Your Project Calculations

Project Name: UnivofMNMorris-JB-RevB2

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=UnivofMNMorris-JB-RevB2&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=IZZkCof0PehB3agB6N5b6FCfLwsfS7kwCFxniubACIOiCsHA4jvSIA7WbiSOEcS2

Array Specification

Product:	Beam
Unique ID:	5P-22.5-8TOP-XD-45-L-4Hx14W-24KG
Duty Classification:	XD
Module Width:	44.60 in
Module Length:	89.50in
Number of Rows:	4
Number of Columns:	14
Total Number of Modules:	56
Desired Tilt Angle:	30
Front Edge Clearance:	8
Total Array Height at Tilt:	15.47 ft
Total Frame Length:	105.00 ft
Frame Weight:	5563 lbs
Array Dimensions N/S:	15.03 ft
Array Dimensions E/W:	105.58 ft
Rail Length:	180.40 in
Rail Spacing:	3.73 ft
Rail Check:	

Support Specifications

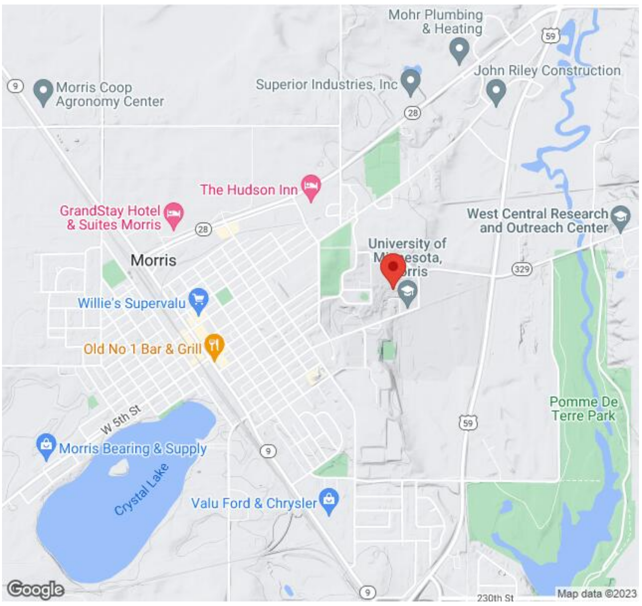
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	11.76 ft
Number of Poles:	5
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 6.25 ft Pile 2: 6.50 ft Pile 3: 6.50 ft Pile 4: 6.50 ft Pile 5: 6.25 ft
Foundation Volume:	18.963 y^3
Foundation Result:	PASSED
Mount Twist:	0.714742 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	600 E 4th St, Morris, MN 56267, USA
Wind Speed:	104 mph
