

Project Name: Springs National Park - V1Jb **Date:** Mon Nov 18 2024
Location: Hot Springs, AR, USA **Number of Modules:** 65
Unique ID: 5P-19.75-6TOP-SD-57-L-5Hx13W-CHH7 **Number of Poles:** 5
Dealer: _____ **Date Sold:** _____



Array Dimensions N/S	18.81 ft
Array Dimensions E/W	98.25 ft
Winter Tilt Angle	5
Front Edge Clearance	14 ft

MT Solar Bill of Materials (5P-19.75-6TOP-SD-57-L-5Hx13W-CHH7)

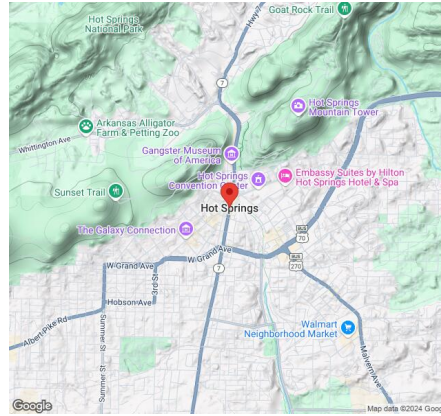
Part	Short Description	BOM Qty
MTS-PC-6	6IN Pole Cap Assembly	5
MTS-HF-SD	H-Frame Assembly-SD	5
MTS-SD-Wing-57	57IN SD Wing	4
MTS-SD-Splice-90	90IN SD Splice	8
MTS-SD-Splice-57	57IN SD Splice	8
MTS-CLAMP-ANGLE-4PK	Angle Clamp	13

Rail Bill of Materials

Part	Qty
Rails (223in)	26
Rail Attachment	104
Module Mid Clamp	104

Part	Qty
Module End Clamp	52
Ground Lug	13

Site Details:



Site Address: Hot Springs, AR, USA

Array Specification

Duty Classification:	SD
Module Width:	44.65 in
Module Length:	89.69in
Number of Rows:	5
Number of Columns:	13
Total Number of Modules:	65
Winter Tilt Angle:	5
Front Edge Clearance:	14
Total Array Height at Tilt:	15.64 ft
Total Frame Length:	96.00 ft
Frame Weight:	5277 lbs
Array Dimensions N/S:	18.81 ft
Array Dimensions E/W:	98.25 ft
Rail Length:	225.75 in
Rail Spacing:	3.78 ft

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	14.82 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 4.50 ft Pile 2: 4.50 ft Pile 3: 4.50 ft Pile 4: 4.50 ft Pile 5: 4.50 ft
Foundation Volume:	13.333 y ³

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	Hot Springs, AR, USA
Wind Speed:	99 mph

Snow Load:

10 psf

Design Disclaimer

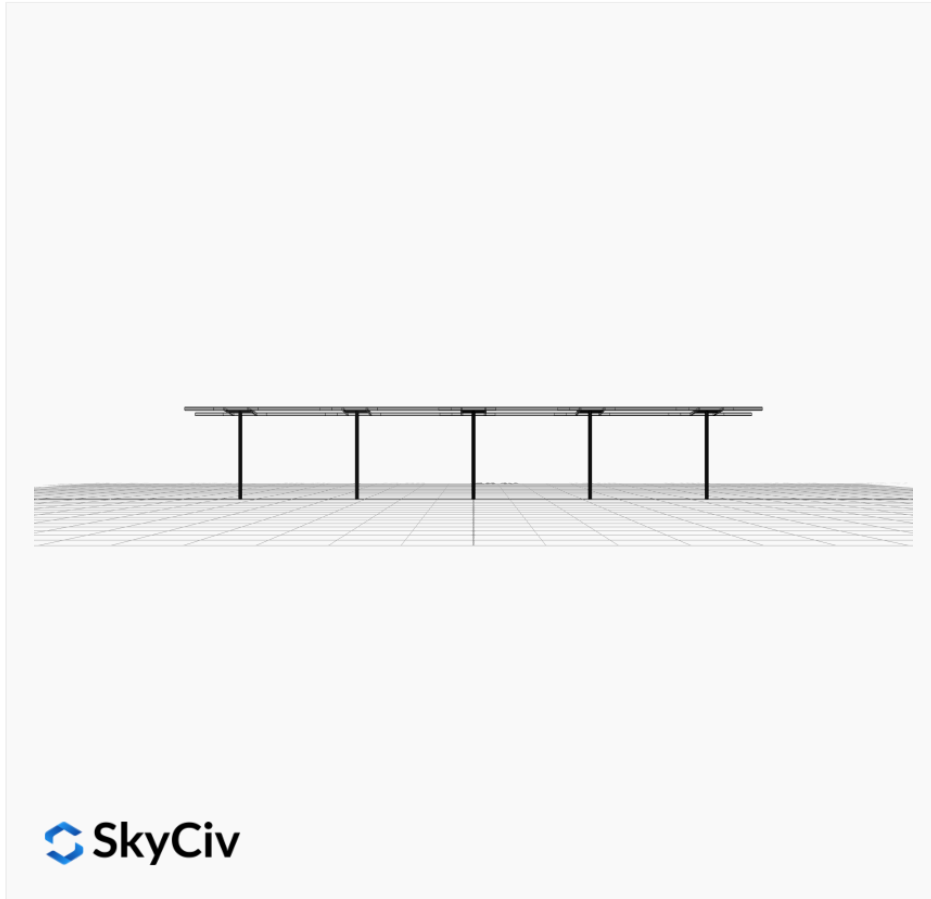
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

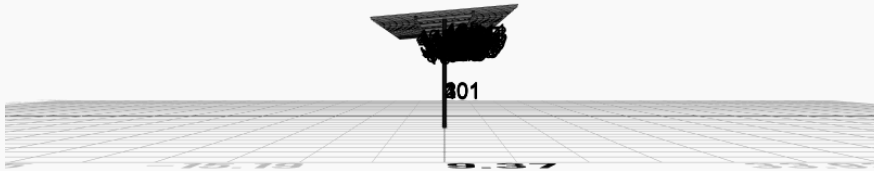
AutoDesigner Input

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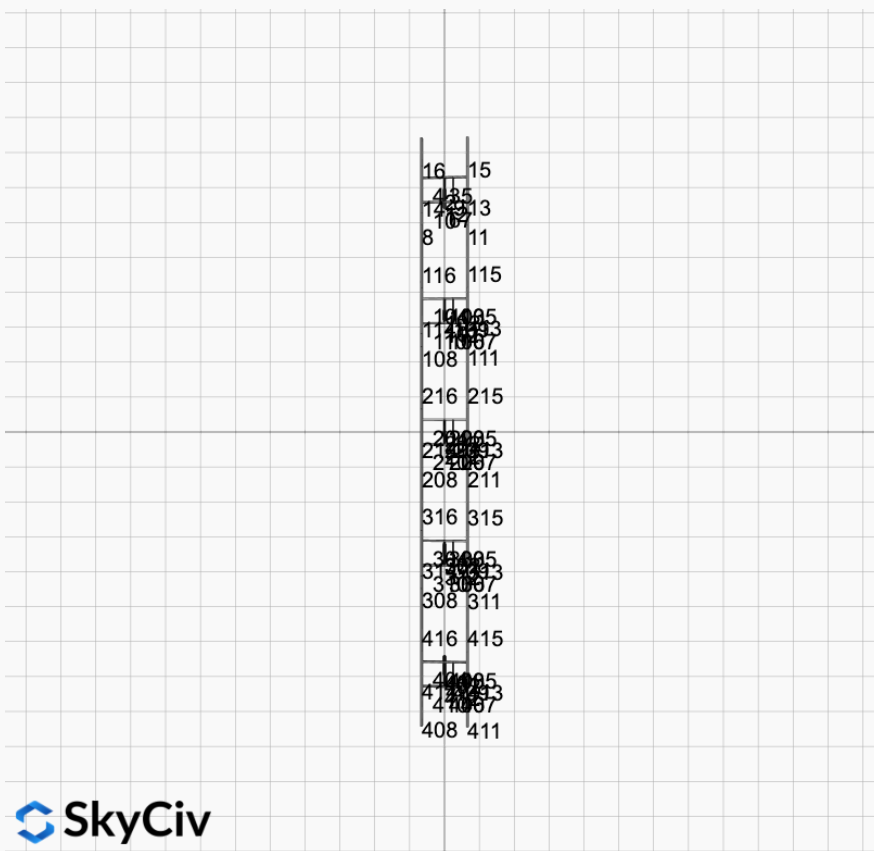
Design Notes:

