Your Project Calculations

Project Name: Van Kleef (RV Carport)

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Van%20Kleef%20(RV%20Carport)&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=LbPnSPqK2EV2TtUWCQk2kS42IT16VWX8stmvZHHJbKoz1jdMfXia06IrJ5RVFTyv

Array Specification

Product:	Beam
Unique ID:	5P-22.5-6TOP-SD-12-L-5Hx15W-30C0
Duty Classification:	SD
Module Width:	39.45 in
Module Length:	79.06in
Number of Rows:	5
Number of Columns:	15
Total Number of Modules:	75
Desired Tilt Angle:	1
Front Edge Clearance:	1
Total Array Height at Tilt:	1.29 ft
Total Frame Length:	99.50 ft
Frame Weight:	2664 lbs
Array Dimensions N/S:	16.65 ft
Array Dimensions E/W:	100.08 ft
Rail Length:	199.75 in
Rail Spacing:	3.29 ft
Rail Check:	Not Checked

Support Specifications

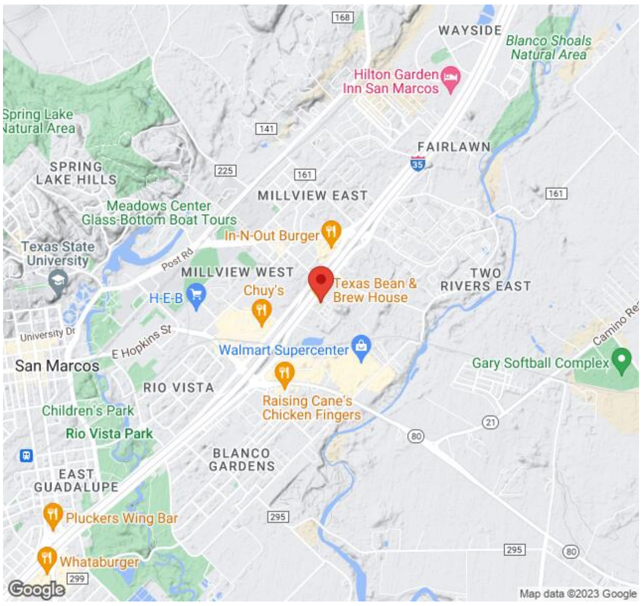
Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	1.15 ft
Number of Poles:	5
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 3.50 ft Pile 2: 4.00 ft Pile 3: 4.00 ft Pile 4: 4.00 ft Pile 5: 3.50 ft
Foundation Volume:	11.259 y^3
Foundation Result:	PASSED
Mount Twist:	0.073677 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	1328 N Interstate 35 Frontage Rd, San Marcos, TX 78666, USA
Wind Speed:	101 mph
Snow Load:	5 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.003024 ksf



Design Disclaimer

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

AutoDesigner Input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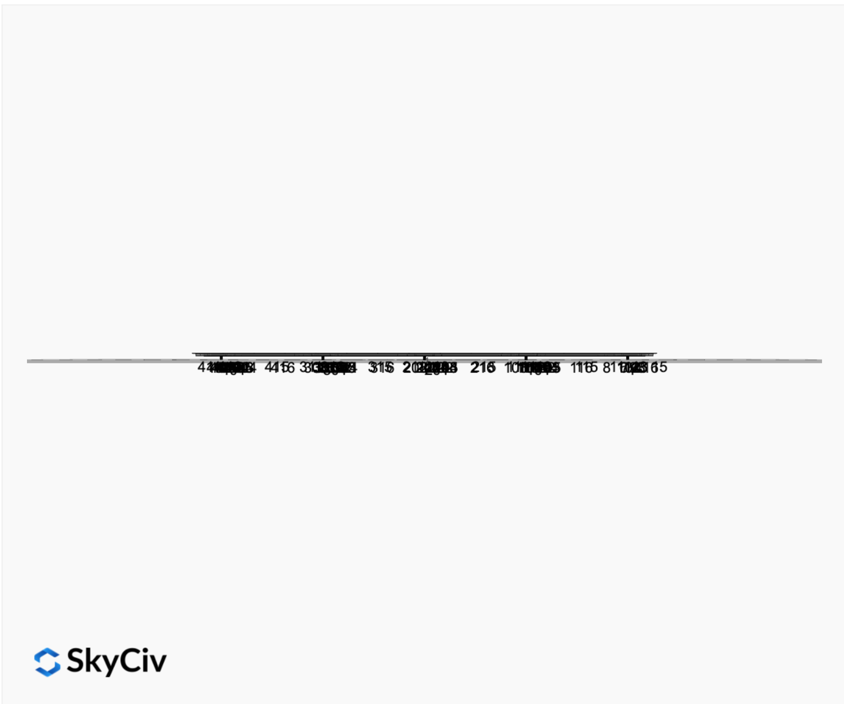
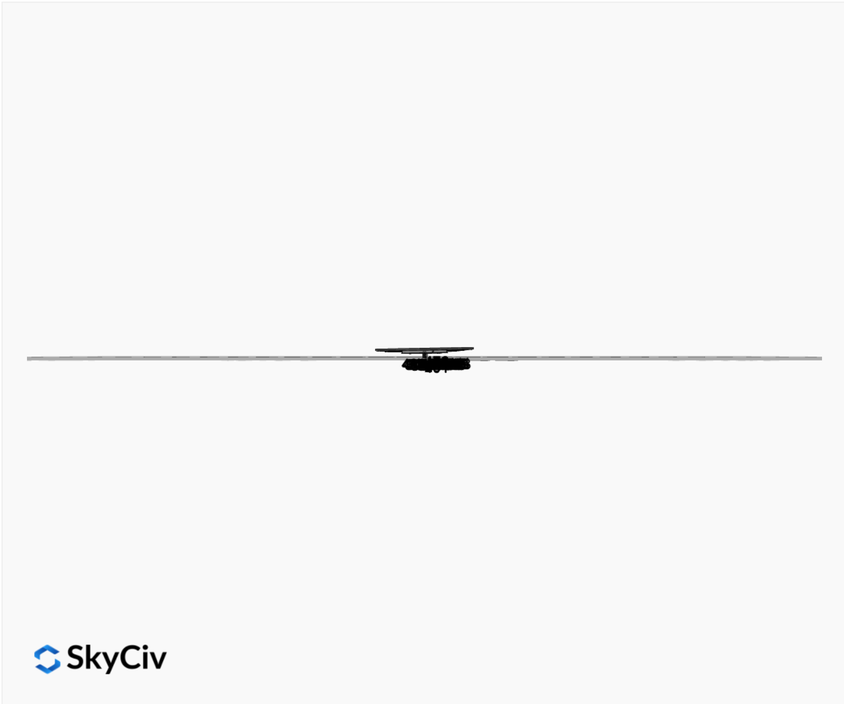
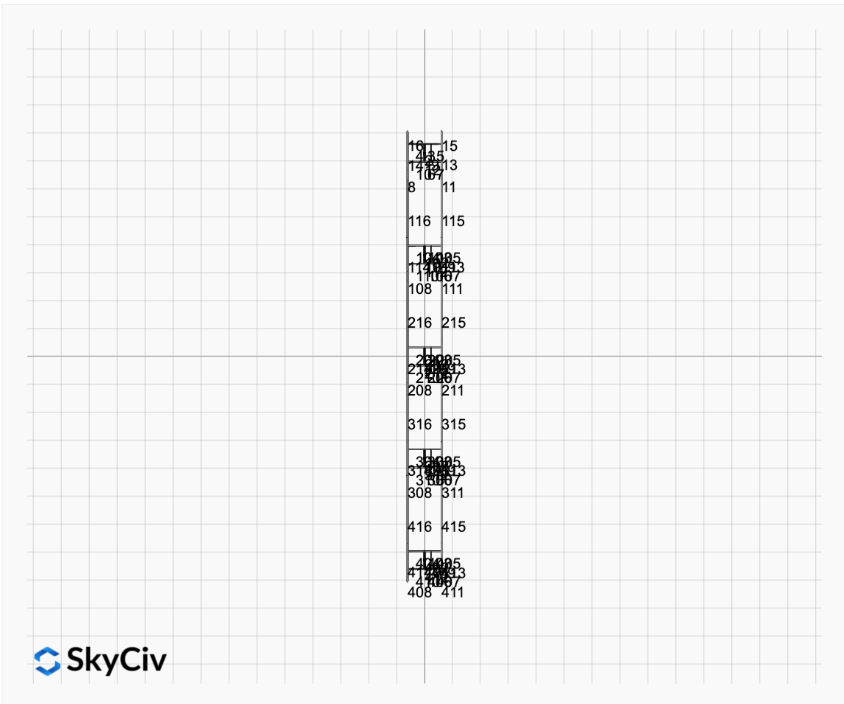
Design Notes:

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



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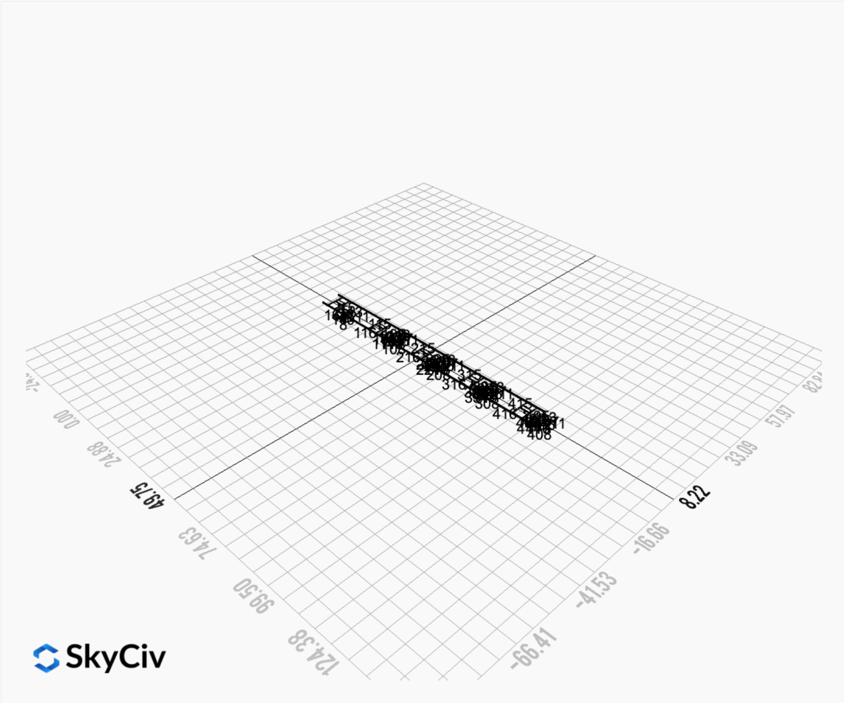
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74.63
99.50
124.38
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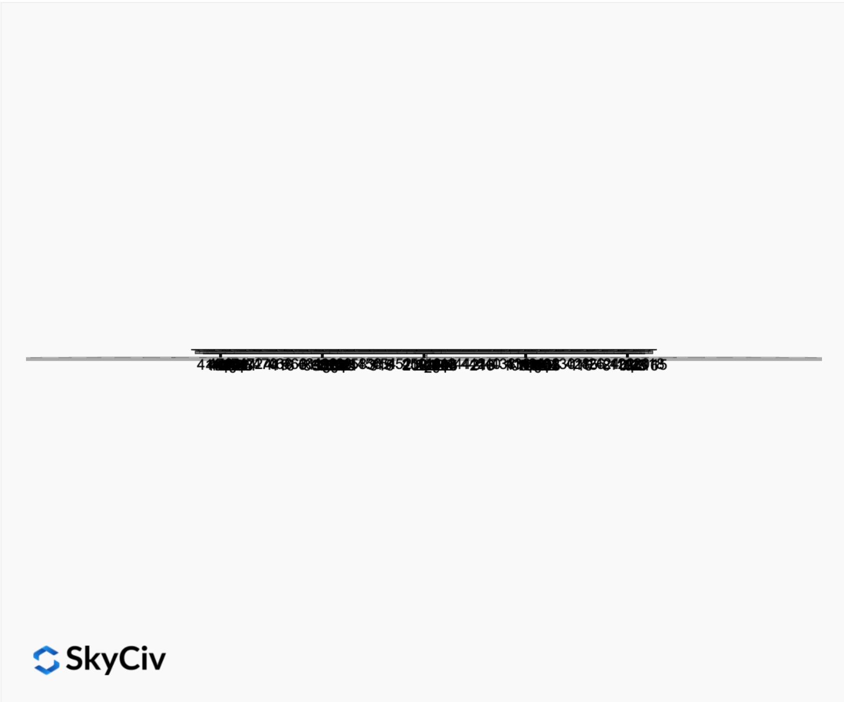
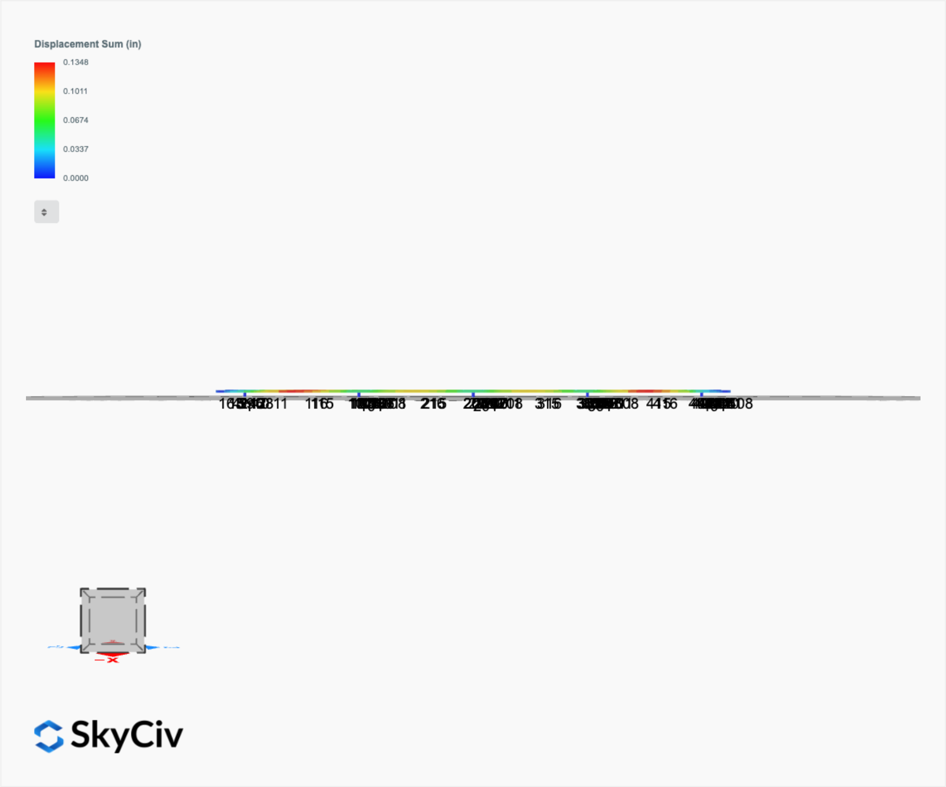
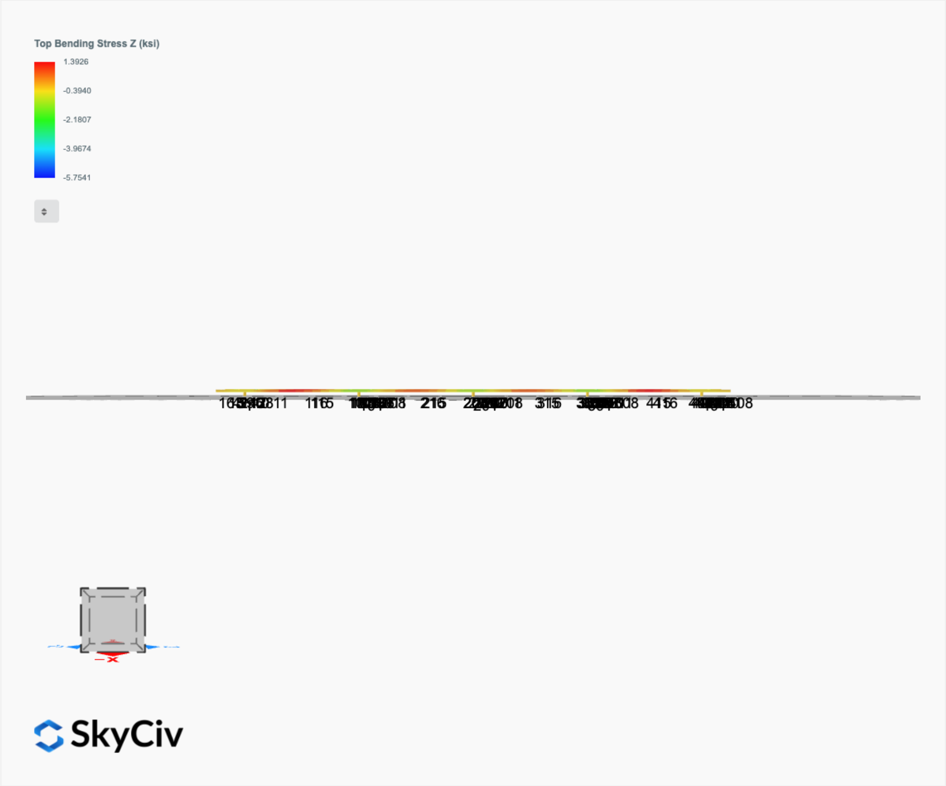
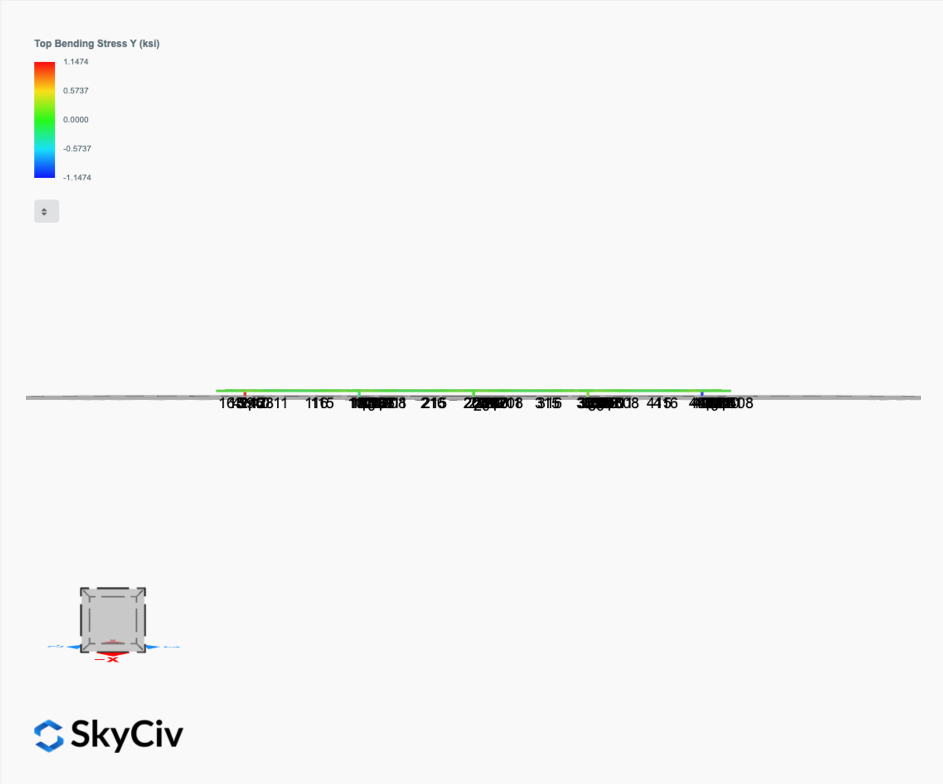
-41.53
-66.41
33.09
51.97

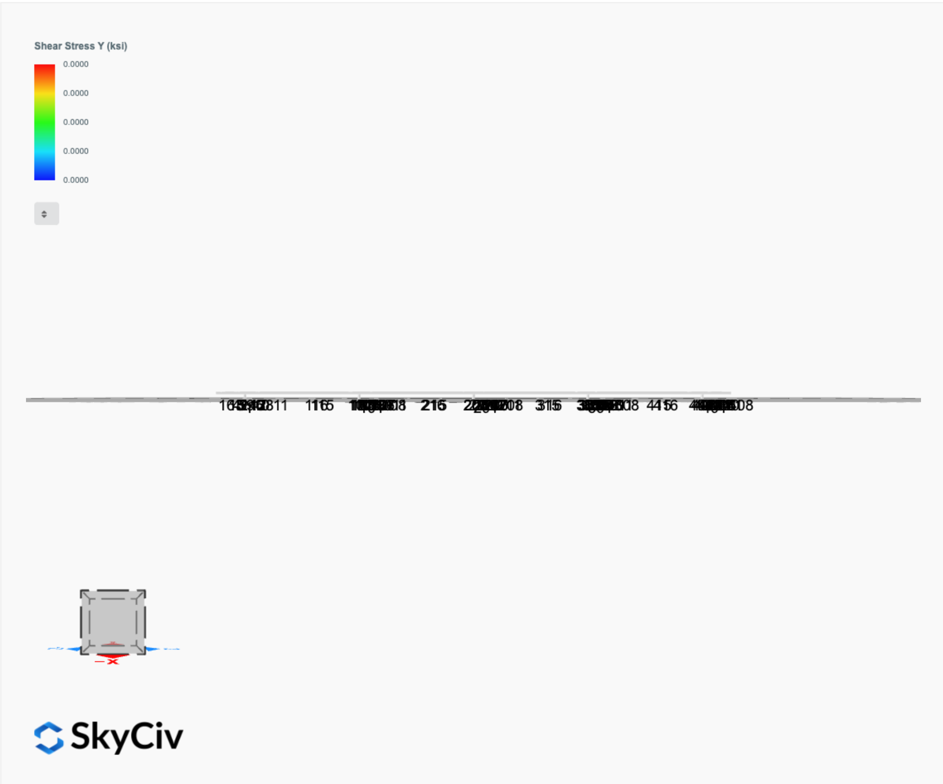


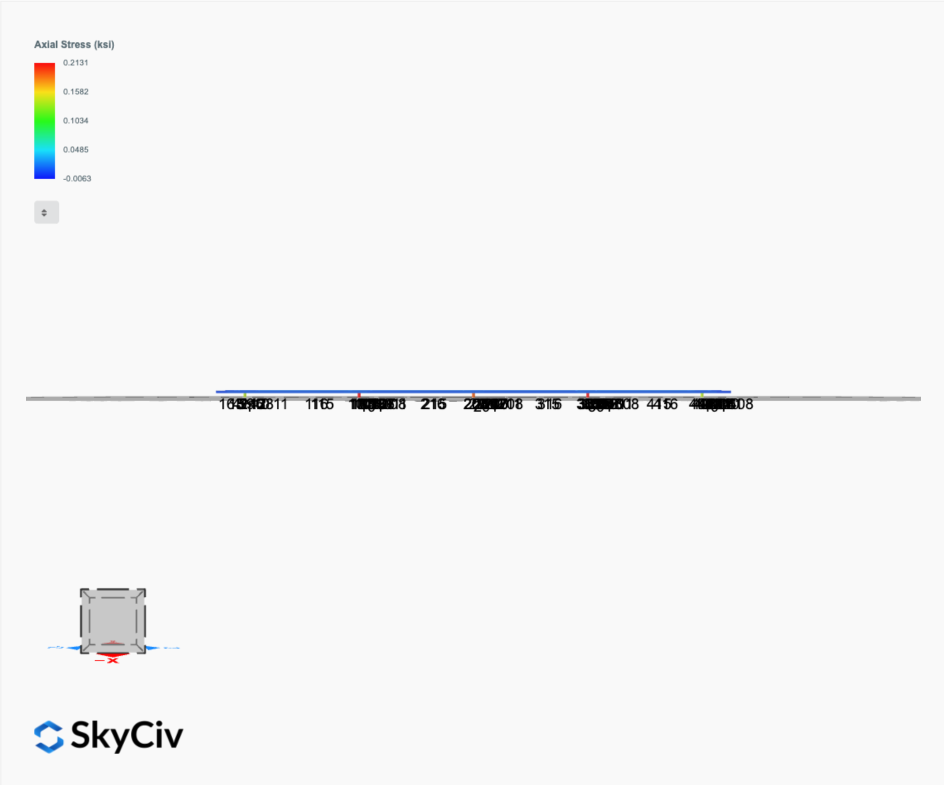
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
1.1474
0.5737
0.0000
-0.5737
-1.1474
SkyCiv


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


Axial Stress (ksi)
0.2131
0.1582
0.1034
0.0485
-0.0063
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0016	1.5876	0.0575	-1.4546	-0.0175	0.0217
ULS: 2. D + L	0.0016	1.5876	0.0575	-1.4546	-0.0175	0.0217
ULS: 3. D + (S or Lr or R)	0.0025	2.3447	0.0882	-2.2319	-0.0269	0.0222
ULS: 3. D + (S or Lr or R)	0.0016	1.5876	0.0575	-1.4546	-0.0175	0.0217
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0022	2.1554	0.0805	-2.0376	-0.0245	0.0221
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0016	1.5876	0.0575	-1.4546	-0.0175	0.0217
ULS: 5b. D + 0.7E	0.0016	1.5876	0.0575	-1.4546	-0.0175	0.0217
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0022	2.1554	0.0805	-2.0376	-0.0245	0.0221
ULS: 8. 0.6D + 0.7E	0.0010	0.9526	0.0345	-0.8728	-0.0105	0.0130
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.0208	2.8854	0.1091	-2.7806	-0.0463	-2.0898
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0208	2.8854	0.1091	-2.7806	-0.0463	-2.0898
ULS: 5a. D + 0.6W_Wind uplift Case A only	-0.0138	2.4591	0.0927	-2.3598	-0.0380	2.5881
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0190	0.6038	0.0177	-0.4324	0.0057	-3.2189
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0146	3.1287	0.1193	-3.0320	-0.0461	-1.5615
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0146	3.1287	0.1193	-3.0320	-0.0461	-1.5615
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0093	2.8090	0.1069	-2.7164	-0.0399	1.9469
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0153	1.4175	0.0507	-1.2709	-0.0071	-2.4084
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0152	2.5610	0.0962	-2.4491	-0.0391	-1.5619
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0152	2.5610	0.0962	-2.4491	-0.0391	-1.5619
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0100	2.2412	0.0839	-2.1335	-0.0329	1.9465
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0147	0.8498	0.0277	-0.6880	-0.0001	-2.4088
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.0215	2.2504	0.0861	-2.1987	-0.0393	-2.0984
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0215	2.2504	0.0861	-2.1987	-0.0393	-2.0984
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	-0.0144	1.8240	0.0697	-1.7779	-0.0310	2.5795
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0184	-0.0312	-0.0053	0.1495	0.0127	-3.2276