Snow Load:	50 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.021993 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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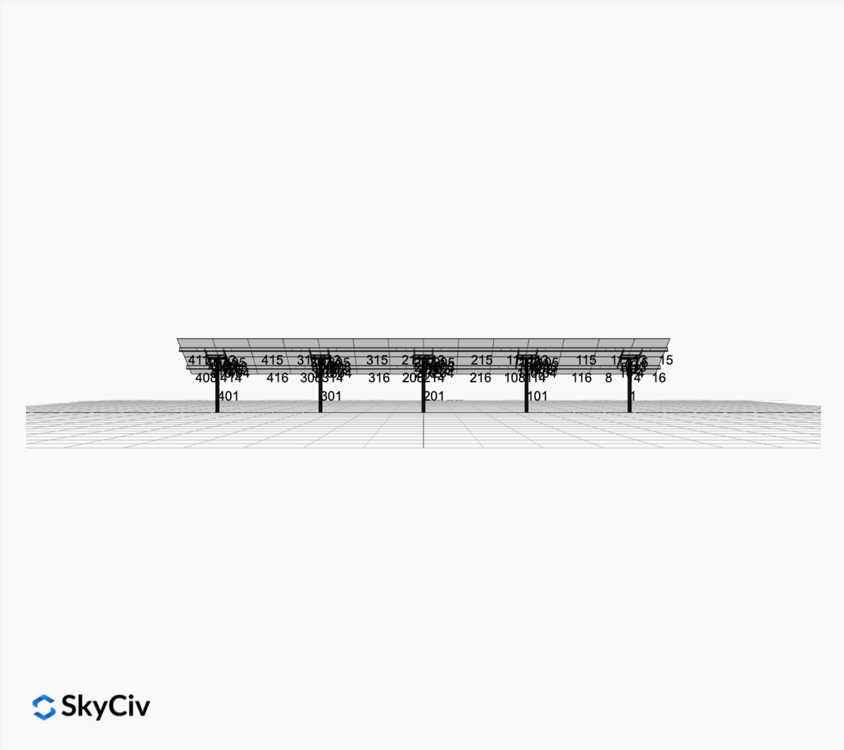
Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Foundation Design and Sizing is approximate only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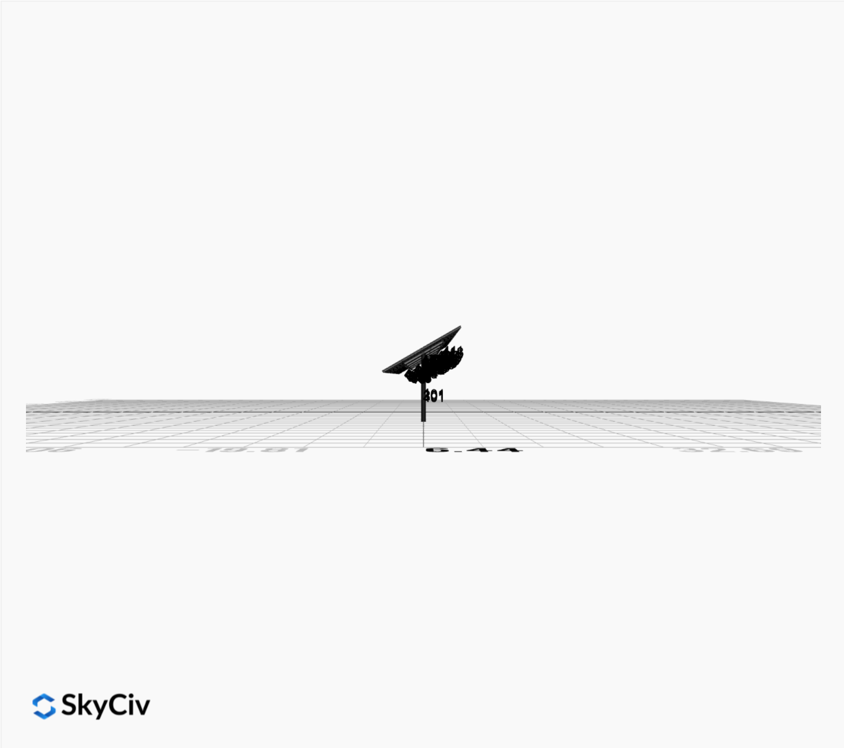
301
201
101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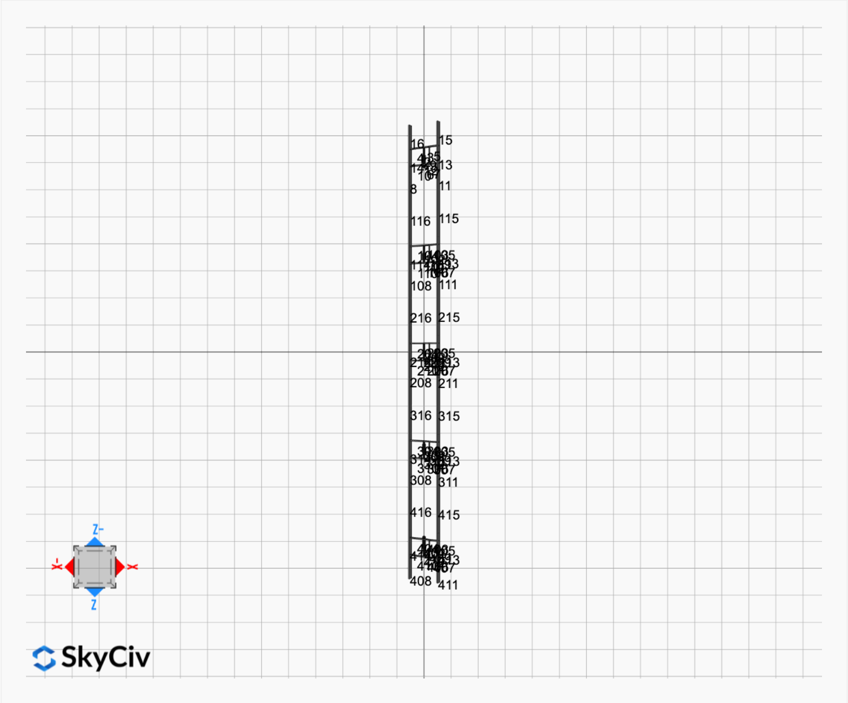
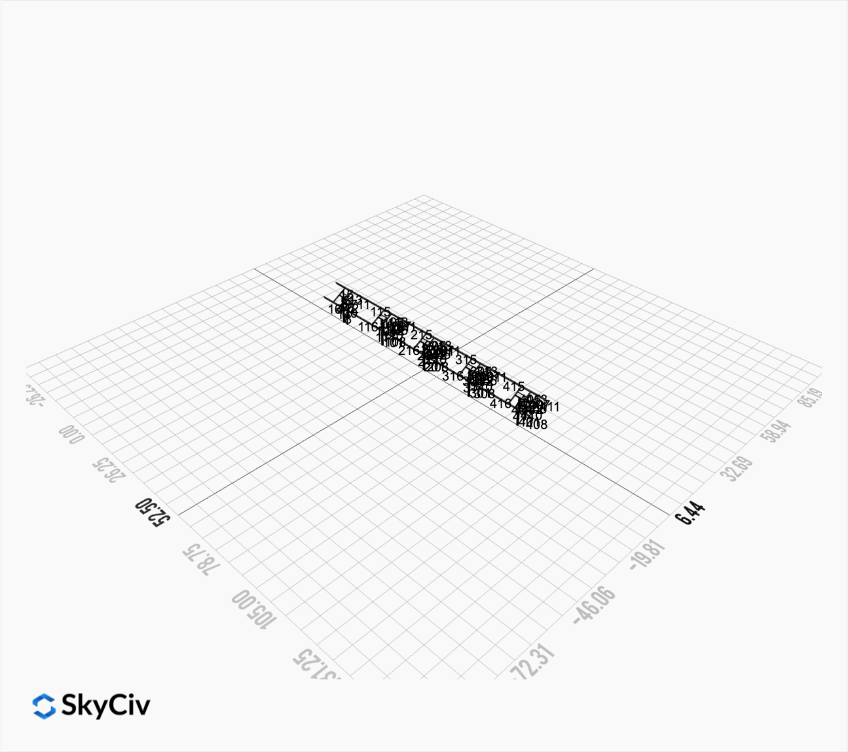
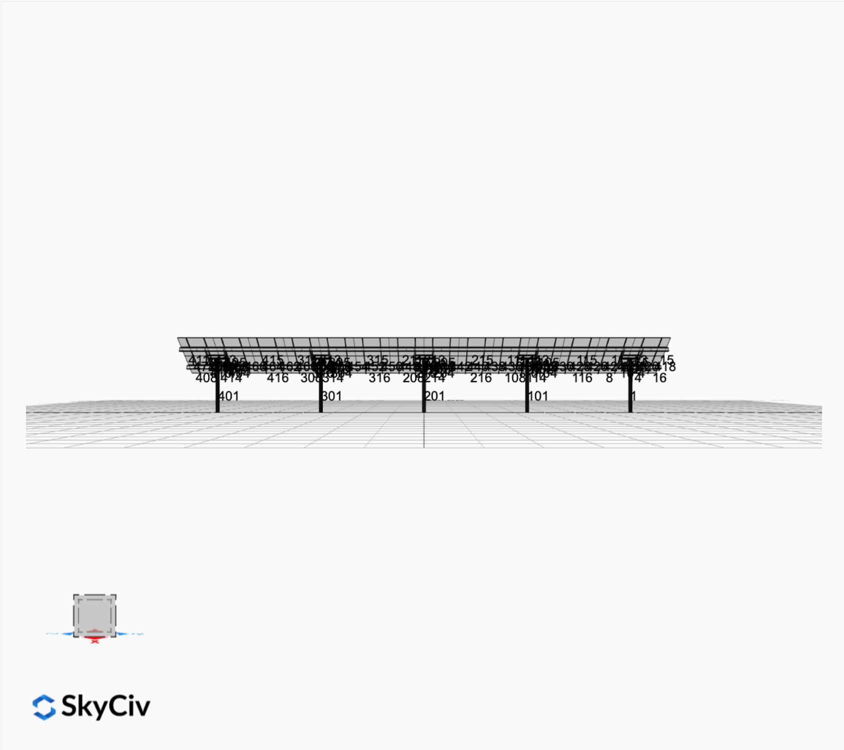
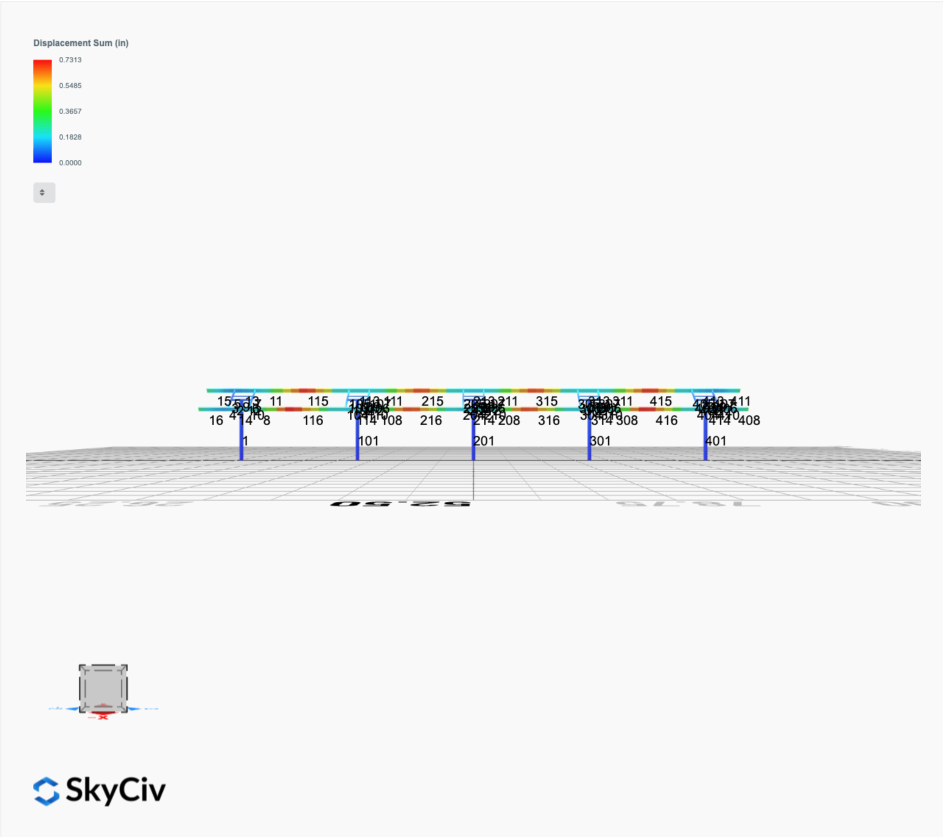
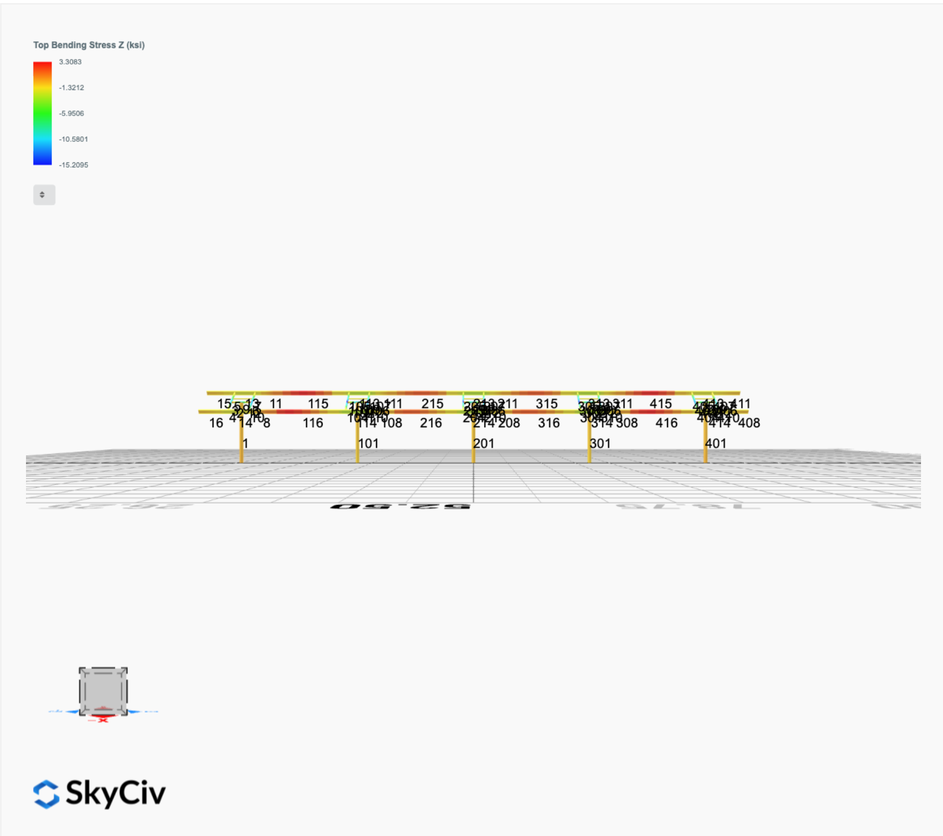