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

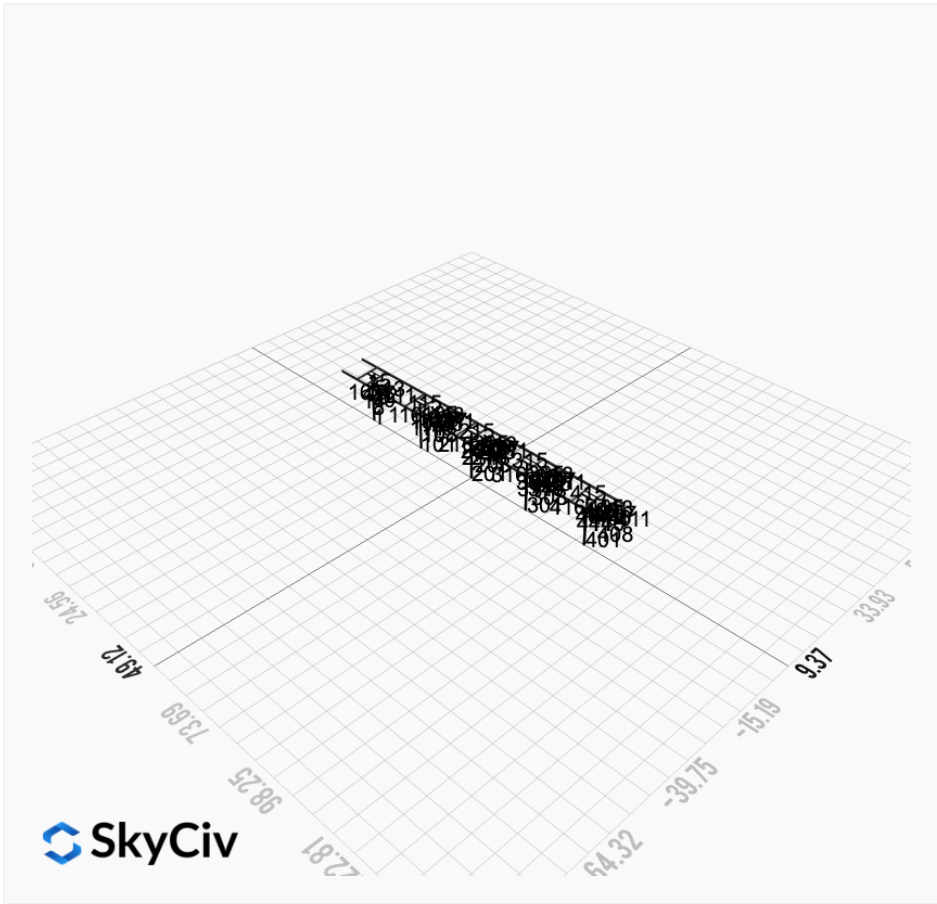




 SkyCiv

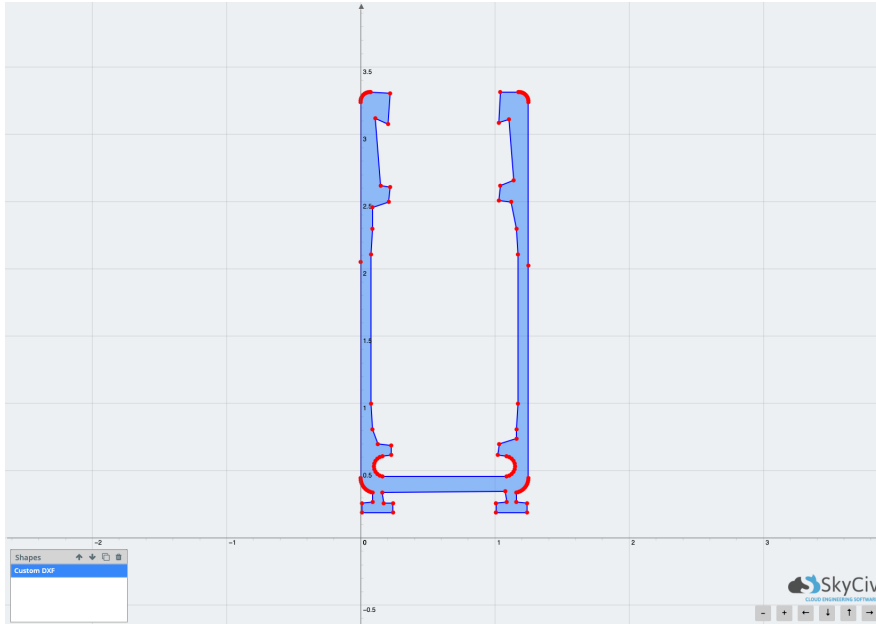


 SkyCiv



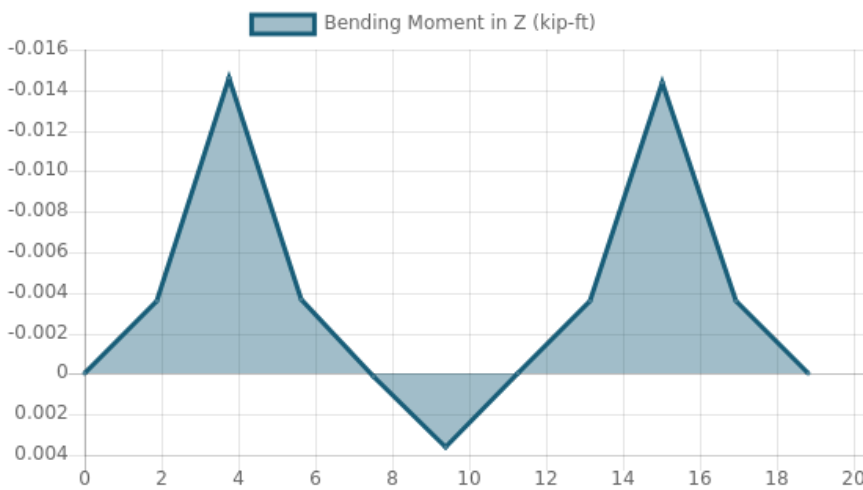
Rail Design Check

Rail Length: 18.8125 ft
Additional Restraints Required: 4ft Spread Clamps
Tributary Width: 3.77875 ft
Material: Aluminium
Density: 169 lb/ft³
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0228 kip/ft
Snow (Y): -0.0020 kip/ft
Wind uplift Case A: 0.0218 kip/ft
Wind uplift Case A: 0.0218 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.0501 kip/ft

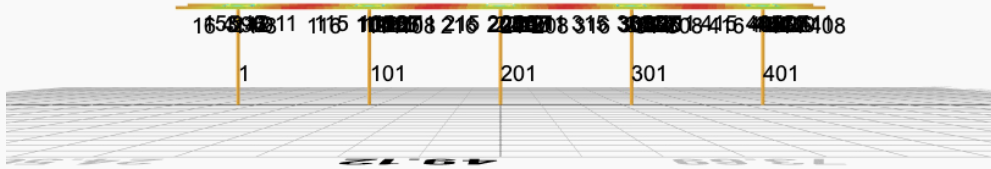
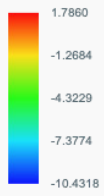


Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	7.58530094	0.220	PASS
Material Yield	34.5	7.58530094	0.220	PASS
Material Strength	37	7.58530094	0.205	PASS

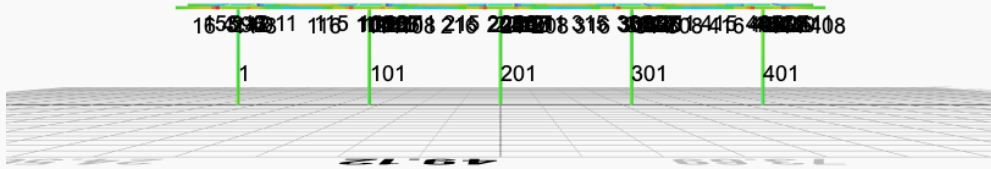
Member 1, ULS: 1. 1.4D



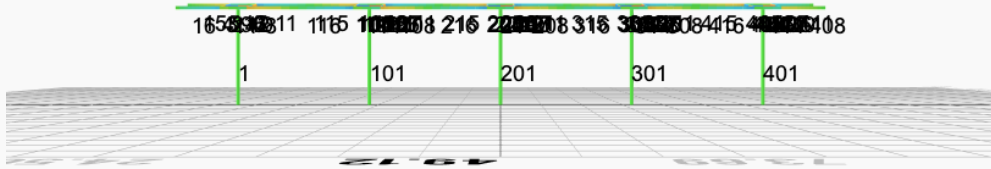
Top Bending Stress Z (ksi)



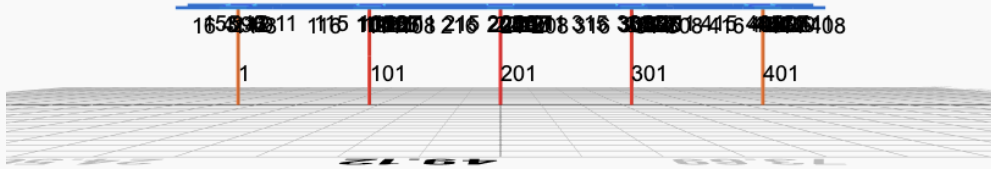
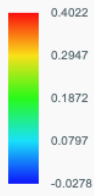
Top Bending Stress Y (ksi)



Shear Stress Y (ksi)



Axial Stress (ksi)



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	-0.0006	2.3392	-0.0063	-0.0300	0.0035	0.0288
ULS: 2. D + L	-0.0006	2.3392	-0.0063	-0.0300	0.0035	0.0288
ULS: 3. D + (S or Lr or R)	-0.0012	4.4328	-0.0131	-0.0626	0.0072	0.0379
ULS: 3. D + (S or Lr or R)	-0.0006	2.3392	-0.0063	-0.0300	0.0035	0.0288
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0010	3.9094	-0.0114	-0.0544	0.0063	0.0357
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0006	2.3392	-0.0063	-0.0300	0.0035	0.0288
ULS: 5b. D + 0.7E	-0.0006	2.3392	-0.0063	-0.0300	0.0035	0.0288
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0010	3.9094	-0.0114	-0.0544	0.0063	0.0357
ULS: 8. 0.6D + 0.7E	-0.0003	1.4035	-0.0038	-0.0180	0.0021	0.0173
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2035	4.6146	-0.0134	-0.0643	0.0038	3.6399
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2035	4.6146	-0.0134	-0.0643	0.0038	3.6399
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0509	1.7252	-0.0041	-0.0194	0.0016	1.5529
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1341	0.8944	-0.0023	-0.0109	0.0063	-6.8689
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1532	5.6160	-0.0167	-0.0802	0.0066	2.7440
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1532	5.6160	-0.0167	-0.0802	0.0066	2.7440
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0376	3.4489	-0.0097	-0.0465	0.0049	1.1787
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1000	2.8258	-0.0084	-0.0401	0.0085	-5.1376
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1527	4.0458	-0.0116	-0.0558	0.0037	2.7371
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1527	4.0458	-0.0116	-0.0558	0.0037	2.7371
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0380	1.8787	-0.0046	-0.0221	0.0021	1.1719
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1004	1.2556	-0.0033	-0.0157	0.0056	-5.1445
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2032	3.6790	-0.0109	-0.0523	0.0024	3.6284
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2032	3.6790	-0.0109	-0.0523	0.0024	3.6284
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0511	0.7896	-0.0015	-0.0074	0.0002	1.5414
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1343	-0.0413	0.0002	0.0012	0.0049	-6.8804