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	4.4466
Shear X	-0.0374
Shear Z	0.1705
Moment X	-4.3473
Moment Y (Twist)	0.0737
Moment Z	5.4010

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	3.1287
Shear X	-0.0215
Shear Z	0.1193
Moment X	-3.0320
Moment Y (Twist)	0.0463
Moment Z	3.2276

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	-0.0019	2.3967	-0.0113	0.2132	0.0057	0.0198
ULS: 2. D + L	-0.0019	2.3967	-0.0113	0.2132	0.0057	0.0198
ULS: 3. D + (S or Lr or R)	-0.0029	3.5859	-0.0174	0.3272	0.0087	0.0192
ULS: 3. D + (S or Lr or R)	-0.0019	2.3967	-0.0113	0.2132	0.0057	0.0198
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0027	3.2886	-0.0159	0.2987	0.0079	0.0193
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0019	2.3967	-0.0113	0.2132	0.0057	0.0198
ULS: 5b. D + 0.7E	-0.0019	2.3967	-0.0113	0.2132	0.0057	0.0198

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0027	3.2886	-0.0159	0.2987	0.0079	0.0193
ULS: 8. 0.6D + 0.7E	-0.0011	1.4380	-0.0068	0.1279	0.0034	0.0119
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.0377	4.4368	-0.0217	0.4098	0.0109	-3.1892
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0377	4.4368	-0.0217	0.4098	0.0109	-3.1892
ULS: 5a. D + 0.6W_Wind uplift Case A only	-0.0255	3.7640	-0.0183	0.3434	0.0084	3.9096
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0248	0.8534	-0.0035	0.0667	0.0026	-4.8907
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0295	4.8186	-0.0236	0.4461	0.0119	-2.3874
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0295	4.8186	-0.0236	0.4461	0.0119	-2.3874
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0204	4.3141	-0.0211	0.3963	0.0100	2.9367
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0173	2.1311	-0.0100	0.1888	0.0057	-3.6635
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0288	3.9268	-0.0191	0.3607	0.0096	-2.3870
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0288	3.9268	-0.0191	0.3607	0.0096	-2.3870
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0196	3.4222	-0.0165	0.3109	0.0077	2.9371
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0181	1.2392	-0.0055	0.1033	0.0034	-3.6631
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.0370	3.4781	-0.0171	0.3245	0.0087	-3.1971
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0370	3.4781	-0.0171	0.3245	0.0087	-3.1971
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	-0.0248	2.8053	-0.0137	0.2581	0.0062	3.9017
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0255	-0.1053	0.0010	-0.0186	0.0004	-4.8986

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	6.8709
Shear X	-0.0625
Shear Z	-0.0339
Moment X	0.6415
Moment Y (Twist)	0.0171
Moment Z	8.1842

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	4.8186
Shear X	-0.0377
Shear Z	-0.0236
Moment X	0.4461
Moment Y (Twist)	0.0119
Moment Z	4.8986

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	0.0006	2.2590	0.0000	-0.0000	0.0000	0.0216
ULS: 2. D + L	0.0006	2.2590	0.0000	-0.0000	0.0000	0.0216
ULS: 3. D + (S or Lr or R)	0.0009	3.3745	0.0000	-0.0000	0.0000	0.0220
ULS: 3. D + (S or Lr or R)	0.0006	2.2590	0.0000	-0.0000	0.0000	0.0216
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0008	3.0956	0.0000	-0.0000	0.0000	0.0219
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0006	2.2590	0.0000	-0.0000	0.0000	0.0216
ULS: 5b. D + 0.7E	0.0006	2.2590	0.0000	-0.0000	0.0000	0.0216
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0008	3.0956	0.0000	-0.0000	0.0000	0.0219
ULS: 8. 0.6D + 0.7E	0.0004	1.3554	0.0000	-0.0000	0.0000	0.0129
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.0328	4.1718	-0.0000	-0.0000	0.0000	-3.0892
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0328	4.1718	-0.0000	-0.0000	0.0000	-3.0892
ULS: 5a. D + 0.6W_Wind uplift Case A only	-0.0218	3.5425	-0.0000	-0.0000	0.0000	3.7979
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0259	0.8099	-0.0000	-0.0000	0.0000	-4.7456
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0242	4.5302	-0.0000	-0.0000	0.0000	-2.3112
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0242	4.5302	-0.0000	-0.0000	0.0000	-2.3112
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0160	4.0583	-0.0000	-0.0000	0.0000	2.8541
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0198	2.0088	-0.0000	-0.0000	0.0000	-3.5535

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	-0.0244	3.6936	-0.0000	-0.0000	0.0000	-2.3115
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0244	3.6936	-0.0000	-0.0000	0.0000	-2.3115
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0162	3.2216	-0.0000	-0.0000	0.0000	2.8538
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0196	1.1722	-0.0000	-0.0000	0.0000	-3.5538
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.0330	3.2683	-0.0000	-0.0000	0.0000	-3.0978
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0330	3.2683	-0.0000	-0.0000	0.0000	-3.0978
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	-0.0221	2.6389	-0.0000	-0.0000	0.0000	3.7892
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0257	-0.0936	-0.0000	-0.0000	0.0000	-4.7542

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	6.4565
Shear X	-0.0556
Shear Z	-0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	7.9452

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	4.5302
Shear X	-0.0330
Shear Z	-0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	4.7542

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	-0.0019	2.3967	0.0113	-0.2132	-0.0057	0.0198
ULS: 2. D + L	-0.0019	2.3967	0.0113	-0.2132	-0.0057	0.0198
ULS: 3. D + (S or Lr or R)	-0.0029	3.5859	0.0174	-0.3272	-0.0087	0.0192
ULS: 3. D + (S or Lr or R)	-0.0019	2.3967	0.0113	-0.2132	-0.0057	0.0198
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0027	3.2886	0.0159	-0.2987	-0.0079	0.0193
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0019	2.3967	0.0113	-0.2132	-0.0057	0.0198
ULS: 5b. D + 0.7E	-0.0019	2.3967	0.0113	-0.2132	-0.0057	0.0198
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0027	3.2886	0.0159	-0.2987	-0.0079	0.0193
ULS: 8. 0.6D + 0.7E	-0.0011	1.4380	0.0068	-0.1279	-0.0034	0.0119
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.0377	4.4368	0.0217	-0.4098	-0.0109	-3.1892
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0377	4.4368	0.0217	-0.4098	-0.0109	-3.1892
ULS: 5a. D + 0.6W_Wind uplift Case A only	-0.0255	3.7640	0.0183	-0.3434	-0.0084	3.9096
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0248	0.8534	0.0035	-0.0667	-0.0026	-4.8907
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0295	4.8186	0.0236	-0.4461	-0.0119	-2.3874
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0295	4.8186	0.0236	-0.4461	-0.0119	-2.3874
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0204	4.3141	0.0211	-0.3963	-0.0100	2.9367
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0173	2.1311	0.0100	-0.1888	-0.0057	-3.6635
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0288	3.9268	0.0191	-0.3607	-0.0096	-2.3870
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0288	3.9268	0.0191	-0.3607	-0.0096	-2.3870
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0196	3.4222	0.0165	-0.3109	-0.0077	2.9371
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0181	1.2392	0.0055	-0.1033	-0.0034	-3.6631
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.0370	3.4781	0.0171	-0.3245	-0.0087	-3.1971
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0370	3.4781	0.0171	-0.3245	-0.0087	-3.1971
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	-0.0248	2.8053	0.0137	-0.2581	-0.0062	3.9017
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0255	-0.1053	-0.0010	0.0186	-0.0004	-4.8986

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.8709
Shear X	-0.0625
Shear Z	0.0339
Moment X	-0.6415
Moment Y (Twist)	0.0171
Moment Z	8.1842

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	4.8186
Shear X	-0.0377
Shear Z	0.0236
Moment X	-0.4461
Moment Y (Twist)	0.0119
Moment Z	4.8986

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	0.0016	1.5876	-0.0575	1.4546	0.0175	0.0217
ULS: 2. D + L	0.0016	1.5876	-0.0575	1.4546	0.0175	0.0217
ULS: 3. D + (S or Lr or R)	0.0025	2.3447	-0.0882	2.2319	0.0269	0.0222
ULS: 3. D + (S or Lr or R)	0.0016	1.5876	-0.0575	1.4546	0.0175	0.0217
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0022	2.1554	-0.0805	2.0376	0.0245	0.0221
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0016	1.5876	-0.0575	1.4546	0.0175	0.0217
ULS: 5b. D + 0.7E	0.0016	1.5876	-0.0575	1.4546	0.0175	0.0217
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0022	2.1554	-0.0805	2.0376	0.0245	0.0221
ULS: 8. 0.6D + 0.7E	0.0010	0.9526	-0.0345	0.8728	0.0105	0.0130
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.0208	2.8854	-0.1091	2.7805	0.0463	-2.0898
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0208	2.8854	-0.1091	2.7805	0.0463	-2.0898
ULS: 5a. D + 0.6W_Wind uplift Case A only	-0.0138	2.4591	-0.0927	2.3598	0.0380	2.5881
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0190	0.6038	-0.0177	0.4324	-0.0057	-3.2189
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0146	3.1287	-0.1193	3.0320	0.0461	-1.5615
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0146	3.1287	-0.1193	3.0320	0.0461	-1.5615
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0093	2.8090	-0.1069	2.7164	0.0399	1.9469
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0153	1.4175	-0.0507	1.2709	0.0071	-2.4084
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.0152	2.5610	-0.0962	2.4491	0.0391	-1.5619
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0152	2.5610	-0.0962	2.4491	0.0391	-1.5619
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	-0.0100	2.2412	-0.0839	2.1335	0.0329	1.9465
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0147	0.8498	-0.0277	0.6880	0.0001	-2.4088
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.0215	2.2504	-0.0861	2.1987	0.0393	-2.0984
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0215	2.2504	-0.0861	2.1987	0.0393	-2.0984
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	-0.0144	1.8240	-0.0697	1.7779	0.0310	2.5795
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0184	-0.0312	0.0053	-0.1495	-0.0127	-3.2276

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	4.4466
Shear X	-0.0374
Shear Z	-0.1705
Moment X	4.3473
Moment Y (Twist)	0.0737
Moment Z	5.4010

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	3.1287
Shear X	-0.0215
Shear Z	-0.1193
Moment X	3.0320
Moment Y (Twist)	0.0463
Moment Z	3.2276

Project Details

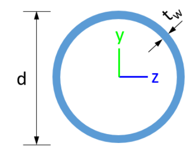
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

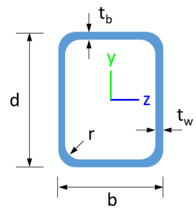
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

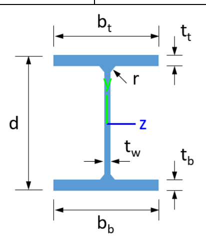
Section Dimensions



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



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28

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

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	2.41	2.41	1.15	-	300	200	1
2	4	1.30	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.17,1.17,1.17,1.16,1.17,1.17,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.17,1.17,1.17,1.17,2.24,1.16,1.16,1.16,1.15	300	200	1
4	15	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.69,1.68,1.67,1.67,1.69,1.69,1.67,1.67,1.68,1.68,1.68,1.68,1.69,1.69,1.67,1.67,1.69,1.68	300	200	1
5	15	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.64,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.69,1.68,1.68,1.67,3.06,1.67,1.67,1.67,1.65	300	200	1
6	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.22,1.19,1.19,1.19,1.18	300	200	1
7	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.71,1.67,1.67,1.67,1.66	300	200	1
8	18	1.33	1.33	2.05	1.36,1.36,1.36,1.36,1.36,1.36,1.37,1.37,1.34,1.40,1.37,1.37,1.34,1.41,1.37,1.37,1.36,1.38,1.37,1.37,1.35,1.38,1.37,1.37,1.33,1.43	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.68	300	200	1
11	18	1.33	1.33	2.05	1.37,1.37,1.37,1.37,1.37,1.37,1.36,1.36,1.39,1.46,1.36,1.36,1.39,1.43,1.37,1.37,1.38,1.35,1.36,1.36,1.38,1.22,1.36,1.36,1.39,1.42	300	200	1
12	4	1.30	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.22,1.23,1.22,1.23,1.22,1.22,1.19,1.19,1.30,1.73,1.20,1.20,1.31,1.58,1.19,1.19,1.27,1.24,1.17,1.17,1.28,1.69,1.22,1.22,1.32,1.49	300	200	1
14	18	4.88	4.00	7.50	1.17,1.17,1.17,1.18,1.17,1.17,1.24,1.24,1.26,1.42,1.25,1.25,1.28,1.49,1.22,1.22,1.18,1.26,1.23,1.23,1.21,1.31,1.25,1.25,1.31,1.63	300	200	1
15	18	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	18	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	7	2.41	2.41	1.15	-	300	200	1
102	4	1.30	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.22,1.18,1.18,1.18,1.17	300	200	1
104	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.68	300	200	1
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.67,1.67,1.67,1.66	300	200	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.18,1.18,1.18,1.17	300	200	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.72,1.67,1.67,1.67,1.66	300	200	1