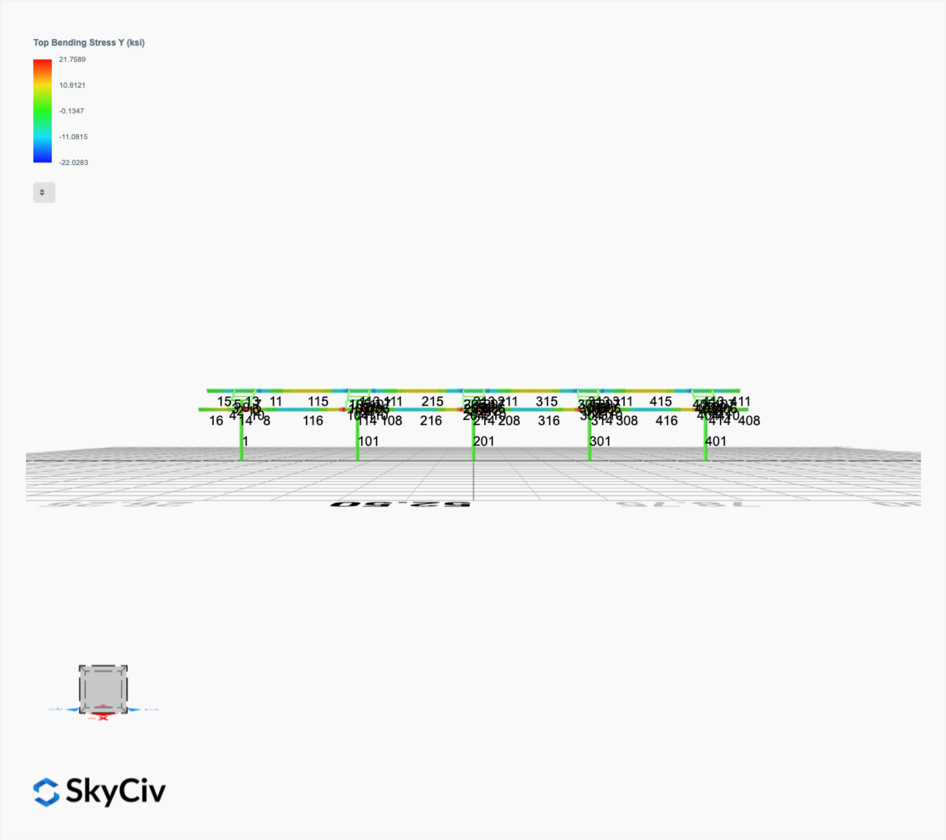


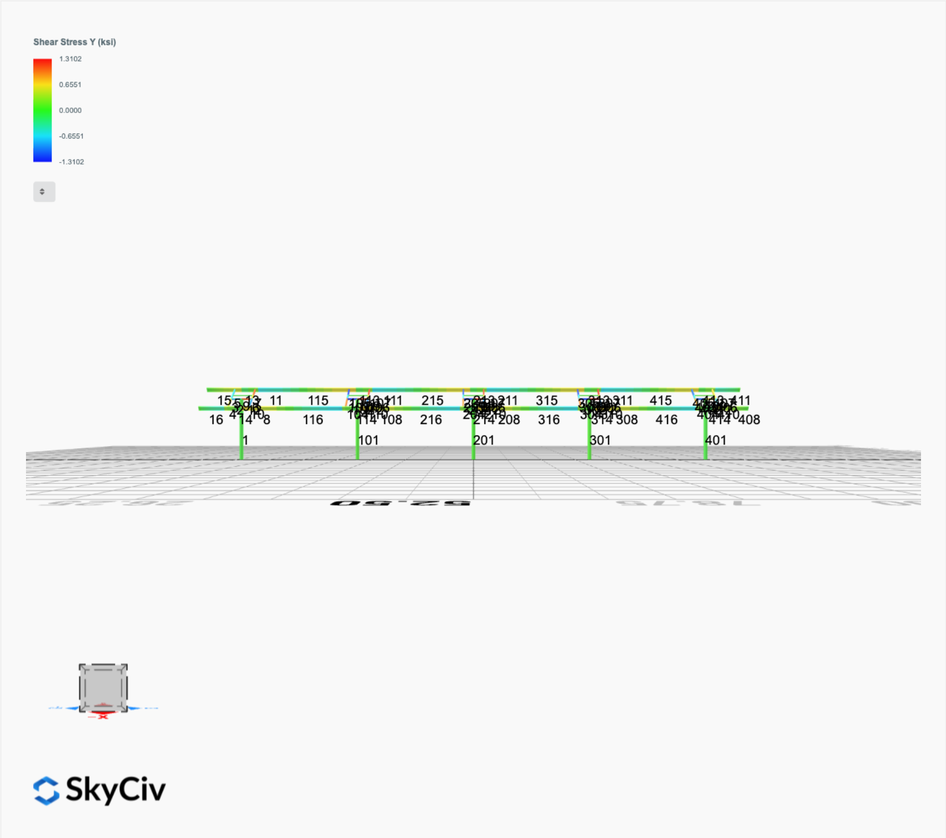


FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
21.7589
10.8121
-0.1347
-11.0815
-22.0283


Shear Stress Y (ksi)
1.3102
0.6551
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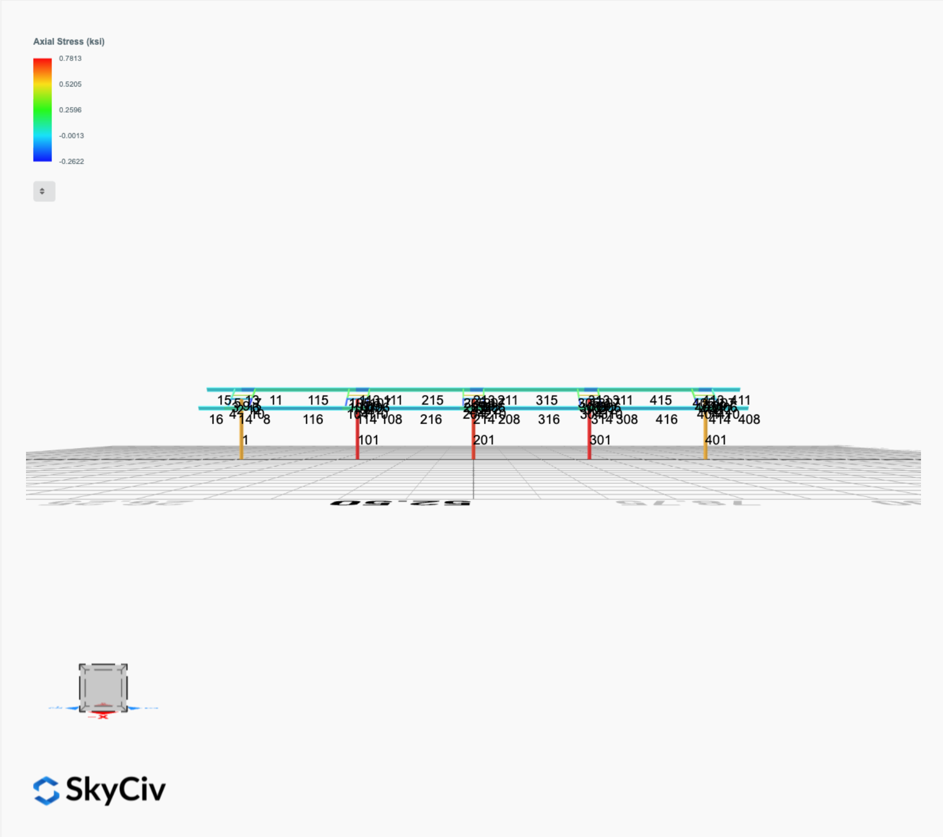
-0.6551
-1.3102