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	8.0530
Shear X	-0.3398
Shear Z	-0.0244
Moment X	-0.1178
Moment Y (Twist)	0.0134
Moment Z	12.2813

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.6160
Shear X	-0.2035
Shear Z	-0.0167
Moment X	-0.0802
Moment Y (Twist)	0.0085
Moment Z	6.8804

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	0.0006	2.4583	0.0023	0.0111	-0.0007	0.0144
ULS: 2. D + L	0.0006	2.4583	0.0023	0.0111	-0.0007	0.0144
ULS: 3. D + (S or Lr or R)	0.0014	4.6827	0.0048	0.0232	-0.0015	0.0079
ULS: 3. D + (S or Lr or R)	0.0006	2.4583	0.0023	0.0111	-0.0007	0.0144
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0012	4.1266	0.0042	0.0202	-0.0013	0.0095

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0006	2.4583	0.0023	0.0111	-0.0007	0.0144
ULS: 5b. D + 0.7E	0.0006	2.4583	0.0023	0.0111	-0.0007	0.0144
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0012	4.1266	0.0042	0.0202	-0.0013	0.0095
ULS: 8. 0.6D + 0.7E	0.0004	1.4750	0.0014	0.0067	-0.0004	0.0087
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2083	4.8753	0.0053	0.0256	-0.0040	3.7459
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2083	4.8753	0.0053	0.0256	-0.0040	3.7459
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0591	1.8060	0.0018	0.0085	-0.0020	1.5555
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1296	0.9238	-0.0000	0.0003	0.0052	-7.0398
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1555	5.9394	0.0065	0.0311	-0.0038	2.8081
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1555	5.9394	0.0065	0.0311	-0.0038	2.8081
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0450	3.6374	0.0038	0.0182	-0.0023	1.1653
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0979	2.9757	0.0024	0.0121	0.0031	-5.2812
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1560	4.2711	0.0046	0.0220	-0.0032	2.8130
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1560	4.2711	0.0046	0.0220	-0.0032	2.8130
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0445	1.9690	0.0019	0.0091	-0.0017	1.1702
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0974	1.3074	0.0006	0.0030	0.0037	-5.2762
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2085	3.8920	0.0044	0.0212	-0.0037	3.7401
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2085	3.8920	0.0044	0.0212	-0.0037	3.7401
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0588	0.8226	0.0008	0.0040	-0.0017	1.5497
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1294	-0.0595	-0.0010	-0.0042	0.0055	-7.0456

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	8.5232
Shear X	-0.3482
Shear Z	0.0094
Moment X	0.0454
Moment Y (Twist)	0.0099
Moment Z	12.5989

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.9394
Shear X	-0.2085
Shear Z	0.0065
Moment X	0.0311
Moment Y (Twist)	0.0055
Moment Z	7.0456

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	-0.0002	2.4773	-0.0000	0.0000	-0.0000	0.0228
ULS: 2. D + L	-0.0002	2.4773	-0.0000	0.0000	-0.0000	0.0228
ULS: 3. D + (S or Lr or R)	-0.0003	4.7224	-0.0000	0.0000	-0.0000	0.0254
ULS: 3. D + (S or Lr or R)	-0.0002	2.4773	-0.0000	0.0000	-0.0000	0.0228
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0003	4.1611	-0.0000	0.0000	-0.0000	0.0248
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0002	2.4773	-0.0000	0.0000	-0.0000	0.0228
ULS: 5b. D + 0.7E	-0.0002	2.4773	-0.0000	0.0000	-0.0000	0.0228
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0003	4.1611	-0.0000	0.0000	-0.0000	0.0248
ULS: 8. 0.6D + 0.7E	-0.0001	1.4864	-0.0000	0.0000	-0.0000	0.0137
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2111	4.9175	0.0000	0.0000	-0.0000	3.7947
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2111	4.9175	0.0000	0.0000	-0.0000	3.7947
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0592	1.8189	-0.0000	0.0000	-0.0000	1.5795
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1294	0.9278	-0.0000	0.0000	-0.0000	-7.1024

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	-0.1585	5.9912	0.0000	0.0000	-0.0000	2.8537
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1585	5.9912	0.0000	0.0000	-0.0000	2.8537
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0442	3.6673	-0.0000	0.0000	-0.0000	1.1923
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0969	2.9989	-0.0000	0.0000	-0.0000	-5.3192
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1584	4.3074	-0.0000	0.0000	-0.0000	2.8517
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1584	4.3074	-0.0000	0.0000	-0.0000	2.8517
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0444	1.9835	-0.0000	0.0000	-0.0000	1.1904
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0970	1.3151	-0.0000	0.0000	-0.0000	-5.3211
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2110	3.9266	0.0000	0.0000	-0.0000	3.7855
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2110	3.9266	0.0000	0.0000	-0.0000	3.7855
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0593	0.8280	-0.0000	0.0000	-0.0000	1.5704
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1294	-0.0631	-0.0000	0.0000	0.0000	-7.1116

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	8.5984
Shear X	-0.3516
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	12.7165

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.9912
Shear X	-0.2111
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	7.1116

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	0.0006	2.4583	-0.0023	-0.0111	0.0007	0.0144
ULS: 2. D + L	0.0006	2.4583	-0.0023	-0.0111	0.0007	0.0144
ULS: 3. D + (S or Lr or R)	0.0014	4.6827	-0.0048	-0.0232	0.0015	0.0079
ULS: 3. D + (S or Lr or R)	0.0006	2.4583	-0.0023	-0.0111	0.0007	0.0144
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0012	4.1266	-0.0042	-0.0202	0.0013	0.0095
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0006	2.4583	-0.0023	-0.0111	0.0007	0.0144
ULS: 5b. D + 0.7E	0.0006	2.4583	-0.0023	-0.0111	0.0007	0.0144
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0012	4.1266	-0.0042	-0.0202	0.0013	0.0095
ULS: 8. 0.6D + 0.7E	0.0004	1.4750	-0.0014	-0.0067	0.0004	0.0087
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2083	4.8753	-0.0053	-0.0256	0.0040	3.7459
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2083	4.8753	-0.0053	-0.0256	0.0040	3.7459
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0591	1.8060	-0.0018	-0.0085	0.0020	1.5555
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1296	0.9238	0.0000	-0.0003	-0.0052	-7.0398
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1555	5.9394	-0.0065	-0.0311	0.0038	2.8081
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1555	5.9394	-0.0065	-0.0311	0.0038	2.8081
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0450	3.6374	-0.0038	-0.0182	0.0023	1.1653
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0979	2.9757	-0.0024	-0.0121	-0.0031	-5.2812
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1560	4.2711	-0.0046	-0.0220	0.0032	2.8130
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1560	4.2711	-0.0046	-0.0220	0.0032	2.8130
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0445	1.9690	-0.0019	-0.0091	0.0017	1.1702
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0974	1.3074	-0.0006	-0.0030	-0.0037	-5.2762

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2085	3.8920	-0.0044	-0.0212	0.0037	3.7401
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2085	3.8920	-0.0044	-0.0212	0.0037	3.7401
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0588	0.8226	-0.0008	-0.0040	0.0017	1.5497
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1294	-0.0595	0.0010	0.0042	-0.0055	-7.0456

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	8.5232
Shear X	-0.3482
Shear Z	-0.0094
Moment X	-0.0454
Moment Y (Twist)	0.0099
Moment Z	12.5989

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.9394
Shear X	-0.2085
Shear Z	-0.0065
Moment X	-0.0311
Moment Y (Twist)	0.0055
Moment Z	7.0456

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	-0.0006	2.3392	0.0063	0.0300	-0.0035	0.0288
ULS: 2. D + L	-0.0006	2.3392	0.0063	0.0300	-0.0035	0.0288
ULS: 3. D + (S or Lr or R)	-0.0012	4.4328	0.0131	0.0626	-0.0072	0.0379
ULS: 3. D + (S or Lr or R)	-0.0006	2.3392	0.0063	0.0300	-0.0035	0.0288
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0010	3.9094	0.0114	0.0544	-0.0063	0.0357
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0006	2.3392	0.0063	0.0300	-0.0035	0.0288
ULS: 5b. D + 0.7E	-0.0006	2.3392	0.0063	0.0300	-0.0035	0.0288
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0010	3.9094	0.0114	0.0544	-0.0063	0.0357
ULS: 8. 0.6D + 0.7E	-0.0003	1.4035	0.0038	0.0180	-0.0021	0.0173
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2035	4.6146	0.0134	0.0643	-0.0038	3.6399
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2035	4.6146	0.0134	0.0643	-0.0038	3.6399
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0509	1.7252	0.0041	0.0194	-0.0016	1.5529
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1341	0.8944	0.0023	0.0109	-0.0063	-6.8689
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1532	5.6160	0.0167	0.0802	-0.0066	2.7440
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1532	5.6160	0.0167	0.0802	-0.0066	2.7440
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0376	3.4489	0.0097	0.0465	-0.0049	1.1787
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1000	2.8258	0.0084	0.0401	-0.0085	-5.1376
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1527	4.0458	0.0116	0.0558	-0.0037	2.7371
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1527	4.0458	0.0116	0.0558	-0.0037	2.7371
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0380	1.8787	0.0046	0.0221	-0.0021	1.1719
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1004	1.2556	0.0033	0.0157	-0.0056	-5.1445
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2032	3.6790	0.0109	0.0523	-0.0024	3.6284
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2032	3.6790	0.0109	0.0523	-0.0024	3.6284
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0511	0.7896	0.0015	0.0074	-0.0002	1.5414
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1343	-0.0413	-0.0002	-0.0012	-0.0049	-6.8804