108	18	1.33	1.33	2.05	2.17,2.17,2.17,2.17,2.17,2.20,2.20,2.08,2.23,2.21,2.21,2.06,2.23,2.19,2.19,2.13,2.21,2.20,2.20,2.11,2.22,2.21,2.21,2.04,2.25	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.68	300	200	1
111	18	1.33	1.33	2.05	2.16,2.16,2.16,2.16,2.16,2.10,2.10,2.21,2.25,2.09,2.09,2.21,2.24,2.13,2.13,2.19,2.06,2.11,2.11,2.20,1.69,2.08,2.08,2.21,2.23	300	200	1
112	4	1.30	1.30	2.00	-	300	200	1
113	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.18,1.03,1.03,1.03,1.12,1.03,1.03,1.03,1.03,1.03,1.03,1.06,1.03,1.03,1.03,1.08	300	200	1
114	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.06,1.03,1.03,1.03,1.09,1.03,1.03,1.03,1.02,1.02,1.03,1.03,1.03,1.03,1.04,1.15	300	200	1
115	18	8.42	8.42	12.95	1.19,1.19,1.19,1.19,1.19,1.19,1.20,1.20,1.18,1.16,1.20,1.20,1.18,1.17,1.19,1.19,1.19,1.20,1.19,1.19,1.18,1.33,1.20,1.20,1.18,1.17	300	200	1
116	18	8.42	8.42	12.95	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.20,1.17,1.18,1.18,1.20,1.17,1.19,1.19,1.19,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.20,1.16	300	200	1
201	7	2.41	2.41	1.15	-	300	200	1
202	4	1.30	1.30	2.00	-	300	200	1
203	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.18,1.18,1.18,1.17	300	200	1
204	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.68	300	200	1
205	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.67,1.67,1.67,1.66	300	200	1
206	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.18,1.18,1.18,1.17	300	200	1
207	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.73,1.67,1.67,1.67,1.66	300	200	1
208	18	1.33	1.33	2.05	2.29,2.29,2.29,2.29,2.29,2.29,2.28,2.28,2.32,2.25,2.28,2.28,2.33,2.24,2.28,2.28,2.30,2.27,2.28,2.28,2.31,2.26,2.28,2.28,2.34,2.22	300	200	1
209	1	2.60	2.60	4.00	-	300	200	1
210	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.68	300	200	1
211	18	1.33	1.33	2.05	2.29,2.29,2.29,2.28,2.29,2.29,2.30,2.30,2.27,2.21,2.31,2.31,2.27,2.23,2.29,2.29,2.28,2.32,2.30,2.30,2.27,1.93,2.31,2.31,2.27,2.24	300	200	1
212	4	1.30	1.30	2.00	-	300	200	1
213	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.15,1.03,1.03,1.03,1.10,1.03,1.03,1.03,1.03,1.03,1.03,1.02,1.03,1.03,1.03,1.07	300	200	1
214	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.06,1.03,1.03,1.03,1.08,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.12	300	200	1
215	18	8.42	8.42	12.95	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.19,1.16,1.16,1.17,1.18,1.16,1.16,1.17,1.16,1.16,1.16,1.17,1.15,1.16,1.16,1.17,1.18	300	200	1
216	18	8.42	8.42	12.95	1.16,1.16,1.16,1.16,1.16,1.16,1.17,1.17,1.16,1.18,1.17,1.17,1.16,1.18,1.17,1.17,1.16,1.17,1.17,1.17,1.16,1.17,1.17,1.17,1.16,1.19	300	200	1
301	7	2.41	2.41	1.15	-	300	200	1

302	4	1.30	1.30	2.00	-	300	200	1
303	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.18,1.18,1.18,1.17	300	200	1
304	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.68	300	200	1
305	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.72,1.67,1.67,1.67,1.66	300	200	1
306	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.18,1.18,1.18,1.22,1.18,1.18,1.18,1.17	300	200	1
307	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.71,1.67,1.67,1.67,1.66	300	200	1
308	18	1.33	1.33	2.05	2.25,2.25,2.25,2.25,2.25,2.25,2.27,2.27,2.22,2.34,2.27,2.27,2.22,2.33,2.26,2.26,2.24,2.28,2.27,2.27,2.23,2.30,2.27,2.27,2.21,2.15	300	200	1
309	1	2.60	2.60	4.00	-	300	200	1
310	15	2.44	2.44	3.75	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.68	300	200	1
311	18	1.33	1.33	2.05	2.25,2.25,2.25,2.25,2.25,2.25,2.23,2.23,2.27,2.14,2.23,2.23,2.27,2.27,2.24,2.24,2.26,2.21,2.23,2.23,2.27,1.56,2.22,2.22,2.28,2.34	300	200	1
312	4	1.30	1.30	2.00	-	300	200	1
313	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.18,1.03,1.03,1.03,1.12,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.06,1.03,1.03,1.03,1.08	300	200	1
314	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.06,1.03,1.03,1.03,1.09,1.03,1.03,1.03,1.03,1.02,1.02,1.03,1.03,1.03,1.03,1.04,1.15	300	200	1
315	18	8.42	8.42	12.95	1.19,1.19,1.19,1.19,1.19,1.19,1.20,1.20,1.19,1.17,1.20,1.20,1.19,1.18,1.20,1.20,1.19,1.20,1.20,1.20,1.19,1.25,1.20,1.20,1.19,1.18	300	200	1
316	18	8.42	8.42	12.95	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.20,1.18,1.19,1.19,1.20,1.18,1.19,1.19,1.20,1.19,1.19,1.19,1.20,1.19,1.19,1.19,1.20,1.17	300	200	1
401	7	2.41	2.41	1.15	-	300	200	1
402	4	1.30	1.30	2.00	-	300	200	1
403	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.22,1.19,1.19,1.19,1.18	300	200	1
404	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.68,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.68,1.67,1.67,1.67,1.68	300	200	1
405	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.71,1.67,1.67,1.67,1.66	300	200	1
406	15	0.92	0.92	1.42	1.17,1.17,1.17,1.16,1.17,1.17,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.17,1.17,1.17,1.17,2.24,1.16,1.16,1.16,1.15	300	200	1
407	15	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.64,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.69,1.68,1.68,1.67,3.06,1.67,1.67,1.67,1.65	300	200	1
408	18	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	1	2.60	2.60	4.00	-	300	200	1
410	15	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.69,1.68,1.67,1.67,1.69,1.69,1.67,1.67,1.68,1.68,1.68,1.68,1.69,1.69,1.67,1.67,1.69,1.68	300	200	1
411	18	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1

412	4	1.30	1.30	2.00	-	00	00	1
413	18	4.88	4.00	7.50	1.22,1.23,1.22,1.23,1.22,1.22,1.19,1.19,1.30,1.73,1.20,1.20,1.31,1.58,1.19,1.19,1.27,1.24,1.17,1.17,1.28,1.69,1.22,1.22,1.32,1.49	300	200	1
414	18	4.88	4.00	7.50	1.17,1.17,1.17,1.18,1.17,1.17,1.24,1.24,1.26,1.42,1.25,1.25,1.28,1.49,1.22,1.22,1.18,1.26,1.23,1.23,1.21,1.31,1.25,1.25,1.31,1.63	300	200	1
415	18	8.42	8.42	12.95	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.11	300	200	1
416	18	8.42	8.42	12.95	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	251.16	248.15	42.30	42.30	75.35	75.35
2	142.83	141.72	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	4.60	29.14	16.61
4	79.65	72.01	10.99	4.60	29.14	16.61
5	79.65	73.44	10.99	4.60	29.14	16.61
6	79.65	74.02	10.99	4.60	29.14	16.61
7	79.65	73.44	10.99	4.60	29.14	16.61
8	120.60	117.88	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	4.60	29.14	16.61
11	120.60	117.88	23.36	6.45	30.09	45.74
12	142.83	141.72	16.17	16.17	42.85	42.85
13	120.60	98.23	20.60	6.45	30.09	45.74
14	120.60	98.23	20.60	6.45	30.09	45.74
15	120.60	113.97	23.36	6.45	30.09	45.74
16	120.60	113.97	23.36	6.45	30.09	45.74
101	251.16	248.15	42.30	42.30	75.35	75.35
102	142.83	141.72	16.17	16.17	42.85	42.85
103	79.65	74.02	10.99	4.60	29.14	16.61
104	79.65	72.01	10.99	4.60	29.14	16.61
105	79.65	73.44	10.99	4.60	29.14	16.61
106	79.65	74.02	10.99	4.60	29.14	16.61
107	79.65	73.44	10.99	4.60	29.14	16.61
108	120.60	117.88	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	4.60	29.14	16.61
111	120.60	117.88	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	98.23	18.13	6.45	30.09	45.74
114	120.60	98.23	17.96	6.45	30.09	45.74
115	120.60	48.60	11.42	6.45	30.09	45.74
116	120.60	48.60	11.42	6.45	30.09	45.74
201	251.16	248.15	42.30	42.30	75.35	75.35
202	142.83	141.72	16.17	16.17	42.85	42.85
203	79.65	74.02	10.99	4.60	29.14	16.61
204	79.65	72.01	10.99	4.60	29.14	16.61
205	79.65	73.44	10.99	4.60	29.14	16.61
206	79.65	74.02	10.99	4.60	29.14	16.61
207	79.65	73.44	10.99	4.60	29.14	16.61

208	120.60	117.88	23.36	6.45	30.09	45.74
209	48.35	43.11	2.85	2.85	14.51	14.51
210	79.65	72.01	10.99	4.60	29.14	16.61
211	120.60	117.88	23.36	6.45	30.09	45.74
212	142.83	141.72	16.17	16.17	42.85	42.85
213	120.60	98.23	17.96	6.45	30.09	45.74
214	120.60	98.23	18.13	6.45	30.09	45.74
215	120.60	48.60	11.32	6.45	30.09	45.74
216	120.60	48.60	11.42	6.45	30.09	45.74
301	251.16	248.15	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	4.60	29.14	16.61
304	79.65	72.01	10.99	4.60	29.14	16.61
305	79.65	73.44	10.99	4.60	29.14	16.61
306	79.65	74.02	10.99	4.60	29.14	16.61
307	79.65	73.44	10.99	4.60	29.14	16.61
308	120.60	117.88	23.36	6.45	30.09	45.74
309	48.35	43.11	2.85	2.85	14.51	14.51
310	79.65	72.01	10.99	4.60	29.14	16.61
311	120.60	117.88	23.36	6.45	30.09	45.74
312	142.83	141.72	16.17	16.17	42.85	42.85
313	120.60	98.23	18.13	6.45	30.09	45.74
314	120.60	98.23	17.96	6.45	30.09	45.74
315	120.60	48.60	11.52	6.45	30.09	45.74
316	120.60	48.60	11.52	6.45	30.09	45.74
401	251.16	248.15	42.30	42.30	75.35	75.35
402	142.83	141.72	16.17	16.17	42.85	42.85
403	79.65	74.02	10.99	4.60	29.14	16.61
404	79.65	72.01	10.99	4.60	29.14	16.61
405	79.65	73.44	10.99	4.60	29.14	16.61
406	79.65	74.02	10.99	4.60	29.14	16.61
407	79.65	73.44	10.99	4.60	29.14	16.61
408	120.60	113.97	23.36	6.45	30.09	45.74
409	48.35	43.11	2.85	2.85	14.51	14.51
410	79.65	72.01	10.99	4.60	29.14	16.61
411	120.60	113.97	23.36	6.45	30.09	45.74
412	142.83	141.72	16.17	16.17	42.85	42.85
413	120.60	98.23	20.60	6.45	30.09	45.74
414	120.60	98.23	20.60	6.45	30.09	45.74
415	120.60	48.60	10.93	6.45	30.09	45.74
416	120.60	48.60	10.93	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	0.018	0.127	0.107	0.000	0.002	0.200	#13	0.064	Not Required	Pass
2	0.001	0.100	0.001	0.031	0.000	0.100	#13	0.052	Not Required	Pass
3	0.001	0.268	0.017	0.025	0.003	0.283	#15	0.044	Not Required	Pass
4	0.000	0.289	0.020	0.029	0.003	0.309	#13	0.117	Not Required	Pass
5	0.000	0.164	0.011	0.027	0.002	0.172	#15	0.073	Not Required	Pass
6	0.000	0.540	0.020	0.057	0.003	0.557	#15	0.044	Not Required	Pass
7	0.000	0.335	0.020	0.054	0.004	0.343	#15	0.073	Not Required	Pass
8	0.001	0.114	0.003	0.038	0.000	0.115	#13	0.088	Not Required	Pass