Axial Stress (ksi)
0.7813
0.5205
0.2596
-0.0013
-0.2622
1
101
201
301
401
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	0.0193	2.3054	0.0575	0.2048	-0.0326	-0.1829
ULS: 2. D + L	0.0193	2.3054	0.0575	0.2048	-0.0326	-0.1829
ULS: 3. D + (S or Lr or R)	0.0789	7.5598	0.2368	0.8448	-0.1348	-0.8218
ULS: 3. D + (S or Lr or R)	0.0193	2.3054	0.0575	0.2048	-0.0326	-0.1829
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0640	6.2462	0.1920	0.6848	-0.1092	-0.6621
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0193	2.3054	0.0575	0.2048	-0.0326	-0.1829
ULS: 5b. D + 0.7E	0.0193	2.3054	0.0575	0.2048	-0.0326	-0.1829
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0640	6.2462	0.1920	0.6848	-0.1092	-0.6621
ULS: 8. 0.6D + 0.7E	0.0116	1.3832	0.0345	0.1229	-0.0196	-0.1097
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9286	5.6410	0.2159	0.7490	-0.4025	23.2887
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9286	5.6410	0.2159	0.7490	-0.4025	23.2887
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6868	-0.5521	-0.0750	-0.2494	0.2769	-19.6192
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4235	-0.0862	-0.0699	-0.2315	0.2705	-23.4400
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3969	8.7480	0.3108	1.0929	-0.3866	16.9416
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3969	8.7480	0.3108	1.0929	-0.3866	16.9416
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3147	4.1032	0.0926	0.3441	0.1229	-15.2393
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1172	4.4525	0.0964	0.3575	0.1181	-18.1049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4416	4.8071	0.1763	0.6130	-0.3100	17.4208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4416	4.8071	0.1763	0.6130	-0.3100	17.4208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2700	0.1623	-0.0419	-0.1359	0.1995	-14.7601
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0724	0.5117	-0.0380	-0.1224	0.1948	-17.6257
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.9363	4.7189	0.1929	0.6671	-0.3894	23.3618
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.9363	4.7189	0.1929	0.6671	-0.3894	23.3618
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6791	-1.4742	-0.0980	-0.3314	0.2899	-19.5460
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4158	-1.0084	-0.0929	-0.3134	0.2836	-23.3669

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	13.9552
Shear X	-3.2465
Shear Z	0.4927
Moment X	1.7465
Moment Y (Twist)	0.7138
Moment Z	40.1129

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.7480
Shear X	-1.9363
Shear Z	0.3108
Moment X	1.0929
Moment Y (Twist)	0.4025
Moment Z	23.4400

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	-0.0197	2.7281	-0.0056	-0.0207	0.0132	0.2352
ULS: 2. D + L	-0.0197	2.7281	-0.0056	-0.0207	0.0132	0.2352
ULS: 3. D + (S or Lr or R)	-0.0807	9.2907	-0.0230	-0.0846	0.0540	0.9140
ULS: 3. D + (S or Lr or R)	-0.0197	2.7281	-0.0056	-0.0207	0.0132	0.2352
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0655	7.6501	-0.0187	-0.0686	0.0438	0.7443
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0197	2.7281	-0.0056	-0.0207	0.0132	0.2352
ULS: 5b. D + 0.7E	-0.0197	2.7281	-0.0056	-0.0207	0.0132	0.2352

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0655	7.6501	-0.0187	-0.0686	0.0438	0.7443
ULS: 8. 0.6D + 0.7E	-0.0118	1.6369	-0.0034	-0.0124	0.0079	0.1411
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4071	6.8996	-0.0015	-0.0104	-0.0181	28.7330
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4071	6.8996	-0.0015	-0.0104	-0.0181	28.7330
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.0290	-0.8501	-0.0075	-0.0236	0.0350	-23.2556
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6711	-0.2375	-0.0169	-0.0558	0.0608	-27.4879
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8560	10.7787	-0.0156	-0.0609	0.0203	22.1177
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8560	10.7787	-0.0156	-0.0609	0.0203	22.1177
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4711	4.9664	-0.0201	-0.0709	0.0601	-16.8738
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2026	5.4258	-0.0271	-0.0950	0.0795	-20.0480
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8103	5.8567	-0.0025	-0.0130	-0.0103	21.6086
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8103	5.8567	-0.0025	-0.0130	-0.0103	21.6086
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5168	0.0444	-0.0070	-0.0229	0.0295	-17.3829
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2484	0.5039	-0.0140	-0.0470	0.0489	-20.5571
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3992	5.8084	0.0008	-0.0022	-0.0233	28.6389
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3992	5.8084	0.0008	-0.0022	-0.0233	28.6389
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.0369	-1.9414	-0.0052	-0.0154	0.0297	-23.3497
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6790	-1.3288	-0.0146	-0.0476	0.0555	-27.5820

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	17.2466
Shear X	-4.0303
Shear Z	-0.0463
Moment X	-0.1643
Moment Y (Twist)	0.1277
Moment Z	49.1844

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.7787
Shear X	-2.4071
Shear Z	-0.0271
Moment X	-0.0950
Moment Y (Twist)	0.0795
Moment Z	28.7330

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	0.0009	2.6853	0.0000	-0.0000	0.0000	0.0466
ULS: 2. D + L	0.0009	2.6853	0.0000	-0.0000	0.0000	0.0466
ULS: 3. D + (S or Lr or R)	0.0036	9.1157	0.0000	-0.0001	0.0002	0.1394
ULS: 3. D + (S or Lr or R)	0.0009	2.6853	0.0000	-0.0000	0.0000	0.0466
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0029	7.5081	0.0000	-0.0001	0.0002	0.1162
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0009	2.6853	0.0000	-0.0000	0.0000	0.0466
ULS: 5b. D + 0.7E	0.0009	2.6853	0.0000	-0.0000	0.0000	0.0466
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0029	7.5081	0.0000	-0.0001	0.0002	0.1162
ULS: 8. 0.6D + 0.7E	0.0005	1.6112	0.0000	-0.0000	0.0000	0.0280
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.3698	6.7951	0.0000	-0.0000	0.0000	28.6391
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.3698	6.7951	0.0000	-0.0000	0.0000	28.6391
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.0323	-0.8355	0.0000	-0.0000	0.0000	-23.4823
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6976	-0.2603	0.0000	-0.0000	0.0000	-27.9966
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7751	10.5904	0.0000	-0.0001	0.0002	21.5605
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7751	10.5904	0.0000	-0.0001	0.0002	21.5605
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5265	4.8675	0.0000	-0.0001	0.0002	-17.5305
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2754	5.2989	0.0000	-0.0001	0.0002	-20.9162