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundation 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	8.0530
Shear X	-0.3398
Shear Z	0.0244
Moment X	0.1178
Moment Y (Twist)	0.0134
Moment Z	12.2814

Result	Value (kip, kip-ft)
Axial	5.6160
Shear X	-0.2035
Shear Z	0.0167
Moment X	0.0802
Moment Y (Twist)	0.0085
Moment Z	6.8804

Project Details

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

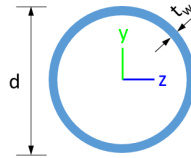


Design Input Information

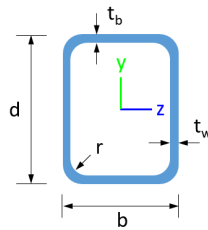
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
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Design Materials			
ID	E (ksi)	F _y (ksi)	F _u (ksi)
1	29000	50	65

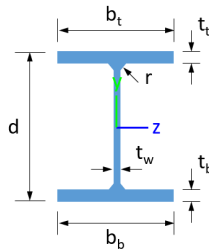
Section Dimensions



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



ID	Name	d (in)	b (in)	t _w (in)	t _b (in)	r (in)	
15	HSS5x3x1/8	5.00	3.00	0.12	0.12	0.12	



ID	Name	d (in)	t _w (in)	b _t (in)	b _b (in)	t _t (in)	t _b (in)	r (in)
18	W6x9	5.90	0.17	3.94	3.94	0.21	0.21	0.25

Section Properties

ID	Name	A (in ²)	J (in ⁴)	I _{yp} (in ⁴)	I _{zp} (in ⁴)	I _w (in ⁶)	S _{yp} (in ³)	S _{zp} (in ³)
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104	79.65	72.01	10.99	6.26	29.14	16.61
105	79.65	73.44	10.99	6.26	29.14	16.61
106	79.65	74.02	10.99	6.26	29.14	16.61
107	79.65	73.44	10.99	6.26	29.14	16.61
108	120.60	115.40	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	6.26	29.14	16.61
111	120.60	115.40	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	84.03	18.24	6.45	30.09	45.74
114	120.60	84.03	18.02	6.45	30.09	45.74
115	120.60	68.63	15.53	6.45	30.09	45.74
116	120.60	68.63	15.61	6.45	30.09	45.74
201	251.16	45.58	42.30	42.30	75.35	75.35
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	6.26	29.14	16.61
204	79.65	72.01	10.99	6.26	29.14	16.61
205	79.65	73.44	10.99	6.26	29.14	16.61
206	79.65	74.02	10.99	6.26	29.14	16.61
207	79.65	73.44	10.99	6.26	29.14	16.61
208	120.60	115.40	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	6.26	29.14	16.61
211	120.60	115.40	23.36	6.45	30.09	45.74
212	142.83	141.72	16.17	16.17	42.85	42.85
213	120.60	84.03	18.21	6.45	30.09	45.74
214	120.60	84.03	17.99	6.45	30.09	45.74
215	120.60	68.63	15.74	6.45	30.09	45.74
216	120.60	68.63	15.64	6.45	30.09	45.74
301	251.16	45.58	42.30	42.30	75.35	75.35
302	142.83	141.72	16.17	16.17	42.85	42.85
303	79.65	74.02	10.99	6.26	29.14	16.61
304	79.65	72.01	10.99	6.26	29.14	16.61
305	79.65	73.44	10.99	6.26	29.14	16.61
306	79.65	74.02	10.99	6.26	29.14	16.61
307	79.65	73.44	10.99	6.26	29.14	16.61
308	120.60	115.40	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.01	10.99	6.26	29.14	16.61
311	120.60	115.40	23.36	6.45	30.09	45.74
312	142.83	141.72	16.17	16.17	42.85	42.85
313	120.60	84.03	18.25	6.45	30.09	45.74
314	120.60	84.03	18.01	6.45	30.09	45.74
315	120.60	68.63	15.74	6.45	30.09	45.74
316	120.60	68.63	15.47	6.45	30.09	45.74
401	251.16	45.58	42.30	42.30	75.35	75.35
402	142.83	141.72	16.17	16.17	42.85	42.85
403	79.65	74.02	10.99	6.26	29.14	16.61
404	79.65	72.01	10.99	6.26	29.14	16.61
405	79.65	73.44	10.99	6.26	29.14	16.61
406	79.65	74.02	10.99	6.26	29.14	16.61
407	79.65	73.44	10.99	6.26	29.14	16.61

407	79.03	73.44	10.99	0.20	29.14	10.01
408	120.60	34.69	23.36	6.45	30.09	45.74
409	48.35	43.11	2.85	2.85	14.51	14.51
410	79.65	72.01	10.99	6.26	29.14	16.61
411	120.60	34.69	23.36	6.45	30.09	45.74
412	142.83	141.72	16.17	16.17	42.85	42.85
413	120.60	84.03	19.34	6.45	30.09	45.74
414	120.60	84.03	19.15	6.45	30.09	45.74
415	120.60	68.63	15.90	6.45	30.09	45.74
416	120.60	68.63	15.35	6.45	30.09	45.74

Design Ratio

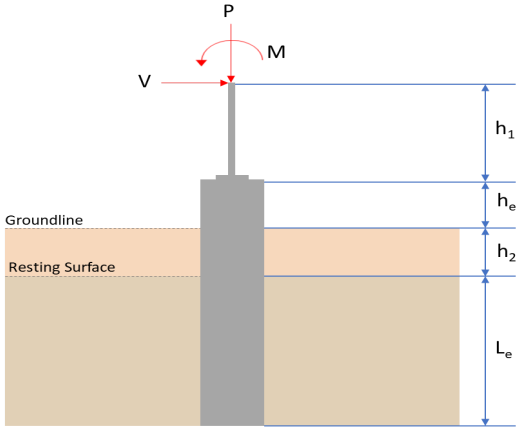
Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	δ	Status
1	0.177	0.290	0.006	0.005	0.000	0.307	#16	0.832	Not Required	Pass
2	0.000	0.442	0.025	0.091	0.004	0.462	#21	0.034	Not Required	Pass
3	0.002	0.662	0.013	0.067	0.002	0.676	#21	0.044	Not Required	Pass
4	0.002	0.646	0.029	0.065	0.005	0.664	#21	0.078	Not Required	Pass
5	0.002	0.410	0.033	0.067	0.007	0.418	#21	0.073	Not Required	Pass
6	0.002	0.650	0.012	0.066	0.001	0.661	#21	0.044	Not Required	Pass
7	0.002	0.403	0.035	0.065	0.007	0.410	#21	0.073	Not Required	Pass
8	0.000	0.048	0.019	0.042	0.002	0.058	#21	0.088	Not Required	Pass
9	0.002	0.081	0.009	0.001	0.000	0.091	#21	0.198	Not Required	Pass
10	0.002	0.632	0.036	0.064	0.006	0.655	#21	0.078	Not Required	Pass
11	0.000	0.048	0.020	0.043	0.002	0.060	#21	0.088	Not Required	Pass
12	0.001	0.427	0.025	0.089	0.004	0.446	#21	0.034	Not Required	Pass
13	0.001	0.233	0.046	0.055	0.002	0.269	#21	0.265	Not Required	Pass
14	0.001	0.232	0.046	0.053	0.002	0.263	#21	0.177	Not Required	Pass
15	0.000	0.100	0.023	0.033	0.001	0.123	#21	Not Required	Not Required	Pass
16	0.000	0.097	0.023	0.032	0.001	0.120	#21	Not Required	Not Required	Pass
101	0.187	0.298	0.002	0.005	0.000	0.314	#16	0.832	Not Required	Pass
102	0.000	0.453	0.025	0.095	0.004	0.472	#21	0.034	Not Required	Pass
103	0.002	0.693	0.013	0.070	0.002	0.707	#21	0.044	Not Required	Pass
104	0.002	0.676	0.031	0.068	0.005	0.698	#21	0.078	Not Required	Pass
105	0.002	0.430	0.031	0.070	0.006	0.437	#21	0.073	Not Required	Pass
106	0.002	0.700	0.015	0.071	0.003	0.714	#21	0.044	Not Required	Pass
107	0.002	0.434	0.031	0.070	0.006	0.442	#21	0.073	Not Required	Pass
108	0.000	0.056	0.016	0.041	0.002	0.063	#21	0.088	Not Required	Pass
109	0.002	0.077	0.008	0.001	0.000	0.086	#21	0.198	Not Required	Pass
110	0.002	0.681	0.030	0.069	0.005	0.701	#21	0.078	Not Required	Pass
111	0.000	0.057	0.017	0.042	0.002	0.064	#21	0.088	Not Required	Pass
112	0.000	0.458	0.026	0.096	0.004	0.478	#21	0.034	Not Required	Pass
113	0.001	0.195	0.042	0.054	0.002	0.223	#21	0.265	Not Required	Pass
114	0.001	0.194	0.042	0.052	0.002	0.218	#21	0.265	Not Required	Pass
115	0.000	0.185	0.024	0.041	0.002	0.208	#21	0.439	Not Required	Pass
116	0.000	0.181	0.024	0.040	0.002	0.205	#21	0.439	Not Required	Pass
201	0.189	0.301	0.000	0.005	0.000	0.317	#16	0.832	Not Required	Pass
202	0.000	0.460	0.026	0.096	0.004	0.480	#21	0.034	Not Required	Pass
203	0.002	0.703	0.013	0.071	0.002	0.717	#21	0.044	Not Required	Pass
204	0.002	0.685	0.030	0.069	0.005	0.706	#21	0.078	Not Required	Pass
205	0.002	0.436	0.031	0.071	0.006	0.444	#21	0.073	Not Required	Pass