9	0.000	0.084	0.011	0.005	0.001	0.095	#13	0.198	Not Required	Pass
10	0.001	0.606	0.016	0.061	0.002	0.623	#13	0.078	Not Required	Pass
11	0.001	0.100	0.004	0.034	0.000	0.101	#15	0.088	Not Required	Pass
12	0.001	0.381	0.005	0.072	0.001	0.386	#13	0.052	Not Required	Pass
13	0.001	0.068	0.009	0.043	0.001	0.070	#15	0.265	Not Required	Pass
14	0.001	0.075	0.011	0.048	0.001	0.075	#13	0.177	Not Required	Pass
15	0.000	0.003	0.000	0.005	0.000	0.003	#15	Not Required	Not Required	Pass
16	0.000	0.004	0.000	0.006	0.000	0.004	#13	Not Required	Not Required	Pass
101	0.028	0.193	0.016	0.001	0.000	0.196	#16	0.064	Not Required	Pass
102	0.000	0.409	0.005	0.083	0.001	0.414	#13	0.052	Not Required	Pass
103	0.000	0.644	0.005	0.066	0.001	0.648	#15	0.044	Not Required	Pass
104	0.000	0.719	0.006	0.073	0.001	0.720	#13	0.078	Not Required	Pass
105	0.000	0.399	0.010	0.065	0.002	0.401	#15	0.073	Not Required	Pass
106	0.000	0.607	0.002	0.061	0.000	0.609	#15	0.044	Not Required	Pass
107	0.000	0.376	0.006	0.061	0.001	0.376	#15	0.073	Not Required	Pass
108	0.000	0.078	0.003	0.044	0.000	0.081	#13	0.088	Not Required	Pass
109	0.000	0.075	0.003	0.001	0.000	0.078	#13	0.198	Not Required	Pass
110	0.000	0.675	0.010	0.068	0.001	0.682	#13	0.078	Not Required	Pass
111	0.001	0.070	0.003	0.039	0.000	0.072	#15	0.088	Not Required	Pass
112	0.000	0.367	0.004	0.077	0.001	0.371	#13	0.034	Not Required	Pass
113	0.001	0.222	0.007	0.052	0.000	0.226	#15	0.265	Not Required	Pass
114	0.001	0.254	0.007	0.058	0.000	0.257	#13	0.265	Not Required	Pass
115	0.002	0.336	0.004	0.043	0.000	0.342	#15	0.557	Not Required	Pass
116	0.002	0.377	0.004	0.048	0.000	0.384	#13	0.557	Not Required	Pass
201	0.026	0.187	0.000	0.001	0.000	0.189	#16	0.064	Not Required	Pass
202	0.000	0.362	0.004	0.075	0.001	0.367	#13	0.034	Not Required	Pass
203	0.000	0.592	0.002	0.060	0.000	0.594	#15	0.044	Not Required	Pass
204	0.000	0.657	0.007	0.067	0.001	0.661	#13	0.078	Not Required	Pass
205	0.000	0.367	0.008	0.060	0.001	0.368	#15	0.073	Not Required	Pass
206	0.000	0.592	0.002	0.060	0.000	0.594	#15	0.044	Not Required	Pass
207	0.000	0.367	0.008	0.060	0.001	0.368	#15	0.073	Not Required	Pass
208	0.000	0.063	0.003	0.042	0.000	0.065	#13	0.088	Not Required	Pass
209	0.000	0.061	0.001	0.001	0.000	0.063	#13	0.198	Not Required	Pass
210	0.000	0.657	0.007	0.067	0.001	0.661	#13	0.078	Not Required	Pass
211	0.001	0.057	0.003	0.038	0.000	0.060	#15	0.088	Not Required	Pass
212	0.000	0.362	0.004	0.075	0.001	0.367	#13	0.034	Not Required	Pass
213	0.001	0.200	0.007	0.047	0.000	0.202	#15	0.265	Not Required	Pass
214	0.001	0.227	0.007	0.052	0.000	0.228	#13	0.265	Not Required	Pass
215	0.002	0.247	0.004	0.038	0.000	0.249	#15	0.557	Not Required	Pass
216	0.001	0.276	0.004	0.042	0.000	0.277	#13	0.557	Not Required	Pass
301	0.028	0.193	0.016	0.001	0.000	0.196	#16	0.064	Not Required	Pass
302	0.000	0.367	0.004	0.077	0.001	0.371	#13	0.034	Not Required	Pass
303	0.000	0.607	0.002	0.061	0.000	0.609	#15	0.044	Not Required	Pass
304	0.000	0.675	0.010	0.068	0.001	0.682	#13	0.078	Not Required	Pass
305	0.000	0.376	0.006	0.061	0.001	0.376	#15	0.073	Not Required	Pass
306	0.000	0.644	0.005	0.066	0.001	0.648	#15	0.044	Not Required	Pass
307	0.000	0.399	0.010	0.065	0.002	0.401	#15	0.073	Not Required	Pass
308	0.001	0.072	0.004	0.048	0.000	0.075	#13	0.088	Not Required	Pass
309	0.000	0.075	0.003	0.001	0.000	0.078	#13	0.198	Not Required	Pass
310	0.000	0.719	0.006	0.073	0.001	0.720	#13	0.078	Not Required	Pass
311	0.001	0.064	0.003	0.043	0.000	0.067	#15	0.088	Not Required	Pass
312	0.000	0.409	0.005	0.083	0.001	0.414	#13	0.052	Not Required	Pass
313	0.001	0.222	0.007	0.052	0.000	0.226	#15	0.265	Not Required	Pass
314	0.001	0.254	0.007	0.058	0.000	0.257	#13	0.265	Not Required	Pass

315	0.002	0.243	0.004	0.039	0.000	0.247	#15	0.557	Not Required	Pass
316	0.001	0.272	0.004	0.044	0.000	0.275	#13	0.557	Not Required	Pass
401	0.018	0.127	0.107	0.000	0.002	0.200	#13	0.064	Not Required	Pass
402	0.001	0.381	0.005	0.072	0.001	0.386	#13	0.052	Not Required	Pass
403	0.000	0.540	0.020	0.057	0.003	0.557	#15	0.044	Not Required	Pass
404	0.001	0.606	0.016	0.061	0.002	0.623	#13	0.078	Not Required	Pass
405	0.000	0.335	0.020	0.054	0.004	0.343	#15	0.073	Not Required	Pass
406	0.001	0.268	0.017	0.025	0.003	0.283	#15	0.044	Not Required	Pass
407	0.000	0.164	0.011	0.027	0.002	0.172	#15	0.073	Not Required	Pass
408	0.000	0.004	0.000	0.006	0.000	0.004	#13	Not Required	Not Required	Pass
409	0.000	0.084	0.011	0.005	0.001	0.095	#13	0.198	Not Required	Pass
410	0.000	0.289	0.020	0.029	0.003	0.309	#13	0.117	Not Required	Pass
411	0.000	0.003	0.000	0.005	0.000	0.003	#15	Not Required	Not Required	Pass
412	0.001	0.100	0.001	0.031	0.000	0.100	#13	0.052	Not Required	Pass
413	0.001	0.068	0.009	0.043	0.001	0.070	#15	0.177	Not Required	Pass
414	0.001	0.075	0.011	0.048	0.001	0.075	#13	0.265	Not Required	Pass
415	0.002	0.361	0.004	0.034	0.000	0.364	#15	0.557	Not Required	Pass
416	0.002	0.405	0.004	0.038	0.000	0.409	#13	0.557	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

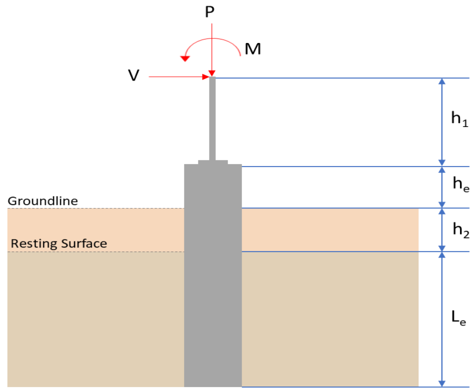
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 3.5$ 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)	3.129	4.447
V_x (kip)	-0.021	-0.037
V_z (kip)	0.119	0.171
M_x (kipft)	-3.032	-4.347
M_z (kipft)	3.228	5.401

Material Properties

$f'_{ck} = 3$ 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,

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

$$H_o = \frac{(-0.021 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0033439 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(3.228\ \text{kipft}) + ((-0.021\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.51401\ \text{kipft/ft}$$

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:
$L_{e,x} = 3.4322\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.119\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.018949\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(3.032\ \text{kipft}) + ((0.119\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.4828\ \text{kipft/ft}$$

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:
$L_{e,z} = 3.4924\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(3.4322\ \text{ft}), (3.4924\ \text{ft})]$$

$$L_{e,req} = 3.492\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (3.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 3.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(3.492\ \text{ft})}{(3.5\ \text{ft})}$$

$$Ratio = 0.99771$$

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

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

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

$$q = \frac{(3.129\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.19556\ \text{kip/ft}^2$$

$q = 0.19556\ \text{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.19556\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.097781$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(3.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 0.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.0033439\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.51401\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.51401\ \text{kipft/ft}) \times (3.5\ \text{ft})) + \left(3 \times (-0.0033439\ \text{kip/ft}) \times (3.5\ \text{ft})^2\right)}{(6 \times (0.51401\ \text{kipft/ft})) + (4 \times (-0.0033439\ \text{kip/ft}) \times (3.5\ \text{ft}))}$$

$$a = 2.3377\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.51401\ \text{kipft/ft})) + (3 \times (-0.0033439\ \text{kip/ft}) \times (3.5\ \text{ft}))]^2}{(3.5\ \text{ft})^2 \times [(3 \times (0.51401\ \text{kipft/ft})) + (2 \times (-0.0033439\ \text{kip/ft}) \times (3.5\ \text{ft}))]}$$

$$p = 0.16466\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.51401\ \text{kipft/ft})) + ((-0.0033439\ \text{kip/ft}) \times (3.5\ \text{ft}))]}{(3.5\ \text{ft})^2}$$

$$s = 0.49779\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(2.3377\ \text{ft})}{2}$$

$$p_a = 0.17533\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.16466\ \text{kip/ft}^2\right)}{\left(0.17533\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.93914$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (3.5\ \mathrm{ft})$$

$$p_s = 0.525\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.49779\ \mathrm{kip/ft^2})}{(0.525\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.94817$$

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

Considering z-direction:

$H_o = 0.018949\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.4828\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.4828\ \mathrm{kipft/ft}) \times (3.5\ \mathrm{ft})) + \left(3 \times (0.018949\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft})^2\right)}{(6 \times (0.4828\ \mathrm{kipft/ft})) + (4 \times (0.018949\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))}$$

$$a = 2.3578\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.4828\ \mathrm{kipft/ft})) + (3 \times (0.018949\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))]^{\ 2}}{(3.5\ \mathrm{ft})^2 \times [(3 \times (0.4828\ \mathrm{kipft/ft})) + (2 \times (0.018949\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))]}$$

$$p = 0.17572\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.4828\ \mathrm{kipft/ft})) + ((0.018949\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))]}{(3.5\ \mathrm{ft})^2}$$

$$s = 0.50543\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.3578\ \mathrm{ft})}{2}$$

$$p_a = 0.17684\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.17572\ \mathrm{kip/ft^2})}{(0.17684\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.99367$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (3.5\ \mathrm{ft})$$

$$p_s = 0.525\ \mathrm{kip/ft^2}$$

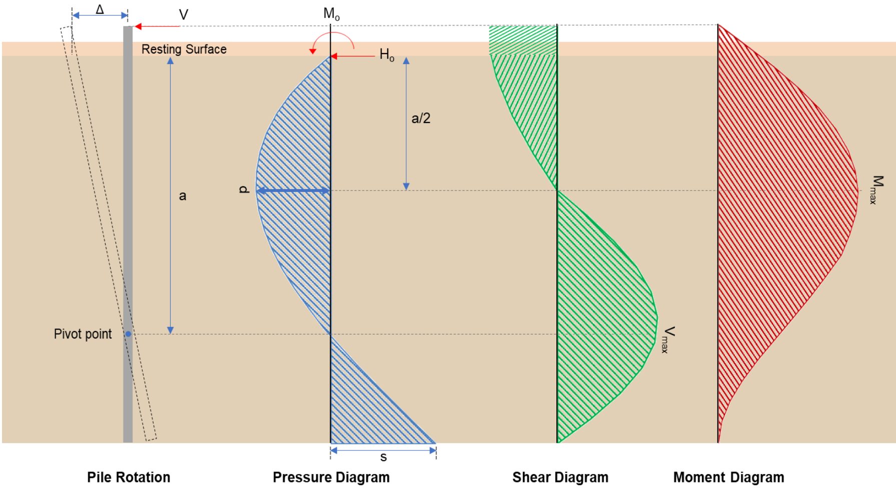
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.50543 \text{ kip/ft}^2)}{(0.525 \text{ kip/ft}^2)}$$

$$Ratio = 0.96273$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.037 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0058917 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(5.401 \text{ kipft}) + ((-0.037 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.86003 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.86003 \text{ kipft/ft})}{(-0.0058917 \text{ kip/ft})}$$

$$E = 145.97 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.86003 \text{ kipft/ft}) \times (3.5 \text{ ft})) + \left(3 \times (-0.0058917 \text{ kip/ft}) \times (3.5 \text{ ft})^2\right)}{(6 \times (0.86003 \text{ kipft/ft})) + (4 \times (-0.0058917 \text{ kip/ft}) \times (3.5 \text{ ft}))}$$

$$a = 2.3379 \text{ ft}$$

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

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

$$V_{max} = ((-0.0058917 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (145.97 \text{ ft})}{(3.5 \text{ ft})} + 3\right) \times \left(\frac{(2.3379 \text{ ft})}{(3.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (145.97 \text{ ft})}{(3.5 \text{ ft})} + 2\right) \times \left(\frac{(2.3379 \text{ ft})}{(3.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 1.7622 \text{ kip}$$