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	-1.7771	5.7677	0.0000	-0.0000	0.0000	21.4910
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7771	5.7677	0.0000	-0.0000	0.0000	21.4910
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5245	0.0447	0.0000	-0.0000	0.0000	-17.6001
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2734	0.4761	0.0000	-0.0000	0.0000	-20.9858
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3702	5.7210	0.0000	-0.0000	0.0000	28.6205
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3702	5.7210	0.0000	-0.0000	0.0000	28.6205
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.0319	-1.9096	0.0000	-0.0000	0.0000	-23.5010
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6972	-1.3344	0.0000	-0.0000	0.0000	-28.0153

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	16.9392
Shear X	-3.9512
Shear Z	0.0000
Moment X	-0.0006
Moment Y (Twist)	0.0013
Moment Z	48.8671

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	10.5904
Shear X	-2.3702
Shear Z	0.0000
Moment X	-0.0001
Moment Y (Twist)	0.0002
Moment Z	28.6391

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	-0.0197	2.7281	0.0056	0.0207	-0.0131	0.2352
ULS: 2. D + L	-0.0197	2.7281	0.0056	0.0207	-0.0131	0.2352
ULS: 3. D + (S or Lr or R)	-0.0807	9.2907	0.0230	0.0844	-0.0535	0.9140
ULS: 3. D + (S or Lr or R)	-0.0197	2.7281	0.0056	0.0207	-0.0131	0.2352
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0655	7.6501	0.0187	0.0685	-0.0434	0.7443
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0197	2.7281	0.0056	0.0207	-0.0131	0.2352
ULS: 5b. D + 0.7E	-0.0197	2.7281	0.0056	0.0207	-0.0131	0.2352
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0655	7.6501	0.0187	0.0685	-0.0434	0.7443
ULS: 8. 0.6D + 0.7E	-0.0118	1.6369	0.0034	0.0124	-0.0079	0.1411
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4071	6.8996	0.0015	0.0104	0.0181	28.7330
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4071	6.8996	0.0015	0.0104	0.0181	28.7330
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.0290	-0.8501	0.0075	0.0236	-0.0350	-23.2556
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.6711	-0.2375	0.0169	0.0558	-0.0608	-27.4879
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8560	10.7787	0.0156	0.0608	-0.0199	22.1176
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8560	10.7787	0.0156	0.0608	-0.0199	22.1176
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4711	4.9664	0.0201	0.0707	-0.0598	-16.8738
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2026	5.4258	0.0271	0.0948	-0.0791	-20.0480
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8103	5.8567	0.0025	0.0130	0.0103	21.6086
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8103	5.8567	0.0025	0.0130	0.0103	21.6086
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.5168	0.0444	0.0070	0.0229	-0.0295	-17.3829
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.2484	0.5039	0.0140	0.0470	-0.0488	-20.5571
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3992	5.8084	-0.0008	0.0022	0.0234	28.6389
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3992	5.8084	-0.0008	0.0022	0.0234	28.6389
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.0369	-1.9414	0.0052	0.0154	-0.0297	-23.3497
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.6790	-1.3288	0.0146	0.0476	-0.0555	-27.5820

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	17.2467
Shear X	-4.0303
Shear Z	0.0463
Moment X	0.1642
Moment Y (Twist)	0.1261
Moment Z	49.1844

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

Result	Value (kip, kip-ft)
Axial	10.7787
Shear X	-2.4071
Shear Z	0.0271
Moment X	0.0948
Moment Y (Twist)	0.0791
Moment Z	28.7330

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	0.0193	2.3054	-0.0575	-0.2048	0.0326	-0.1829
ULS: 2. D + L	0.0193	2.3054	-0.0575	-0.2048	0.0326	-0.1829
ULS: 3. D + (S or Lr or R)	0.0789	7.5598	-0.2368	-0.8452	0.1352	-0.8215
ULS: 3. D + (S or Lr or R)	0.0193	2.3054	-0.0575	-0.2048	0.0326	-0.1829
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0640	6.2462	-0.1920	-0.6851	0.1096	-0.6618
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0193	2.3054	-0.0575	-0.2048	0.0326	-0.1829
ULS: 5b. D + 0.7E	0.0193	2.3054	-0.0575	-0.2048	0.0326	-0.1829
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0640	6.2462	-0.1920	-0.6851	0.1096	-0.6618
ULS: 8. 0.6D + 0.7E	0.0116	1.3832	-0.0345	-0.1229	0.0196	-0.1097
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.9286	5.6410	-0.2159	-0.7490	0.4025	23.2887
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.9286	5.6410	-0.2159	-0.7490	0.4025	23.2887
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6868	-0.5521	0.0750	0.2494	-0.2768	-19.6191
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4235	-0.0862	0.0699	0.2315	-0.2705	-23.4400
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3969	8.7480	-0.3108	-1.0933	0.3870	16.9419
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3969	8.7480	-0.3108	-1.0933	0.3870	16.9419
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3147	4.1031	-0.0926	-0.3445	-0.1225	-15.2390
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1172	4.4525	-0.0964	-0.3579	-0.1178	-18.1047
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4416	4.8071	-0.1763	-0.6130	0.3100	17.4208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4416	4.8071	-0.1763	-0.6130	0.3100	17.4208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2699	0.1623	0.0419	0.1358	-0.1995	-14.7601
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0724	0.5117	0.0380	0.1224	-0.1947	-17.6257
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.9363	4.7189	-0.1929	-0.6671	0.3894	23.3619
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.9363	4.7189	-0.1929	-0.6671	0.3894	23.3619
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6791	-1.4742	0.0980	0.3313	-0.2899	-19.5460
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4158	-1.0084	0.0929	0.3134	-0.2836	-23.3668

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	13.9551
Shear X	-3.2465
Shear Z	-0.4928
Moment X	-1.7486
Moment Y (Twist)	0.7147
Moment Z	40.1135