206	0.002	0.703	0.013	0.071	0.002	0.717	#21	0.044	Not Required	Pass
207	0.002	0.436	0.031	0.071	0.006	0.444	#21	0.073	Not Required	Pass
208	0.000	0.054	0.016	0.041	0.002	0.060	#21	0.088	Not Required	Pass
209	0.002	0.077	0.008	0.001	0.000	0.086	#21	0.198	Not Required	Pass
210	0.002	0.685	0.030	0.069	0.005	0.706	#21	0.078	Not Required	Pass
211	0.000	0.055	0.016	0.042	0.002	0.061	#21	0.088	Not Required	Pass
212	0.000	0.460	0.026	0.096	0.004	0.480	#21	0.034	Not Required	Pass
213	0.001	0.200	0.042	0.054	0.002	0.229	#21	0.265	Not Required	Pass
214	0.001	0.200	0.041	0.053	0.002	0.224	#21	0.265	Not Required	Pass
215	0.001	0.190	0.023	0.042	0.002	0.214	#21	0.439	Not Required	Pass
216	0.000	0.187	0.024	0.041	0.002	0.210	#21	0.439	Not Required	Pass
301	0.187	0.298	0.002	0.005	0.000	0.314	#16	0.832	Not Required	Pass
302	0.000	0.458	0.026	0.096	0.004	0.478	#21	0.034	Not Required	Pass
303	0.002	0.700	0.015	0.071	0.003	0.714	#21	0.044	Not Required	Pass
304	0.002	0.681	0.030	0.069	0.005	0.701	#21	0.078	Not Required	Pass
305	0.002	0.434	0.031	0.070	0.006	0.442	#21	0.073	Not Required	Pass
306	0.002	0.693	0.013	0.070	0.002	0.707	#21	0.044	Not Required	Pass
307	0.002	0.430	0.031	0.070	0.006	0.437	#21	0.073	Not Required	Pass
308	0.000	0.054	0.016	0.040	0.002	0.060	#21	0.088	Not Required	Pass
309	0.002	0.077	0.008	0.001	0.000	0.086	#21	0.198	Not Required	Pass
310	0.002	0.676	0.031	0.068	0.005	0.698	#21	0.078	Not Required	Pass
311	0.000	0.055	0.016	0.041	0.002	0.061	#21	0.088	Not Required	Pass
312	0.000	0.453	0.025	0.095	0.004	0.472	#21	0.034	Not Required	Pass
313	0.001	0.195	0.042	0.054	0.002	0.223	#21	0.265	Not Required	Pass
314	0.001	0.194	0.042	0.052	0.002	0.218	#21	0.265	Not Required	Pass
315	0.001	0.191	0.023	0.042	0.002	0.214	#21	0.439	Not Required	Pass
316	0.000	0.187	0.024	0.041	0.002	0.211	#21	0.439	Not Required	Pass
401	0.177	0.290	0.006	0.005	0.000	0.307	#16	0.832	Not Required	Pass
402	0.001	0.427	0.025	0.089	0.004	0.446	#21	0.034	Not Required	Pass
403	0.002	0.650	0.012	0.066	0.001	0.661	#21	0.044	Not Required	Pass
404	0.002	0.632	0.036	0.064	0.006	0.655	#21	0.078	Not Required	Pass
405	0.002	0.403	0.035	0.065	0.007	0.410	#21	0.073	Not Required	Pass
406	0.002	0.662	0.013	0.067	0.002	0.676	#21	0.044	Not Required	Pass
407	0.002	0.410	0.033	0.067	0.007	0.419	#21	0.073	Not Required	Pass
408	0.000	0.097	0.023	0.032	0.001	0.120	#21	Not Required	Not Required	Pass
409	0.002	0.081	0.009	0.001	0.000	0.091	#21	0.198	Not Required	Pass
410	0.002	0.646	0.029	0.065	0.005	0.664	#21	0.078	Not Required	Pass
411	0.000	0.100	0.023	0.033	0.001	0.123	#21	Not Required	Not Required	Pass
412	0.000	0.442	0.025	0.091	0.004	0.462	#21	0.034	Not Required	Pass
413	0.001	0.233	0.046	0.055	0.002	0.269	#21	0.177	Not Required	Pass
414	0.001	0.232	0.046	0.053	0.002	0.263	#21	0.265	Not Required	Pass
415	0.000	0.183	0.024	0.043	0.002	0.206	#21	0.439	Not Required	Pass
416	0.000	0.179	0.024	0.042	0.002	0.203	#21	0.439	Not Required	Pass

Definitions

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

A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/compression)
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																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry</p> <p>Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 4.5$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resisting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1" data-bbox="368 1088 1225 1189"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1" data-bbox="655 1290 940 1480"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>5.616</td> <td>8.053</td> </tr> <tr> <td>V_x (kip)</td> <td>-0.203</td> <td>-0.340</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.017</td> <td>-0.024</td> </tr> <tr> <td>M_x (kipft)</td> <td>-0.080</td> <td>-0.118</td> </tr> <tr> <td>M_z (kipft)</td> <td>6.880</td> <td>12.281</td> </tr> </tbody> </table> <p>Material Properties</p> <p>$f'_{ck} = 2.5$ ksi - Concrete strength.</p>	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	Load Component	ASD	LRFD	P (kip)	5.616	8.053	V_x (kip)	-0.203	-0.340	V_z (kip)	-0.017	-0.024	M_x (kipft)	-0.080	-0.118	M_z (kipft)	6.880	12.281	
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	<p>Required depth to resist lateral loads (ASD)</p> <p>H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction:</p> <p>H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-0.203 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.032325 \text{ kip/ft}$																											

M_o - Moment per length of pile,

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

$$M_o = \frac{(6.88 \text{ kipft}) + ((-0.203 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.0955 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 4.2965 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.08 \text{ kipft}) + ((-0.017 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.012739 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.95256 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.2965 \text{ ft}), (0.95256 \text{ ft})]$$

$$L_{e,req} = 4.296 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$Ratio = \frac{(4.296 \text{ ft})}{(4.5 \text{ ft})}$$

$$Ratio = 0.95467$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.616 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.351 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.351 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.1755$$

Status: **PASS**
Ratio: **0.180**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.032325 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.0955 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.0955 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.0955 \text{ kipft/ft})) + (4 \times (-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0305 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.0955 \text{ kipft/ft})) + (3 \times (-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.0955 \text{ kipft/ft})) + (2 \times (-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.19249 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.0955 \text{ kipft/ft})) + ((-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.60611 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.0305 \text{ ft})}{2}$$

$$p_a = 0.22729 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.19249 \text{ kip/ft}^2)}{(0.22729 \text{ kip/ft}^2)}$$

$$Ratio = 0.84689$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.60611 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.89794$$

Status: **PASS**
Ratio: **0.850**

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

Considering z-direction:

$H_o = -0.002707 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.012739 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.012739 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.002707 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.012739 \text{ kipft/ft})) + (4 \times (-0.002707 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.146 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.012739 \text{ kipft/ft})) + (3 \times (-0.002707 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (0.012739 \text{ kipft/ft})) + (2 \times (-0.002707 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.00055521 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.012739 \text{ kipft/ft})) + ((-0.002707 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.0039396 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.146 \text{ ft})}{2}$$

$$p_a = 0.23595 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.00055521 \text{ kip/ft}^2)}{(0.23595 \text{ kip/ft}^2)}$$

$$Ratio = 0.0023531$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

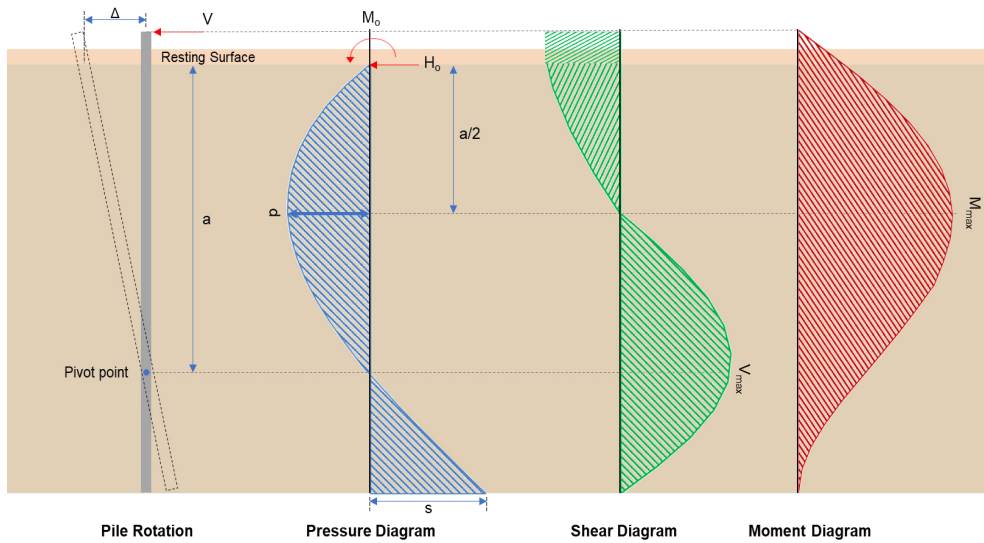
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0039396 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.0058365$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.34 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.05414 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.281 \text{ kipft}) + ((-0.34 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.9556 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.9556 \text{ kipft/ft})}{(-0.05414 \text{ kip/ft})}$$

$$E = 36.121 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.9556 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.05414 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times 1.9556) + (4 \times (-0.05414) \times 4.5)}$$

$$a = \frac{(6 \times (1.9556 \text{ kipft/ft})) + (4 \times (-0.05414 \text{ kip/ft}) \times (4.5 \text{ ft}))}{}$$

$$a = 3.0288 \text{ ft}$$

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

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

$$V_{max} = ((-0.05414 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (36.121 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0288 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (36.121 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0288 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 3.2276 \text{ kip}$$