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

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

$$M_{max} = ((-0.0058917\ \text{kip/ft}) \times (48\ \text{in}) \times (3.5\ \text{ft})) \times \left[\left(\frac{(145.97\ \text{ft})}{(3.5\ \text{ft})} + \frac{(2.3379\ \text{ft})}{2 \times (3.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (145.97\ \text{ft})}{(3.5\ \text{ft})} + 3\right) \times \left(\frac{(2.3379\ \text{ft})}{2 \times (3.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (145.97\ \text{ft})}{(3.5\ \text{ft})} + 2\right) \times \left(\frac{(2.3379\ \text{ft})}{2 \times (3.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 3.0763\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.171\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.027229\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(4.347\ \text{kipft}) + ((0.171\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.6922\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.6922\ \text{kipft/ft})}{(0.027229\ \text{kip/ft})}$$

$$E = 25.421\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.6922\ \text{kipft/ft}) \times (3.5\ \text{ft})) + \left(3 \times (0.027229\ \text{kip/ft}) \times (3.5\ \text{ft})^2\right)}{(6 \times (0.6922\ \text{kipft/ft})) + (4 \times (0.027229\ \text{kip/ft}) \times (3.5\ \text{ft}))}$$

$$a = 2.3579\ \text{ft}$$

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

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

$$V_{max} = ((0.027229\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (25.421\ \text{ft})}{(3.5\ \text{ft})} + 3\right) \times \left(\frac{(2.3579\ \text{ft})}{(3.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (25.421\ \text{ft})}{(3.5\ \text{ft})} + 2\right) \times \left(\frac{(2.3579\ \text{ft})}{(3.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 1.4755\ \text{kip}$$

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

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

$$M_{max} = ((0.027229\ \text{kip/ft}) \times (48\ \text{in}) \times (3.5\ \text{ft})) \times \left[\left(\frac{(25.421\ \text{ft})}{(3.5\ \text{ft})} + \frac{(2.3579\ \text{ft})}{2 \times (3.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (25.421\ \text{ft})}{(3.5\ \text{ft})} + 3\right) \times \left(\frac{(2.3579\ \text{ft})}{2 \times (3.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (25.421\ \text{ft})}{(3.5\ \text{ft})} + 2\right) \times \left(\frac{(2.3579\ \text{ft})}{2 \times (3.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.547 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(4.447 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -102.12 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-102.12 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 3183.4\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(4.447\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0013969$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,max} = 324.49\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 4.447\ \mathrm{kip} \rightarrow 4447\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(4447\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 130.39\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,b} = 406.27\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (130.39\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 130.39\ \mathrm{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 807.65\ \text{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(807.65\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((130.39\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 117.83\ \text{kip}$$ **Considering x-direction:** $V_{max} = 1.7622\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(1.7622\ \text{kip})}{(117.83\ \text{kip})}$$ $$Ratio = 0.014955$$	Status: **PASS** Ratio: **0.010**
	Considering z-direction: $V_{max} = 1.4755\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(1.4755\ \text{kip})}{(117.83\ \text{kip})}$$ $$Ratio = 0.012522$$	Status: **PASS** Ratio: **0.010**
	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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 273.423 kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\text{ kipft}), (2545.9\text{ kipft})]$$ $$\phi M_n = 273.42\text{ kipft}$$ **Considering x-direction:** $M_{max} = 3.0763\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(3.0763\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.011251$$	Status: **PASS** Ratio: **0.010**
	Considering z-direction: $M_{max} = 2.547\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(2.547\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.0093151$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

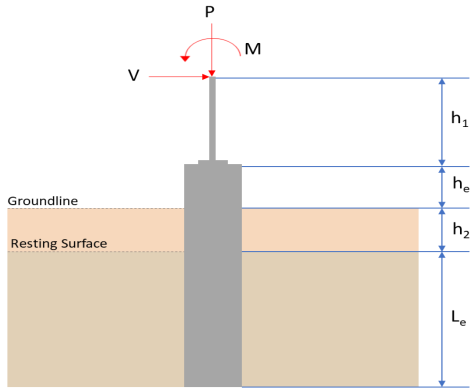
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 3.5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	3.129	4.447
V_x (kip)	-0.021	-0.037
V_z (kip)	-0.119	-0.171
M_x (kipft)	3.032	4.347
M_z (kipft)	3.228	5.401

Material Properties

$f'_{ck} = 3\ \text{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.021\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0033439\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(3.228\ \mathrm{kipft}) + ((-0.021\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.51401\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 3.4322\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.119\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.018949\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(3.032\ \mathrm{kipft}) + ((-0.119\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.4828\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 3.2682\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(3.4322\ \mathrm{ft}), (3.2682\ \mathrm{ft})]$$

$$L_{e,req} = 3.432\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (3.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 3.5\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(3.432\ \mathrm{ft})}{(3.5\ \mathrm{ft})}$$

$$Ratio = 0.98057$$

Status: PASS
Ratio: 0.980

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(3.129\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.19556\ \mathrm{kip/ft}^2$$

$q = 0.19556\ \mathrm{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.19556\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.097781$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(3.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 0.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.0033439\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.51401\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.51401\ \mathrm{kipft/ft}) \times (3.5\ \mathrm{ft})) + \left(3 \times (-0.0033439\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft})^2\right)}{(6 \times (0.51401\ \mathrm{kipft/ft})) + (4 \times (-0.0033439\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))}$$

$$a = 2.3377\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.51401\ \mathrm{kipft/ft})) + (3 \times (-0.0033439\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))]^2}{(3.5\ \mathrm{ft})^2 \times [(3 \times (0.51401\ \mathrm{kipft/ft})) + (2 \times (-0.0033439\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))]}$$

$$p = 0.16466\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.51401\ \mathrm{kipft/ft})) + ((-0.0033439\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))]}{(3.5\ \mathrm{ft})^2}$$

$$s = 0.49779\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.3377\ \mathrm{ft})}{2}$$

$$p_a = 0.17533\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.16466\ \mathrm{kip/ft^2}\right)}{\left(0.17533\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93914$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (3.5\text{ ft})$$

$$p_s = 0.525\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.49779\text{ kip/ft}^2)}{(0.525\text{ kip/ft}^2)}$$

$$Ratio = 0.94817$$

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

Considering z-direction:

$H_o = -0.018949\text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.4828\text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.4828\text{ kipft/ft}) \times (3.5\text{ ft})) + \left(3 \times (-0.018949\text{ kip/ft}) \times (3.5\text{ ft})^2\right)}{(6 \times (0.4828\text{ kipft/ft})) + (4 \times (-0.018949\text{ kip/ft}) \times (3.5\text{ ft}))}$$

$$a = 2.3578\text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.4828\text{ kipft/ft})) + (3 \times (-0.018949\text{ kip/ft}) \times (3.5\text{ ft}))]^2}{(3.5\text{ ft})^2 \times [(3 \times (0.4828\text{ kipft/ft})) + (2 \times (-0.018949\text{ kip/ft}) \times (3.5\text{ ft}))]}$$

$$p = 0.13963\text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.4828\text{ kipft/ft})) + ((-0.018949\text{ kip/ft}) \times (3.5\text{ ft}))]}{(3.5\text{ ft})^2}$$

$$s = 0.44047\text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\text{ psf/ft}) \times \frac{(2.3578\text{ ft})}{2}$$

$$p_a = 0.17684\text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.13963\text{ kip/ft}^2)}{(0.17684\text{ kip/ft}^2)}$$

$$Ratio = 0.78958$$

Status: **PASS**
Ratio: **0.790**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\text{ psf/ft}) \times (3.5\text{ ft})$$

$$p_s = 0.525\text{ kip/ft}^2$$

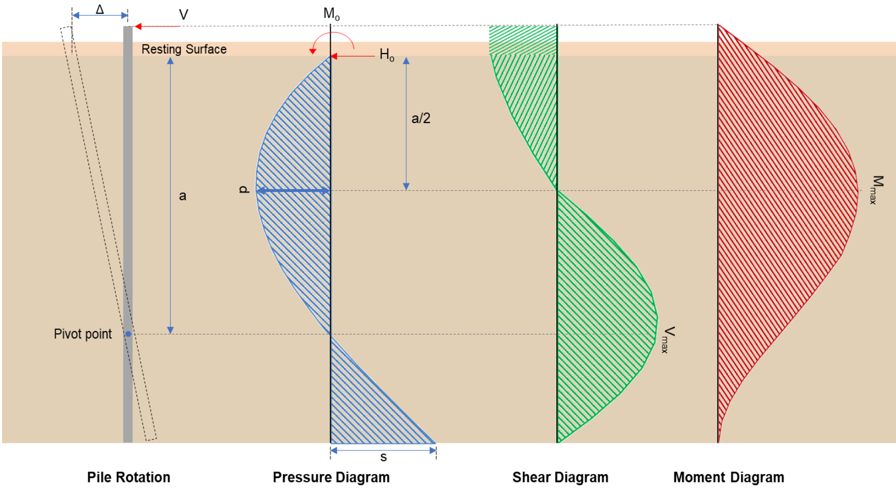
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.44047\ \mathrm{kip/ft^2})}{(0.525\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.83898$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.037\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0058917\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(5.401\ \mathrm{kipft}) + ((-0.037\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.86003\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.86003\ \mathrm{kipft/ft})}{(-0.0058917\ \mathrm{kip/ft})}$$

$$E = 145.97\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.86003\ \mathrm{kipft/ft}) \times (3.5\ \mathrm{ft})) + \left(3 \times (-0.0058917\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft})^2\right)}{(6 \times (0.86003\ \mathrm{kipft/ft})) + (4 \times (-0.0058917\ \mathrm{kip/ft}) \times (3.5\ \mathrm{ft}))}$$

$$a = 2.3379\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.0058917\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (145.97\ \mathrm{ft})}{(3.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.3379\ \mathrm{ft})}{(3.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (145.97\ \mathrm{ft})}{(3.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.3379\ \mathrm{ft})}{(3.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 1.7622\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.0058917\ \text{kip/ft}) \times (48\ \text{in}) \times (3.5\ \text{ft})) \times \left[\left(\frac{(145.97\ \text{ft})}{(3.5\ \text{ft})} + \frac{(2.3379\ \text{ft})}{2 \times (3.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (145.97\ \text{ft})}{(3.5\ \text{ft})} + 3\right) \times \left(\frac{(2.3379\ \text{ft})}{2 \times (3.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (145.97\ \text{ft})}{(3.5\ \text{ft})} + 2\right) \times \left(\frac{(2.3379\ \text{ft})}{2 \times (3.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 3.0763\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.171\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.027229\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(4.347\ \text{kipft}) + ((-0.171\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.6922\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.6922\ \text{kipft/ft})}{(-0.027229\ \text{kip/ft})}$$

$$E = 25.421\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.6922\ \text{kipft/ft}) \times (3.5\ \text{ft})) + \left(3 \times (-0.027229\ \text{kip/ft}) \times (3.5\ \text{ft})^2\right)}{(6 \times (0.6922\ \text{kipft/ft})) + (4 \times (-0.027229\ \text{kip/ft}) \times (3.5\ \text{ft}))}$$

$$a = 2.3579\ \text{ft}$$

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

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

$$V_{max} = ((-0.027229\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (25.421\ \text{ft})}{(3.5\ \text{ft})} + 3\right) \times \left(\frac{(2.3579\ \text{ft})}{(3.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (25.421\ \text{ft})}{(3.5\ \text{ft})} + 2\right) \times \left(\frac{(2.3579\ \text{ft})}{(3.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 1.4755\ \text{kip}$$

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

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

$$M_{max} = ((-0.027229\ \text{kip/ft}) \times (48\ \text{in}) \times (3.5\ \text{ft})) \times \left[\left(\frac{(25.421\ \text{ft})}{(3.5\ \text{ft})} + \frac{(2.3579\ \text{ft})}{2 \times (3.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (25.421\ \text{ft})}{(3.5\ \text{ft})} + 3\right) \times \left(\frac{(2.3579\ \text{ft})}{2 \times (3.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (25.421\ \text{ft})}{(3.5\ \text{ft})} + 2\right) \times \left(\frac{(2.3579\ \text{ft})}{2 \times (3.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.547 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(4.447 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -102.12 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-102.12 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 3183.4\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(4.447\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0013969$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,max} = 324.49\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 4.447\ \text{kip} \rightarrow 4447\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(4447\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 130.39\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + (0.05 \times (3000\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,b} = 406.27\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \text{kip}), (130.39\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 130.39\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 807.65\ \text{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(807.65\ \text{kip}), (50.894\ \text{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((130.39\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 117.83\ \text{kip}$$

Considering x-direction:

$V_{max} = 1.7622\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.7622\ \text{kip})}{(117.83\ \text{kip})}$$

$$Ratio = 0.014955$$

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

Considering z-direction:

$V_{max} = 1.4755\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.4755\ \text{kip})}{(117.83\ \text{kip})}$$

$$Ratio = 0.012522$$

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

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\text{ kipft}), (2545.9\text{ kipft})]$$ $$\phi M_n = 273.42\text{ kipft}$$ **Considering x-direction:** $M_{max} = 3.0763\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(3.0763\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.011251$$	Status: **PASS** Ratio: **0.010**
	Considering z-direction: $M_{max} = 2.547\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(2.547\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.0093151$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

