$$

$$E = 32\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.5361\text{ kipft/ft}) \times (5.5\text{ ft})) + \left(3 \times (-0.11051\text{ kip/ft}) \times (5.5\text{ ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (3.5361\ \mathrm{kipft/ft})) + (4 \times (-0.11051\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.7138\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.11051\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (32\ \mathrm{ft})}{(5.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.7138\ \mathrm{ft})}{(5.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (32\ \mathrm{ft})}{(5.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.7138\ \mathrm{ft})}{(5.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 4.8528\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.11051\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (5.5\ \mathrm{ft})) \times \left[\left(\frac{(32\ \mathrm{ft})}{(5.5\ \mathrm{ft})} + \frac{(3.7138\ \mathrm{ft})}{2 \times (5.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (32\ \mathrm{ft})}{(5.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(3.7138\ \mathrm{ft})}{2 \times (5.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (32\ \mathrm{ft})}{(5.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(3.7138\ \mathrm{ft})}{2 \times (5.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 13.122\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.029\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0046178\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.096\ \mathrm{kipft}) + ((0.029\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.015287\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.015287\ \mathrm{kipft/ft})}{(0.0046178\ \mathrm{kip/ft})}$$

$$E = 3.3103\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015287\ \mathrm{kipft/ft}) \times (5.5\ \mathrm{ft})) + \left(3 \times (0.0046178\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft})^2\right)}{(6 \times (0.015287\ \mathrm{kipft/ft})) + (4 \times (0.0046178\ \mathrm{kip/ft}) \times (5.5\ \mathrm{ft}))}$$

$$a = 3.9075\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.0046178 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.3103 \text{ ft})}{(5.5 \text{ ft})} + 3\right) \times \left(\frac{(3.9075 \text{ ft})}{(5.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.3103 \text{ ft})}{(5.5 \text{ ft})} + 2\right) \times \left(\frac{(3.9075 \text{ ft})}{(5.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.031946 \text{ kip}$$

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

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

$$M_{max} = ((0.0046178 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(3.3103 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9075 \text{ ft})}{2 \times (5.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.3103 \text{ ft})}{(5.5 \text{ ft})} + 3\right) \times \left(\frac{(3.9075 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.3103 \text{ ft})}{(5.5 \text{ ft})} + 2\right) \times \left(\frac{(3.9075 \text{ ft})}{2 \times (5.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.078766 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(10.377 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.251 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-84.251 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(10.377\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.003879$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\ D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.377 \text{ kip} \rightarrow 10377 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(10377 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.87 \text{ kip}$$

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

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.87 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.87 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.87 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111 \text{ kip}$$

Considering x-direction:

$V_{max} = 4.8528 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(4.8528\ \text{kip})}{(111\ \text{kip})}$$ $$Ratio = 0.043721$$	Status: **PASS** Ratio: **0.040**
	Considering z-direction: $V_{max} = 0.031946\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.031946\ \text{kip})}{(111\ \text{kip})}$$ $$Ratio = 0.00028781$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 13.122\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(13.122\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.052572$$	Status: **PASS** Ratio: **0.050**
	Considering z-direction: $M_{max} = 0.078766\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.078766\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.00031557$$	Status: **PASS** Ratio: **0.000**