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

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

$$M_{max} = ((-0.05414 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(36.121 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0288 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (36.121 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0288 \text{ ft})}{(2 \times (4.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (36.121 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0288 \text{ ft})}{(2 \times (4.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 7.1723 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.024 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0038217 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.118 \text{ kipft}) + ((-0.024 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.01879 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.01879 \text{ kipft/ft})}{(-0.0038217 \text{ kip/ft})}$$

$$E = 4.9167 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.01879 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.0038217 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.01879 \text{ kipft/ft})) + (4 \times (-0.0038217 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.1421 \text{ ft}$$

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

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

$$V_{max} = ((-0.0038217 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.9167 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.1421 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (4.9167 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.1421 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.039644 \text{ kip}$$

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

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

$$M_{max} = ((-0.0038217 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(4.9167 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.1421 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (4.9167 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.1421 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.9167 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.1421 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.082994 \text{ kipft}$$

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,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(8.053 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.329 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.329 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3 s_{rebar} - Minimum spacing of reinforcement,</p> <p>25.7.2.2 Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>25.7.2.1 s_{ties} - Maximum spacing of ties,</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p style="text-align: center;">$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p style="text-align: center;">$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p style="text-align: center;">$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p style="text-align: center;">$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p style="text-align: center;">$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p style="text-align: center;">$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2 ϕP_N - Allowable axial compressive strength</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y k A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p><i>Ratio - Capacity</i></p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(8.053 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0030103$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2 b_w = 48 in - Effective width, d - Effective depth</p> <p>22.5.5.1.3 λ_s - size effect modification factor</p> <p>22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.053 \text{ kip} \rightarrow 8053 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(8053 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.56 \text{ kip}$$

22.5.5.1.2 The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,
 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min} [(296.21 \text{ kip}), (119.56 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.56 \text{ kip}$$

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.56 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.79 \text{ kip}$$

Considering x-direction:

$V_{max} = 3.2276 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(3.2276 \text{ kip})}{(110.79 \text{ kip})}$$

$$Ratio = 0.029131$$

Considering z-direction:

$V_{max} = 0.039644 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.039644 \text{ kip})}{(110.79 \text{ kip})}$$

$$Ratio = 0.00035782$$

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

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

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

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 7.1723 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(7.1723 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.028735$$

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

Considering z-direction:

$M_{max} = 0.082994 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.082994 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00033251$$

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

REFERENCES	CALCULATIONS	RESULTS
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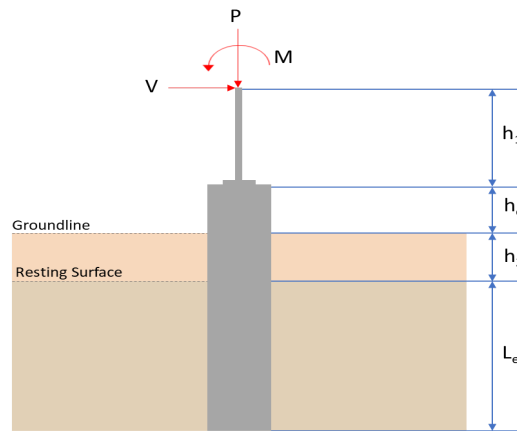
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 4.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.939	8.523
V_x (kip)	-0.209	-0.348
V_z (kip)	0.006	0.009
M_x (kipft)	0.031	0.045
M_z (kipft)	7.046	12.599

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,

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

$$H_o = \frac{(-0.209 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.03328 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.046 \text{ kipft}) + ((-0.209 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.122 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 4.3288 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.006 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.00095541 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.031 \text{ kipft}) + ((0.006 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0049363 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.76 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(4.3288 \text{ ft}), (0.76 \text{ ft})]$$

$$L_{e,req} = 4.329 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(4.329 \text{ ft})}{(4.5 \text{ ft})}$$

$$\text{Ratio} = 0.962$$

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

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

$$q = \frac{(5.939 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.37119 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.37119 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.18559$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.03328 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.122 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.122 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.122 \text{ kipft/ft})) + (4 \times (-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0306 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.122 \text{ kipft/ft})) + (3 \times (-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.122 \text{ kipft/ft})) + (2 \times (-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.197 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.122 \text{ kipft/ft})) + ((-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.6205 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.0306 \text{ ft})}{2}$$

$$p_a = 0.2273 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.197 \text{ kip/ft}^2)}{(0.2273 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.86671$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.6205 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.91926$$

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

Status: **PASS**
Ratio: **0.920**

Considering z-direction:

$H_o = 0.00095541 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.0049363 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0049363 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.0049363 \text{ kipft/ft})) + (4 \times (0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.1378 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0049363 \text{ kipft/ft})) + (3 \times (0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (0.0049363 \text{ kipft/ft})) + (2 \times (0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.001686 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.0049363 \text{ kipft/ft})) + ((0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.0041991 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.1378 \text{ ft})}{2}$$

$$p_a = 0.23533 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.001686 \text{ kip/ft}^2)}{(0.23533 \text{ kip/ft}^2)}$$

$$Ratio = 0.0071645$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

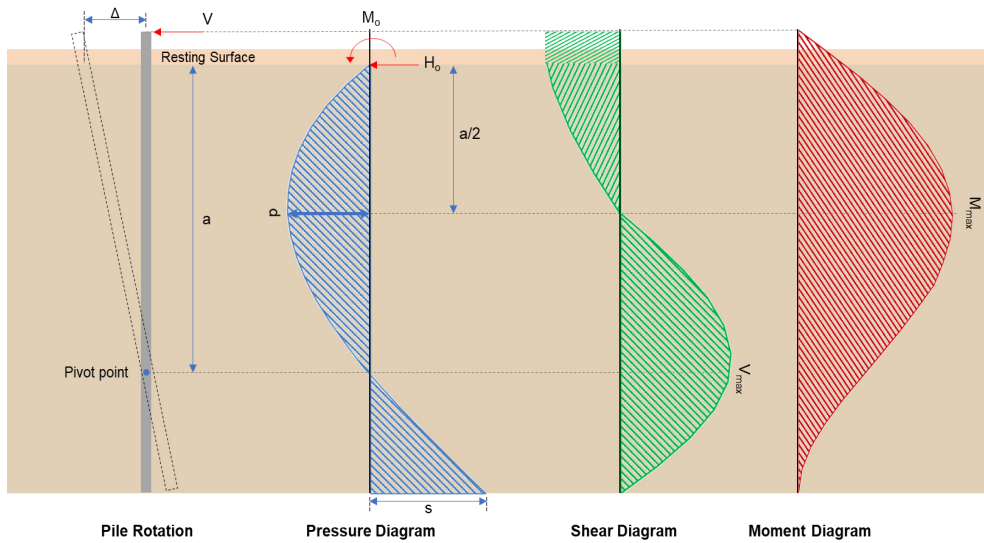
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0041991 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.0062209$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.348 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.055414 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.599 \text{ kipft}) + ((-0.348 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.0062 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.0062 \text{ kipft/ft})}{(-0.055414 \text{ kip/ft})}$$

$$E = 36.204 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.0062 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.055414 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times 2.0062) + (4 \times (-0.055414) \times 4.5)}$$

$$a = \frac{(-0.055414 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (2.0062 \text{ kipft/ft})) + (4 \times (-0.055414 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0287 \text{ ft}$$

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

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

$$V_{max} = ((-0.055414 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (36.204 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0287 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (36.204 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0287 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 3.3108 \text{ kip}$$

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

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

$$M_{max} = ((-0.055414 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(36.204 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0287 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (36.204 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0287 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (36.204 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0287 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 7.3575 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.009 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0014331 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.045 \text{ kipft}) + ((0.009 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0071656 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0071656 \text{ kipft/ft})}{(0.0014331 \text{ kip/ft})}$$

$$E = 5 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0071656 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (0.0014331 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.0071656 \text{ kipft/ft})) + (4 \times (0.0014331 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.1406 \text{ ft}$$

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

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

$$V_{max} = ((0.0014331 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.1406 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (5 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.1406 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.015054 \text{ kip}$$

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

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

$$M_{max} = ((0.0014331 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(5 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.1406 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (5 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.1406 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.1406 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.031544 \text{ kipft}$$

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,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(8.523 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.313 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.313 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(8.523 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.003186$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.523 \text{ kip} \rightarrow 8523 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(8523 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.62 \text{ kip}$$

22.5.5.1.2 The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,
 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.62 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.62 \text{ kip}$$

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.62 \text{ kip}) + (50.894 \text{ kip}))$$

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

Considering x-direction:

$V_{max} = 3.3108 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(3.3108 \text{ kip})}{(110.84 \text{ kip})}$$

$$Ratio = 0.029872$$

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

Considering z-direction:

$V_{max} = 0.015054 \text{ kip}$ - Maximum shear force in the z-direction,
Ratio - Capacity

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

$$Ratio = \frac{(0.015054 \text{ kip})}{(110.84 \text{ kip})}$$

$$Ratio = 0.00013582$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 7.3575 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(7.3575 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.029477$$

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

Considering z-direction:

$M_{max} = 0.031544 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.031544 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00012638$$

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

REFERENCES	CALCULATIONS	RESULTS
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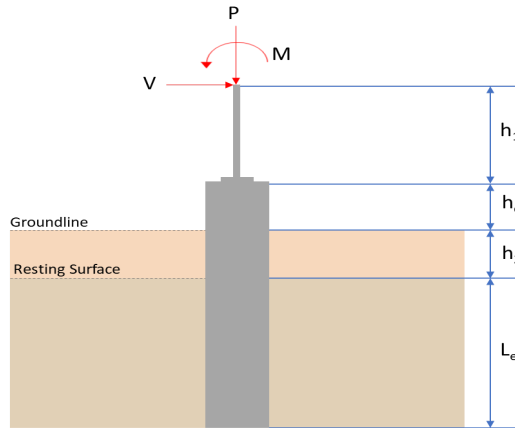
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 4.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.991	8.598
V_x (kip)	-0.211	-0.352
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	7.112	12.716

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,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.112 \text{ kipft}) + ((-0.211 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.1325 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 4.3418 \text{ ft}$ - 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,