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	8.7480
Shear X	-1.9363
Shear Z	-0.3108
Moment X	-1.0933
Moment Y (Twist)	0.4025
Moment Z	23.4400

Project Details

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

Design Input Information

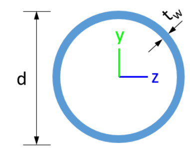
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

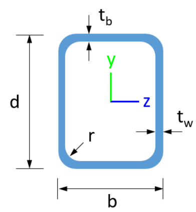
Design Materials

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

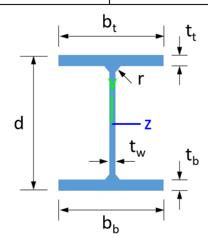
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
9	8in Pipe Sch 40	8.63	0.32					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
17	HSS5x3x1/4	5.00	3.00	0.23	0.23	0.23		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
20	W10x12	9.87	0.19	3.96	3.96	0.21	0.21	0.30

Section Properties

ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21

17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	9	24.69	24.69	11.76	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.15,1.16,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.16,1.18,1.18,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.75,1.67,1.67,1.67,1.67,1.68,1.68,1.61,1.71,1.67,1.67,1.66,2.05	300	200	1
5	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.58,1.59,1.58,1.59,1.59,1.59,1.57,1.57,1.50,1.93,1.56,1.56,1.55,1.34,1.58,1.58,1.60,1.63,1.57,1.57,1.52,2.07,1.56,1.56,1.55,1.04	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.98,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.71,1.67,1.67,1.66,1.58	300	200	1
11	20	1.33	1.33	2.05	1.63,1.63,1.63,1.63,1.63,1.63,1.71,1.71,2.10,2.09,1.73,1.73,1.82,1.93,1.67,1.67,1.58,1.52,1.71,1.71,2.08,2.08,1.74,1.74,1.79,1.90	300	200	1
12	6	4.20	4.20	2.00	-	300	200	1
13	20	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.09,1.09,1.17,1.09,1.09,1.08,1.10,1.10,1.10,1.11,1.10,1.09,1.09,1.06,1.15,1.09,1.09,1.08,1.10	300	200	1
14	20	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.20,1.10,1.10,1.10,2.65,1.10,1.10,1.10,1.12,1.10,1.10,1.09,1.23,1.10,1.10,1.10,1.44	300	200	1
15	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	24.69	24.69	11.76	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.82,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.56	300	200	1
105	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1

108	20	1.33	1.33	2.05	2.24,2.24,2.24,2.24,2.24,2.24,2.24,2.24,2.27,2.26,2.24,2.24,2.25,1.71,2.24,2.24,2.23,2.24,2.24,2.24,2.26,2.27,2.24,2.24,2.25,1.51	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.83,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.56	300	200	1
111	20	1.33	1.33	2.05	2.27,2.26,2.27,2.27,2.26,2.27,2.33,2.33,1.83,2.09,2.34,2.34,2.14,2.14,2.29,2.29,2.23,2.19,2.33,2.33,2.08,2.10,2.35,2.35,2.21,2.14	300	200	1
112	6	4.20	4.20	2.00	-	300	200	1
113	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.10,1.16,1.05,1.05,1.05,1.06,1.04,1.04,1.03,1.03,1.04,1.04,1.08,1.13,1.05,1.05,1.05,1.06	300	200	1
114	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.04,1.06,1.11,1.04,1.04,1.04,1.05,1.03,1.03,1.03,1.03,1.04,1.04,1.05,1.15,1.04,1.04,1.04,1.04	300	200	1
115	20	8.42	8.42	12.95	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.15,1.10,1.11,1.14,1.14,1.13,1.13,1.16,1.16,1.17,1.19,1.15,1.15,1.11,1.11,1.14,1.14,1.13,1.13	300	200	1
116	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.17,1.17,1.17,1.21,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.17,1.17,1.17,1.53	300	200	1
201	9	24.69	24.69	11.76	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.80,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.52	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
208	20	1.33	1.33	2.05	2.28,2.27,2.28,2.27,2.27,2.28,2.27,2.27,2.24,2.26,2.26,2.26,2.26,2.14,2.27,2.27,2.28,2.27,2.27,2.27,2.24,2.26,2.26,2.26,2.26,2.11	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.80,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.52	300	200	1
211	20	1.33	1.33	2.05	2.25,2.25,2.25,2.25,2.25,2.25,2.28,2.28,2.13,2.33,2.29,2.29,2.31,2.30,2.26,2.26,2.24,2.23,2.28,2.28,2.26,2.32,2.29,2.29,2.30,2.29	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.02,1.03,1.03,1.03,1.04,1.03,1.03,1.03,1.03	300	200	1
214	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.08,1.03,1.03,1.03,1.85,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.11,1.03,1.03,1.03,1.01	300	200	1
215	20	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.15,1.16,1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.17,1.17,1.16,1.17,1.17,1.17,1.17,1.17	300	200	1
216	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.17,1.17,1.17,1.17,1.20,1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.17,1.17,1.17,1.17,1.18	300	200	1
301	9	24.69	24.69	11.76	-	300	200	1

302	6	4.20	4.20	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.83,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.56	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
308	20	1.33	1.33	2.05	2.32,2.31,2.32,2.31,2.31,2.32,2.32,2.32,2.29,2.15,2.33,2.33,2.33,1.17,2.32,2.32,2.31,2.32,2.32,2.32,2.35,2.13,2.33,2.33,2.33,1.45	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.82,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.70,1.67,1.67,1.66,1.56	300	200	1
311	20	1.33	1.33	2.05	2.30,2.30,2.30,2.29,2.30,2.30,2.11,2.11,1.43,1.63,2.10,2.10,2.04,1.99,2.14,2.14,2.30,2.25,2.11,2.11,1.59,1.72,2.10,2.10,2.08,2.05	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.10,1.16,1.05,1.05,1.05,1.06,1.04,1.04,1.03,1.03,1.04,1.04,1.08,1.13,1.05,1.05,1.05,1.06	300	200	1
314	20	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.04,1.06,1.11,1.04,1.04,1.04,1.05,1.03,1.03,1.03,1.03,1.04,1.04,1.05,1.15,1.04,1.04,1.04,1.04	300	200	1
315	20	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.12,1.13,1.16,1.16,1.15,1.15,1.17,1.17,1.18,1.19,1.16,1.16,1.13,1.14,1.16,1.16,1.15,1.15	300	200	1
316	20	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.13,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.46	300	200	1
401	9	24.69	24.69	11.76	-	300	200	1
402	6	4.20	4.20	2.00	-	300	200	1
403	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.19,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
404	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.98,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.71,1.67,1.67,1.66,1.58	300	200	1
405	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66	300	200	1
406	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.15,1.16,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.16,1.18,1.18,1.17,1.17	300	200	1
407	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.63,1.65,1.67,1.67,1.66,1.66	300	200	1
408	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	3	2.60	2.60	4.00	-	300	200	1
410	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.75,1.67,1.67,1.67,1.67,1.68,1.68,1.61,1.71,1.67,1.67,1.66,2.05	300	200	1
411	20	7.88	7.88	3.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1