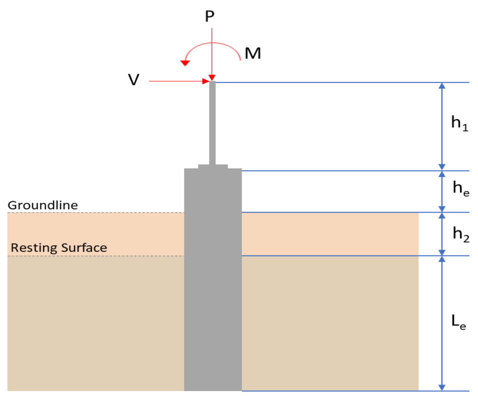
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.819	6.871
V_x (kip)	-0.038	-0.063
V_z (kip)	-0.024	-0.034
M_x (kipft)	0.446	0.641
M_z (kipft)	4.899	8.184

Material Properties

$f'_{ck} = 3\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.038\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.006051\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(4.899\ \text{kipft}) + ((-0.038\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.7801\ \text{kipft/ft}$$

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:
$L_{e,x} = 3.936\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.446\ \text{kipft}) + ((-0.024\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.071019\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.7416\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(3.936\ \text{ft}), (1.7416\ \text{ft})]$$

$$L_{e,req} = 3.936\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(3.936\ \text{ft})}{(4\ \text{ft})}$$

$$Ratio = 0.984$$

Status: PASS
Ratio: 0.980

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.819\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.30119\ \text{kip/ft}^2$$

$q = 0.30119\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.30119\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.15059$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.006051\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.7801\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.7801\ \text{kipft/ft}) \times (4\ \text{ft})) + \left(3 \times (-0.006051\ \text{kip/ft}) \times (4\ \text{ft})^2\right)}{(6 \times (0.7801\ \text{kipft/ft})) + (4 \times (-0.006051\ \text{kip/ft}) \times (4\ \text{ft}))}$$

$$a = 2.6734\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.7801\ \text{kipft/ft})) + (3 \times (-0.006051\ \text{kip/ft}) \times (4\ \text{ft}))]^2}{(4\ \text{ft})^2 \times [(3 \times (0.7801\ \text{kipft/ft})) + (2 \times (-0.006051\ \text{kip/ft}) \times (4\ \text{ft}))]}$$

$$p = 0.18998\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.7801\ \text{kipft/ft})) + ((-0.006051\ \text{kip/ft}) \times (4\ \text{ft}))]}{(4\ \text{ft})^2}$$

$$s = 0.576\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(2.6734\ \text{ft})}{2}$$

$$p_a = 0.20051\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18998\ \text{kip/ft}^2\right)}{\left(0.20051\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.94751$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4\ \mathrm{ft})$$

$$p_s = 0.6\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.576\ \mathrm{kip/ft^2}\right)}{\left(0.6\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96$$

Status: PASS
Ratio: 0.960

Considering z-direction:

$H_o = -0.0038217\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.071019\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.071019\ \mathrm{kipft/ft}) \times (4\ \mathrm{ft})) + \left(3 \times (-0.0038217\ \mathrm{kip/ft}) \times (4\ \mathrm{ft})^2\right)}{(6 \times (0.071019\ \mathrm{kipft/ft})) + (4 \times (-0.0038217\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))}$$

$$a = 2.7085\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.071019\ \mathrm{kipft/ft})) + (3 \times (-0.0038217\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]^2}{(4\ \mathrm{ft})^2 \times [(3 \times (0.071019\ \mathrm{kipft/ft})) + (2 \times (-0.0038217\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]}$$

$$p = 0.014577\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.071019\ \mathrm{kipft/ft})) + ((-0.0038217\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]}{(4\ \mathrm{ft})^2}$$

$$s = 0.047532\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.7085\ \mathrm{ft})}{2}$$

$$p_a = 0.20314\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.014577\ \mathrm{kip/ft^2}\right)}{\left(0.20314\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.071758$$

Status: PASS
Ratio: 0.070

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4\ \mathrm{ft})$$

$$p_s = 0.6\ \mathrm{kip/ft^2}$$

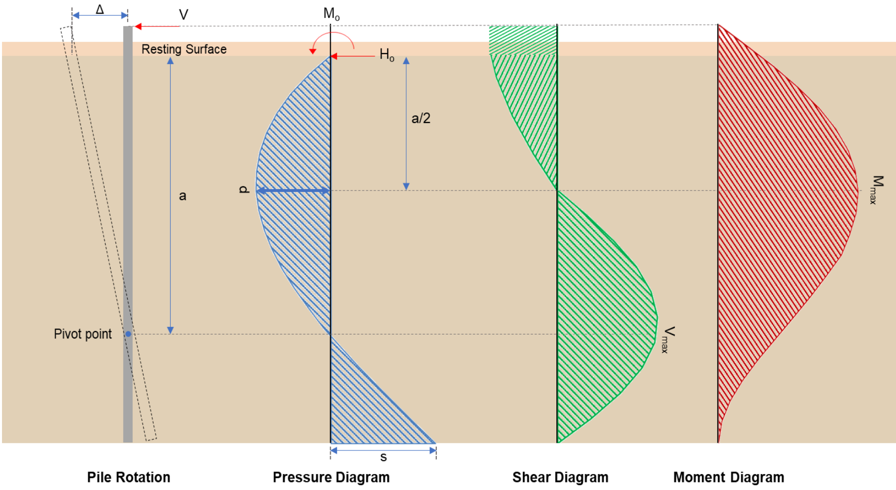
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.047532 \text{ kip/ft}^2)}{(0.6 \text{ kip/ft}^2)}$$

$$Ratio = 0.07922$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.063 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.010032 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(8.184 \text{ kipft}) + ((-0.063 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.3032 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.3032 \text{ kipft/ft})}{(-0.010032 \text{ kip/ft})}$$

$$E = 129.9 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.3032 \text{ kipft/ft}) \times (4 \text{ ft})) + \left(3 \times (-0.010032 \text{ kip/ft}) \times (4 \text{ ft})^2\right)}{(6 \times (1.3032 \text{ kipft/ft})) + (4 \times (-0.010032 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.6734 \text{ ft}$$

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

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

$$V_{max} = ((-0.010032 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (129.9 \text{ ft})}{(4 \text{ ft})} + 3\right) \times \left(\frac{(2.6734 \text{ ft})}{(4 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (129.9 \text{ ft})}{(4 \text{ ft})} + 2\right) \times \left(\frac{(2.6734 \text{ ft})}{(4 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 2.3421 \text{ kip}$$

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

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

$$M_{max} = ((-0.010032\text{ kip/ft})\times(48\text{ in})\times(4\text{ ft}))\times\left[\left(\frac{(129.9\text{ ft})}{(4\text{ ft})}+\frac{(2.6734\text{ ft})}{2\times(4\text{ ft})}\right) - \left[\left(\frac{4\times(129.9\text{ ft})}{(4\text{ ft})}+3\right)\times\left(\frac{(2.6734\text{ ft})}{2\times(4\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(129.9\text{ ft})}{(4\text{ ft})}+2\right)\times\left(\frac{(2.6734\text{ ft})}{2\times(4\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 4.6693\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.034\text{ kip})}{1.57\times(48\text{ in})}$$

$$H_o = -0.005414\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.641\text{ kipft})+((-0.034\text{ kip})\times(0\text{ ft}))}{1.57\times(48\text{ in})}$$

$$M_o = 0.10207\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.10207\text{ kipft/ft})}{(-0.005414\text{ kip/ft})}$$

$$E = 18.853\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4\times(0.10207\text{ kipft/ft})\times(4\text{ ft}))+\left(3\times(-0.005414\text{ kip/ft})\times(4\text{ ft})^2\right)}{(6\times(0.10207\text{ kipft/ft}))+(4\times(-0.005414\text{ kip/ft})\times(4\text{ ft}))}$$

$$a = 2.708\text{ ft}$$

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

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

$$V_{max} = ((-0.005414\text{ kip/ft})\times(48\text{ in}))\times\left[1-\left[3\times\left(\frac{4\times(18.853\text{ ft})}{(4\text{ ft})}+3\right)\times\left(\frac{(2.708\text{ ft})}{(4\text{ ft})}\right)^2\right]+\left[4\times\left(\frac{3\times(18.853\text{ ft})}{(4\text{ ft})}+2\right)\times\left(\frac{(2.708\text{ ft})}{(4\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.19524\text{ kip}$$

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

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

$$M_{max} = ((-0.005414\text{ kip/ft})\times(48\text{ in})\times(4\text{ ft}))\times\left[\left(\frac{(18.853\text{ ft})}{(4\text{ ft})}+\frac{(2.708\text{ ft})}{2\times(4\text{ ft})}\right) - \left[\left(\frac{4\times(18.853\text{ ft})}{(4\text{ ft})}+3\right)\times\left(\frac{(2.708\text{ ft})}{2\times(4\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(18.853\text{ ft})}{(4\text{ ft})}+2\right)\times\left(\frac{(2.708\text{ ft})}{2\times(4\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.38254 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(6.871 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - \left(0.85 \times (3 \text{ ksi})\right)}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -102.04 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-102.04 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 3183.4\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.871\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0021584$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,
22.5.5.1.1 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,max} = 324.49\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 6.871\ \mathrm{kip} \rightarrow 6871\ \mathrm{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(6871\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 130.71\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,
22.5.5.1.2 $V_{c,b}$ - Shear strength of concrete (b)

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,b} = 406.27\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (130.71\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 130.71\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 807.65\ \text{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(807.65\ \text{kip}), (50.894\ \text{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((130.71\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 118.04\ \text{kip}$$

Considering x-direction:

$V_{max} = 2.3421\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(2.3421\ \text{kip})}{(118.04\ \text{kip})}$$

$$Ratio = 0.019841$$

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

Considering z-direction:

$V_{max} = 0.19524\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.19524\ \text{kip})}{(118.04\ \text{kip})}$$

$$Ratio = 0.001654$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$ $$\phi M_n = 273.42 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 4.6693 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(4.6693 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.017077$$	Status: **PASS** Ratio: **0.020**
	Considering z-direction: $M_{max} = 0.38254 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.38254 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.0013991$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

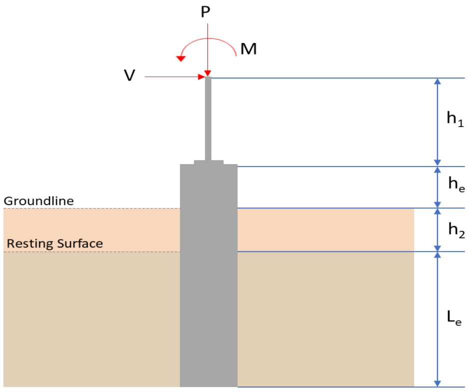
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 4\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.530	6.457
V_x (kip)	-0.033	-0.056
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	4.754	7.945

Material Properties

$f'_{ck} = 3\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.033\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0052548\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(4.754\ \text{kipft}) + ((-0.033\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.75701\ \text{kipft/ft}$$

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:
$L_{e,x} = 3.9003\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

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

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(3.9003\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 3.9\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 4\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(3.9\ \text{ft})}{(4\ \text{ft})}$$

$$Ratio = 0.975$$

Status: PASS
Ratio: 0.970

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.53\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.28313\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.28313\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.14156$$

Status: PASS
Ratio: 0.140

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.0052548\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.75701\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.75701\ \mathrm{kipft/ft}) \times (4\ \mathrm{ft})) + \left(3 \times (-0.0052548\ \mathrm{kip/ft}) \times (4\ \mathrm{ft})^2\right)}{(6 \times (0.75701\ \mathrm{kipft/ft})) + (4 \times (-0.0052548\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))}$$

$$a = 2.6727\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.75701\ \mathrm{kipft/ft})) + (3 \times (-0.0052548\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]^2}{(4\ \mathrm{ft})^2 \times [(3 \times (0.75701\ \mathrm{kipft/ft})) + (2 \times (-0.0052548\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]}$$

$$p = 0.18487\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.75701\ \mathrm{kipft/ft})) + ((-0.0052548\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))]}{(4\ \mathrm{ft})^2}$$

$$s = 0.55987\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(2.6727\ \mathrm{ft})}{2}$$

$$p_a = 0.20045\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18487\ \mathrm{kip/ft^2}\right)}{\left(0.20045\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.92227$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (4\ \mathrm{ft})$$

$$p_s = 0.6\ \mathrm{kip/ft^2}$$

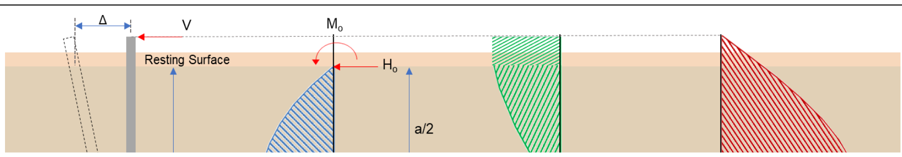
$Ratio$ - Lateral soil capacity

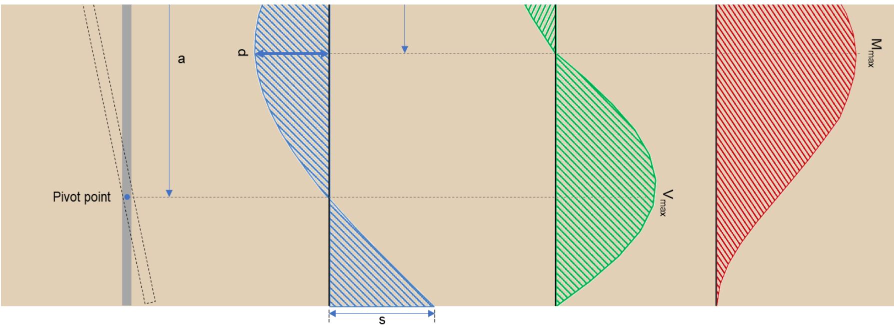
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(0.55987\ \mathrm{kip/ft^2}\right)}{\left(0.6\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93312$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.056\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.0089172\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(7.945\text{ kipft}) + ((-0.056\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 1.2651\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.2651\text{ kipft/ft})}{(-0.0089172\text{ kip/ft})}$$

$$E = 141.88\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.2651\text{ kipft/ft}) \times (4\text{ ft})) + \left(3 \times (-0.0089172\text{ kip/ft}) \times (4\text{ ft})^2\right)}{(6 \times (1.2651\text{ kipft/ft})) + (4 \times (-0.0089172\text{ kip/ft}) \times (4\text{ ft}))}$$

$$a = 2.6728\text{ ft}$$

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

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

$$V_{max} = ((-0.0089172\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (141.88\text{ ft})}{(4\text{ ft})} + 3\right) \times \left(\frac{(2.6728\text{ ft})}{(4\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (141.88\text{ ft})}{(4\text{ ft})} + 2\right) \times \left(\frac{(2.6728\text{ ft})}{(4\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 2.2716\text{ kip}$$