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

$$L_{e,req} = \text{MAX}[(4.3418 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 4.342 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(4.342 \text{ ft})}{(4.5 \text{ ft})}$$

$$\text{Ratio} = 0.96489$$

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

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

$$q = \frac{(5.991 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.37444 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.37444 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.18722$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.033599$ kip/ft - Lateral force per length of pile,

$M_o = 1.1325$ kipft/ft - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.1325 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.033599 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.1325 \text{ kipft/ft})) + (4 \times (-0.033599 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0306 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.1325 \text{ kipft/ft})) + (3 \times (-0.033599 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.1325 \text{ kipft/ft})) + (2 \times (-0.033599 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.19884 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.1325 \text{ kipft/ft})) + ((-0.033599 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.6263 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.0306 \text{ ft})}{2}$$

$$p_a = 0.2273 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.19884 \text{ kip/ft}^2)}{(0.2273 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.87481$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

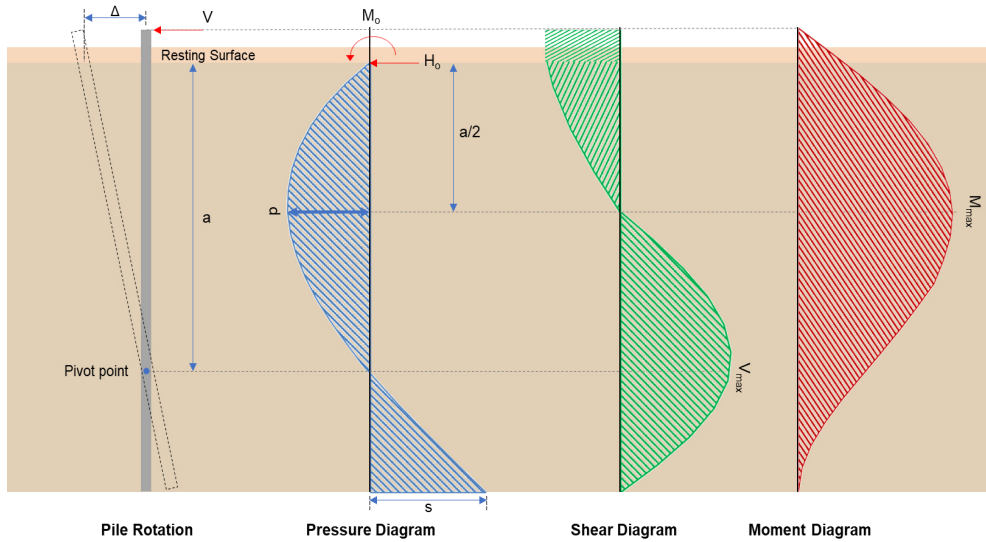
$$p_s = 0.675 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.6263 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.352 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.056051 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.716 \text{ kipft}) + ((-0.352 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.0248 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.0248 \text{ kipft/ft})}{(-0.056051 \text{ kip/ft})}$$

$$E = 36.125 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.0248 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.056051 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (2.0248 \text{ kipft/ft})) + (4 \times (-0.056051 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0288 \text{ ft}$$

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

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

$$V_{max} = ((-0.056051 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (36.125 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0288 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (36.125 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0288 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 3.3419 \text{ kip}$$

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

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

$$M_{max} = ((-0.056051 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(36.125 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0288 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (36.125 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0288 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (36.125 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0288 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 7.4263 \text{ kipft}$$

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,
 $\alpha = 0.8$ - Alpha factor for axial strength,
 $A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(8.598 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.31 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.31 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$\text{Ratio} = 0.96556$$

25.2.3

s_{rebar} - Minimum spacing of reinforcement,

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

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

Ratio - Capacity

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

$$Ratio = \frac{(8.598 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.003214$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2 b_w = 48 in - Effective width,
 d - Effective depth

$$d = 0.80 D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.598 \text{ kip} \rightarrow 8598 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(8598 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.63 \text{ kip}$$

22.5.5.1.2 The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,
 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.63 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.63 \text{ kip}$$

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

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

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

Considering x-direction:

$V_{max} = 3.3419 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(3.3419 \text{ kip})}{(110.84 \text{ kip})}$$

$$\text{Ratio} = 0.03015$$

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

Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus

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

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

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

 $\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

 M_n shall be the lesser of: $\phi M_{n,1}$

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

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

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

14.5.2.1b

 $\phi M_{n,2}$

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

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

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

Therefore,

 ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction: $M_{max} = 7.4263 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(7.4263 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.029753$$

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

REFERENCES	CALCULATIONS	RESULTS
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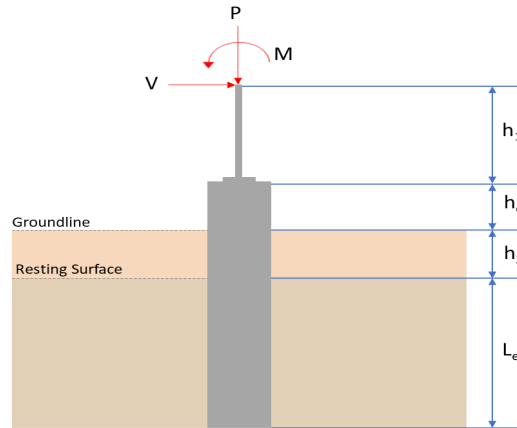
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 4.5$ ft - Total pile length

$h_1 = 0$ ft - Lateral load height from the top of the pile,

$h_2 = 0$ ft - Depth to resisting surface

$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.939	8.523
V_x (kip)	-0.209	-0.348
V_z (kip)	-0.006	-0.009
M_x (kipft)	-0.031	-0.045
M_z (kipft)	7.046	12.599

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,

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

$$H_o = \frac{(-0.209 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.03328 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.046 \text{ kipft}) + ((-0.209 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.122 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 4.3288 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.006 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.00095541 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.031 \text{ kipft}) + ((-0.006 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0049363 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.7077 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(4.3288 \text{ ft}), (0.7077 \text{ ft})]$$

$$L_{e,req} = 4.329 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(4.329 \text{ ft})}{(4.5 \text{ ft})}$$

$$\text{Ratio} = 0.962$$

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

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

$$q = \frac{(5.939 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.37119 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.37119 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.18559$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.03328 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.122 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.122 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.122 \text{ kipft/ft})) + (4 \times (-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0306 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.122 \text{ kipft/ft})) + (3 \times (-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.122 \text{ kipft/ft})) + (2 \times (-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.197 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.122 \text{ kipft/ft})) + ((-0.03328 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.6205 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.0306 \text{ ft})}{2}$$

$$p_a = 0.2273 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.197 \text{ kip/ft}^2)}{(0.2273 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.86671$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.6205 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.91926$$

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

Status: **PASS**
Ratio: **0.920**

Considering z-direction:

$H_o = -0.00095541 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.0049363 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0049363 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.0049363 \text{ kipft/ft})) + (4 \times (-0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.1378 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.0049363 \text{ kipft/ft})) + (3 \times (-0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 [(3 \times (0.0049363 \text{ kipft/ft})) + (2 \times (-0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.00027961 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.0049363 \text{ kipft/ft})) + ((-0.00095541 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.0016513 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.1378 \text{ ft})}{2}$$

$$p_a = 0.23533 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.00027961 \text{ kip/ft}^2)}{(0.23533 \text{ kip/ft}^2)}$$

$$Ratio = 0.0011881$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

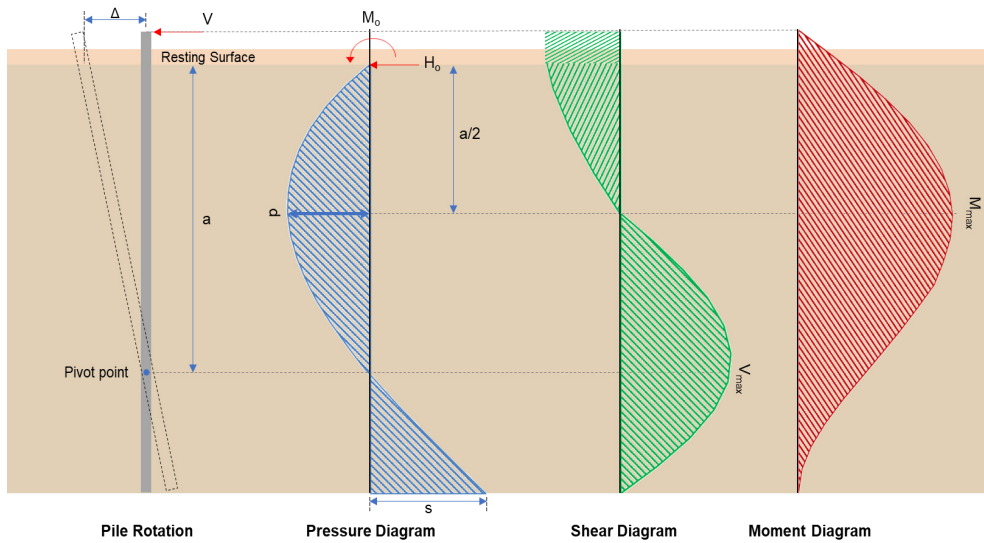
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.0016513 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.0024464$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.348 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.055414 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.599 \text{ kipft}) + ((-0.348 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.0062 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(2.0062 \text{ kipft/ft})}{(-0.055414 \text{ kip/ft})}$$

$$E = 36.204 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.0062 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.055414 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times 2.0062) + (4 \times (-0.055414) \times 4.5)}$$

$$a = \frac{(-0.055414 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (2.0062 \text{ kipft/ft})) + (4 \times (-0.055414 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0287 \text{ ft}$$

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

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

$$V_{max} = ((-0.055414 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (36.204 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0287 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (36.204 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0287 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 3.3108 \text{ kip}$$