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

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

$$M_{max} = ((-0.0089172\text{ kip/ft}) \times (48\text{ in}) \times (4\text{ ft})) \times \left[\left(\frac{(141.88\text{ ft})}{(4\text{ ft})} + \frac{(2.6728\text{ ft})}{2 \times (4\text{ ft})}\right) - \left[\left(\frac{4 \times (141.88\text{ ft})}{(4\text{ ft})} + 3\right) \times \left(\frac{(2.6728\text{ ft})}{2 \times (4\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (141.88\text{ ft})}{(4\text{ ft})} + 2\right) \times \left(\frac{(2.6728\text{ ft})}{2 \times (4\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 4.53 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(6.457 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -102.05 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-102.05 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

		Ties: **#3(0.375 in) - 10 in**	
	22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 3183.4\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(6.457\text{ kip})}{(3183.4\text{ kip})}$$ $$Ratio = 0.0020283$$	Status: **PASS** Ratio: **0.000**

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \to 3000\text{ psi}$,

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\text{ psi})} \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,max} = 324.49\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \to 3000\text{ psi}$, $P = 6.457\text{ kip} \to 6457\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\text{ psi})} + \frac{(6457\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 130.66\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \to 3000\text{ psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\text{ psi})} + (0.05 \times (3000\text{ psi}))\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,b} = 406.27\text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\text{ kip}), (130.66\text{ kip}), (406.27\text{ kip})\right]$$

$$V_c = 130.66\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 807.65\ \text{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(807.65\ \text{kip}), (50.894\ \text{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((130.66\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 118.01\ \text{kip}$$

Considering x-direction:

$V_{max} = 2.2716\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(2.2716\ \text{kip})}{(118.01\ \text{kip})}$$

$$Ratio = 0.01925$$

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

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:
$\phi M_{n,1}$

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

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

$$\phi M_{n,1} = 273.423kipft$$

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

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

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

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

$$\phi M_{n,2} = 2545.9\ \text{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(273.42\ \text{kipft}), (2545.9\ \text{kipft})]$$

$$\phi M_n = 273.42\ \text{kipft}$$

Considering x-direction:

$M_{max} = 4.53\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(4.53\ \text{kipft})}{(273.42\ \text{kipft})}$$

$$Ratio = 0.016568$$

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

REFERENCES	CALCULATIONS	RESULTS

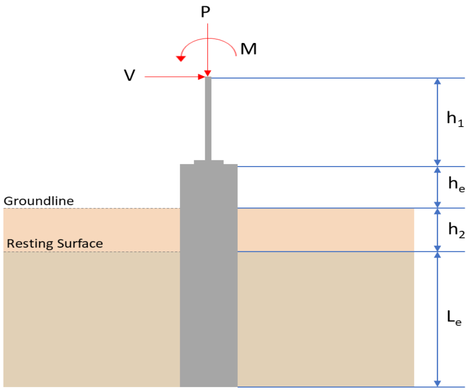
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 4\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.819	6.871
V_x (kip)	-0.038	-0.063
V_z (kip)	0.024	0.034
M_x (kipft)	-0.446	-0.641
M_z (kipft)	4.899	8.184

Material Properties

$f'_{ck} = 3\ \text{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.038\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.006051\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(4.899 \text{ kipft}) + ((-0.038 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.7801 \text{ kipft/ft}$$

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:
$L_{e,x} = 3.936 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.446 \text{ kipft}) + ((0.024 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.071019 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.8272 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(3.936 \text{ ft}), (1.8272 \text{ ft})]$$

$$L_{e,req} = 3.936 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (4 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(3.936 \text{ ft})}{(4 \text{ ft})}$$

$$Ratio = 0.984$$

Status: **PASS**
Ratio: **0.980**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.819 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.30119 \text{ kip/ft}^2$$

$q = 0.30119 \text{ kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.30119 \text{ kip/ft}^2\right)}{(2000 \text{ psf})}$$

$$Ratio = 0.15059$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.006051 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.7801 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.7801 \text{ kipft/ft}) \times (4 \text{ ft})) + \left(3 \times (-0.006051 \text{ kip/ft}) \times (4 \text{ ft})^2\right)}{(6 \times (0.7801 \text{ kipft/ft})) + (4 \times (-0.006051 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.6734 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.7801 \text{ kipft/ft})) + (3 \times (-0.006051 \text{ kip/ft}) \times (4 \text{ ft}))]^{\,2}}{(4 \text{ ft})^2 \times [(3 \times (0.7801 \text{ kipft/ft})) + (2 \times (-0.006051 \text{ kip/ft}) \times (4 \text{ ft}))]}$$

$$p = 0.18998 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.7801 \text{ kipft/ft})) + ((-0.006051 \text{ kip/ft}) \times (4 \text{ ft}))]}{(4 \text{ ft})^2}$$

$$s = 0.576 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(2.6734 \text{ ft})}{2}$$

$$p_a = 0.20051 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.18998 \text{ kip/ft}^2\right)}{\left(0.20051 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.94751$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (4\ \text{ft})$$

$$p_s = 0.6\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.576\ \text{kip/ft}^2\right)}{\left(0.6\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.96$$

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

Considering z-direction:

$H_o = 0.0038217\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.071019\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.071019\ \text{kipft/ft}) \times (4\ \text{ft})) + \left(3 \times (0.0038217\ \text{kip/ft}) \times (4\ \text{ft})^2\right)}{(6 \times (0.071019\ \text{kipft/ft})) + (4 \times (0.0038217\ \text{kip/ft}) \times (4\ \text{ft}))}$$

$$a = 2.7085\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.071019\ \text{kipft/ft})) + (3 \times (0.0038217\ \text{kip/ft}) \times (4\ \text{ft}))]^{\ 2}}{(4\ \text{ft})^2 \times [(3 \times (0.071019\ \text{kipft/ft})) + (2 \times (0.0038217\ \text{kip/ft}) \times (4\ \text{ft}))]}$$

$$p = 0.020944\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.071019\ \text{kipft/ft})) + ((0.0038217\ \text{kip/ft}) \times (4\ \text{ft}))]}{(4\ \text{ft})^2}$$

$$s = 0.058997\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(2.7085\ \text{ft})}{2}$$

$$p_a = 0.20314\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.020944\ \text{kip/ft}^2\right)}{\left(0.20314\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.10311$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (4\ \text{ft})$$

$$p_s = 0.6\ \text{kip/ft}^2$$

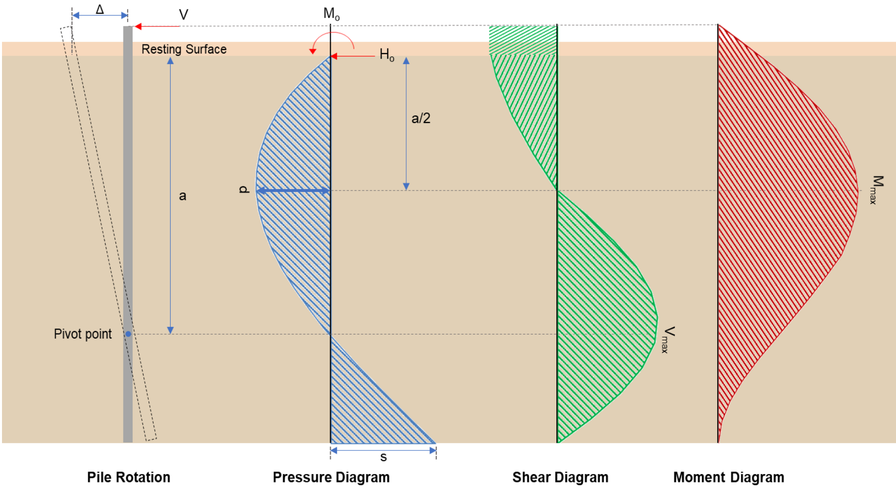
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.058997\ \mathrm{kip/ft^2})}{(0.6\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.098328$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.063\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.010032\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(8.184\ \mathrm{kipft}) + ((-0.063\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 1.3032\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.3032\ \mathrm{kipft/ft})}{(-0.010032\ \mathrm{kip/ft})}$$

$$E = 129.9\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.3032\ \mathrm{kipft/ft}) \times (4\ \mathrm{ft})) + \left(3 \times (-0.010032\ \mathrm{kip/ft}) \times (4\ \mathrm{ft})^2\right)}{(6 \times (1.3032\ \mathrm{kipft/ft})) + (4 \times (-0.010032\ \mathrm{kip/ft}) \times (4\ \mathrm{ft}))}$$

$$a = 2.6734\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.010032\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (129.9\ \mathrm{ft})}{(4\ \mathrm{ft})} + 3\right) \times \left(\frac{(2.6734\ \mathrm{ft})}{(4\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (129.9\ \mathrm{ft})}{(4\ \mathrm{ft})} + 2\right) \times \left(\frac{(2.6734\ \mathrm{ft})}{(4\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 2.3421\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.010032 \text{ kip/ft}) \times (48 \text{ in}) \times (4 \text{ ft})) \times \left[\left(\frac{(129.9 \text{ ft})}{(4 \text{ ft})} + \frac{(2.6734 \text{ ft})}{2 \times (4 \text{ ft})} \right) - \left[\left(\frac{4 \times (129.9 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left(\frac{(2.6734 \text{ ft})}{2 \times (4 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (129.9 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left(\frac{(2.6734 \text{ ft})}{2 \times (4 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 4.6693 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.034 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.005414 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.641 \text{ kipft}) + ((0.034 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.10207 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.10207 \text{ kipft/ft})}{(0.005414 \text{ kip/ft})}$$

$$E = 18.853 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10207 \text{ kipft/ft}) \times (4 \text{ ft})) + \left(3 \times (0.005414 \text{ kip/ft}) \times (4 \text{ ft})^2\right)}{(6 \times (0.10207 \text{ kipft/ft})) + (4 \times (0.005414 \text{ kip/ft}) \times (4 \text{ ft}))}$$

$$a = 2.708 \text{ ft}$$

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

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

$$V_{max} = ((0.005414 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (18.853 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left(\frac{(2.708 \text{ ft})}{(4 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (18.853 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left(\frac{(2.708 \text{ ft})}{(4 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.19524 \text{ kip}$$

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

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

$$M_{max} = ((0.005414 \text{ kip/ft}) \times (48 \text{ in}) \times (4 \text{ ft})) \times \left[\left(\frac{(18.853 \text{ ft})}{(4 \text{ ft})} + \frac{(2.708 \text{ ft})}{2 \times (4 \text{ ft})} \right) - \left[\left(\frac{4 \times (18.853 \text{ ft})}{(4 \text{ ft})} + 3 \right) \times \left(\frac{(2.708 \text{ ft})}{2 \times (4 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (18.853 \text{ ft})}{(4 \text{ ft})} + 2 \right) \times \left(\frac{(2.708 \text{ ft})}{2 \times (4 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.38254 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(6.871 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -102.04 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-102.04 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 3183.4\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.871\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0021584$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,max} = 324.49\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 6.871\ \mathrm{kip} \rightarrow 6871\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(6871\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 130.71\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,b} = 406.27\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (130.71\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 130.71\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 807.65\ \text{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(807.65\ \text{kip}), (50.894\ \text{kip})\right]$$

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((130.71\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 118.04\ \text{kip}$$

Considering x-direction:

$V_{max} = 2.3421\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(2.3421\ \text{kip})}{(118.04\ \text{kip})}$$

$$Ratio = 0.019841$$

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

Considering z-direction:

$V_{max} = 0.19524\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.19524\ \text{kip})}{(118.04\ \text{kip})}$$

$$Ratio = 0.001654$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2545.9\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\ \text{kipft}), (2545.9\ \text{kipft})]$$ $$\phi M_n = 273.42\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 4.6693\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(4.6693\ \text{kipft})}{(273.42\ \text{kipft})}$$ $$Ratio = 0.017077$$	Status: **PASS** Ratio: **0.020**
	Considering z-direction: $M_{max} = 0.38254\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.38254\ \text{kipft})}{(273.42\ \text{kipft})}$$ $$Ratio = 0.0013991$$	Status: **PASS** Ratio: **0.000**