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

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

$$M_{max} = ((-0.055414 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(36.204 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0287 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (36.204 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0287 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (36.204 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0287 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 7.3575 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.009 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0014331 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.045 \text{ kipft}) + ((-0.009 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0071656 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0071656 \text{ kipft/ft})}{(-0.0014331 \text{ kip/ft})}$$

$$E = 5 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0071656 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.0014331 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.0071656 \text{ kipft/ft})) + (4 \times (-0.0014331 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.1406 \text{ ft}$$

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

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

$$V_{max} = ((-0.0014331 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (5 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.1406 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (5 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.1406 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.015054 \text{ kip}$$

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

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

$$M_{max} = ((-0.0014331 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(5 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.1406 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (5 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.1406 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (5 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.1406 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.031544 \text{ kipft}$$

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,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(8.523 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.313 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.313 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(8.523 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.003186$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.523 \text{ kip} \rightarrow 8523 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(8523 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.62 \text{ kip}$$

22.5.5.1.2 The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,
 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.62 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.62 \text{ kip}$$

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.62 \text{ kip}) + (50.894 \text{ kip}))$$

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

Considering x-direction:

$V_{max} = 3.3108 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(3.3108 \text{ kip})}{(110.84 \text{ kip})}$$

$$Ratio = 0.029872$$

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

Considering z-direction:

$V_{max} = 0.015054 \text{ kip}$ - Maximum shear force in the z-direction,
Ratio - Capacity

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

$$Ratio = \frac{(0.015054 \text{ kip})}{(110.84 \text{ kip})}$$

$$Ratio = 0.00013582$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

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

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

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

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

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 7.3575 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(7.3575 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.029477$$

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

Considering z-direction:

$M_{max} = 0.031544 \text{ kipft}$ - Maximum moment in the z-direction,

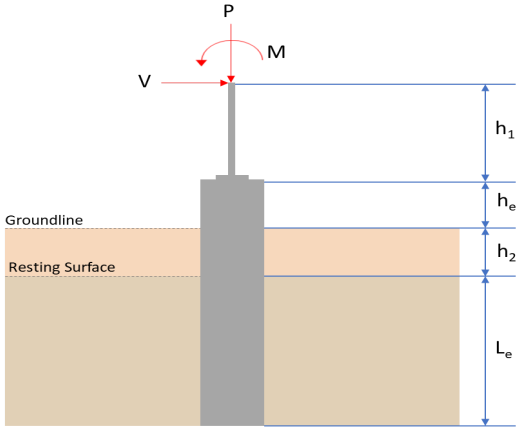
Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.031544 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00012638$$

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

REFERENCES	CALCULATIONS	RESULTS																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry</p> <p>Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 4.5$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resisting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1" data-bbox="368 1088 1225 1189"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1" data-bbox="655 1290 940 1480"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>5.616</td> <td>8.053</td> </tr> <tr> <td>V_x (kip)</td> <td>-0.203</td> <td>-0.340</td> </tr> <tr> <td>V_z (kip)</td> <td>0.017</td> <td>0.024</td> </tr> <tr> <td>M_x (kipft)</td> <td>0.080</td> <td>0.118</td> </tr> <tr> <td>M_z (kipft)</td> <td>6.880</td> <td>12.281</td> </tr> </tbody> </table> <p>Material Properties</p> <p>$f'_{ck} = 2.5$ ksi - Concrete strength.</p>	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	Load Component	ASD	LRFD	P (kip)	5.616	8.053	V_x (kip)	-0.203	-0.340	V_z (kip)	0.017	0.024	M_x (kipft)	0.080	0.118	M_z (kipft)	6.880	12.281	
Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)																									
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M_x (kipft)	0.080	0.118																										
M_z (kipft)	6.880	12.281																										
	<p>Required depth to resist lateral loads (ASD)</p> <p>H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction:</p> <p>H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-0.203 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.032325 \text{ kip/ft}$																											

M_o - Moment per length of pile,

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

$$M_o = \frac{(6.88 \text{ kipft}) + ((-0.203 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.0955 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,x} = 4.2965 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.08 \text{ kipft}) + ((0.017 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.012739 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 1.0602 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(4.2965 \text{ ft}), (1.0602 \text{ ft})]$$

$$L_{e,req} = 4.296 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

Ratio - Embedded depth

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

$$Ratio = \frac{(4.296 \text{ ft})}{(4.5 \text{ ft})}$$

$$Ratio = 0.95467$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.616 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.351 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.351 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.1755$$

Status: **PASS**
Ratio: **0.180**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.032325 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.0955 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.0955 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.0955 \text{ kipft/ft})) + (4 \times (-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0305 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.0955 \text{ kipft/ft})) + (3 \times (-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.0955 \text{ kipft/ft})) + (2 \times (-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.19249 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.0955 \text{ kipft/ft})) + ((-0.032325 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.60611 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.0305 \text{ ft})}{2}$$

$$p_a = 0.22729 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.19249 \text{ kip/ft}^2)}{(0.22729 \text{ kip/ft}^2)}$$

$$Ratio = 0.84689$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.60611 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.89794$$

Status: **PASS**
Ratio: **0.850**

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

Considering z-direction:

$H_o = 0.002707 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.012739 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.012739 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (0.002707 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.012739 \text{ kipft/ft})) + (4 \times (0.002707 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.146 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.012739 \text{ kipft/ft})) + (3 \times (0.002707 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (0.012739 \text{ kipft/ft})) + (2 \times (0.002707 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.0045313 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.012739 \text{ kipft/ft})) + ((0.002707 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.011158 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.146 \text{ ft})}{2}$$

$$p_a = 0.23595 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0045313 \text{ kip/ft}^2)}{(0.23595 \text{ kip/ft}^2)}$$

$$Ratio = 0.019204$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

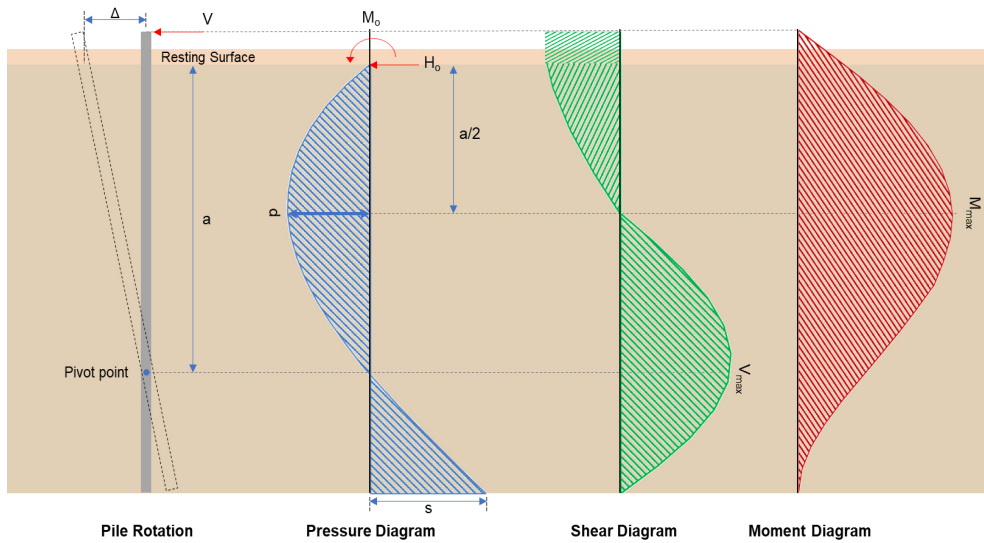
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{(0.011158 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.016531$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.34 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.05414 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(12.281 \text{ kipft}) + ((-0.34 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.9556 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.9556 \text{ kipft/ft})}{(-0.05414 \text{ kip/ft})}$$

$$E = 36.121 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.9556 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.05414 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times 1.9556) + (4 \times (-0.05414) \times 4.5)}$$

$$a = \frac{(6 \times (1.9556 \text{ kipft/ft})) + (4 \times (-0.05414 \text{ kip/ft}) \times (4.5 \text{ ft}))}{}$$

$$a = 3.0288 \text{ ft}$$

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

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

$$V_{max} = ((-0.05414 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (36.121 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0288 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (36.121 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0288 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 3.2276 \text{ kip}$$

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

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

$$M_{max} = ((-0.05414 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(36.121 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0288 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (36.121 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0288 \text{ ft})}{(2 \times (4.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (36.121 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0288 \text{ ft})}{(2 \times (4.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 7.1723 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.024 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0038217 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.118 \text{ kipft}) + ((0.024 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.01879 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.01879 \text{ kipft/ft})}{(0.0038217 \text{ kip/ft})}$$

$$E = 4.9167 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.01879 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (0.0038217 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.01879 \text{ kipft/ft})) + (4 \times (0.0038217 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.1421 \text{ ft}$$

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

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

$$V_{max} = ((0.0038217 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.9167 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.1421 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (4.9167 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.1421 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.039644 \text{ kip}$$

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

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

$$M_{max} = ((0.0038217 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(4.9167 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.1421 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (4.9167 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.1421 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.9167 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.1421 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.082994 \text{ kipft}$$

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,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(8.053 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.329 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.329 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = \text{Min spacing of reinforcement,}$</p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>s_{ties} - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p>Ratio - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(8.053 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0030103$	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p>λ_s - size effect modification factor</p> $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.053 \text{ kip} \rightarrow 8053 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(8053 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.56 \text{ kip}$$

22.5.5.1.2 The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,
 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min} [(296.21 \text{ kip}), (119.56 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.56 \text{ kip}$$

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.56 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.79 \text{ kip}$$

Considering x-direction:

$V_{max} = 3.2276 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(3.2276 \text{ kip})}{(110.79 \text{ kip})}$$

$$Ratio = 0.029131$$

Considering z-direction:

$V_{max} = 0.039644 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.039644 \text{ kip})}{(110.79 \text{ kip})}$$

$$Ratio = 0.00035782$$

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

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

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

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 7.1723 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(7.1723 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.028735$$

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

Considering z-direction:

$M_{max} = 0.082994 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.082994 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00033251$$

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