412	6	1.30	1.30	2.00	-	300	200	1
413	20	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.09,1.09,1.17,1.09,1.09,1.08,1.10,1.10,1.10,1.11,1.11,1.09,1.09,1.06,1.15,1.09,1.09,1.08,1.10	300	200	1
414	20	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.09,1.20,1.10,1.10,1.10,2.67,1.10,1.10,1.10,1.12,1.10,1.10,1.09,1.23,1.10,1.10,1.10,1.44	300	200	1
415	20	8.42	8.42	12.95	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.15,1.14,1.11,1.11,1.12,1.13,1.12,1.12,1.12,1.12,1.11,1.11,1.14,1.14,1.11,1.11,1.12,1.12	300	200	1
416	20	8.42	8.42	12.95	1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.12,1.12,1.12,1.12,1.86,1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.13,1.12,1.12,1.12,1.21	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	179.64	83.29	83.29	113.39	113.39
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	229.64	27.16	27.16	75.30	75.30
13	159.30	116.35	32.39	6.46	56.26	44.91
14	159.30	116.35	33.31	6.46	56.26	44.91
15	159.30	55.15	46.90	6.46	56.26	44.91
16	159.30	55.15	46.90	6.46	56.26	44.91
101	377.97	179.64	83.29	83.29	113.39	113.39
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	142.47	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	142.47	46.90	6.46	56.26	44.91
112	251.01	229.64	27.16	27.16	75.30	75.30
113	159.30	116.35	31.48	6.46	56.26	44.91
114	159.30	116.35	31.48	6.46	56.26	44.91
115	159.30	48.27	14.61	6.46	56.26	44.91
116	159.30	48.27	15.28	6.46	56.26	44.91
201	377.97	179.64	83.29	83.29	113.39	113.39
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95

208	159.30	142.47	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	142.47	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	31.17	6.46	56.26	44.91
214	159.30	116.35	30.87	6.46	56.26	44.91
215	159.30	48.27	15.28	6.46	56.26	44.91
216	159.30	48.27	15.54	6.46	56.26	44.91
301	377.97	179.64	83.29	83.29	113.39	113.39
302	251.01	229.64	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	142.47	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	142.47	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	116.35	31.48	6.46	56.26	44.91
314	159.30	116.35	31.48	6.46	56.26	44.91
315	159.30	48.27	14.88	6.46	56.26	44.91
316	159.30	48.27	15.01	6.46	56.26	44.91
401	377.97	179.64	83.29	83.29	113.39	113.39
402	251.01	229.64	27.16	27.16	75.30	75.30
403	151.65	150.70	20.17	14.14	54.12	28.95
404	151.65	145.15	20.17	14.14	54.12	28.95
405	151.65	149.10	20.17	14.14	54.12	28.95
406	151.65	150.70	20.17	14.14	54.12	28.95
407	151.65	149.10	20.17	14.14	54.12	28.95
408	159.30	55.15	46.90	6.46	56.26	44.91
409	75.10	66.32	4.25	4.25	22.53	22.53
410	151.65	145.15	20.17	14.14	54.12	28.95
411	159.30	55.15	46.90	6.46	56.26	44.91
412	251.01	248.88	27.16	27.16	75.30	75.30
413	159.30	116.35	32.39	6.46	56.26	44.91
414	159.30	116.35	33.31	6.46	56.26	44.91
415	159.30	48.27	14.74	6.46	56.26	44.91
416	159.30	48.27	14.74	6.46	56.26	44.91

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	0.078	0.482	0.048	0.028	0.004	0.521	#13	0.504	Not Required	Pass
2	0.005	0.332	0.112	0.077	0.021	0.422	#21	0.036	Not Required	Pass
3	0.007	0.511	0.042	0.050	0.010	0.525	#21	0.046	Not Required	Pass
4	0.006	0.508	0.135	0.051	0.031	0.611	#21	0.082	Not Required	Pass
5	0.007	0.317	0.123	0.051	0.033	0.351	#21	0.076	Not Required	Pass
6	0.011	0.647	0.090	0.065	0.017	0.742	#21	0.046	Not Required	Pass
7	0.011	0.401	0.231	0.064	0.059	0.459	#21	0.076	Not Required	Pass
8	0.003	0.087	0.286	0.041	0.024	0.290	#24	0.102	Not Required	Pass

9	0.019	0.057	0.080	0.002	0.004	0.142	#21	0.206	Not Required	Pass
10	0.012	0.630	0.213	0.063	0.045	0.747	#21	0.082	Not Required	Pass
11	0.005	0.083	0.297	0.042	0.024	0.303	#24	0.102	Not Required	Pass
12	0.003	0.481	0.138	0.103	0.023	0.589	#21	0.174	Not Required	Pass
13	0.007	0.179	0.623	0.053	0.029	0.750	#21	0.306	Not Required	Pass
14	0.008	0.176	0.609	0.052	0.029	0.719	#21	0.204	Not Required	Pass
15	0.000	0.050	0.155	0.022	0.012	0.205	#21	Not Required	Not Required	Pass
16	0.000	0.050	0.155	0.022	0.012	0.205	#21	Not Required	Not Required	Pass
101	0.096	0.591	0.005	0.036	0.000	0.629	#13	0.504	Not Required	Pass
102	0.005	0.513	0.158	0.113	0.026	0.647	#21	0.036	Not Required	Pass
103	0.011	0.722	0.055	0.072	0.001	0.783	#21	0.046	Not Required	Pass
104	0.011	0.729	0.227	0.073	0.048	0.873	#21	0.082	Not Required	Pass
105	0.011	0.448	0.239	0.071	0.063	0.513	#21	0.076	Not Required	Pass
106	0.011	0.718	0.055	0.071	0.002	0.774	#21	0.046	Not Required	Pass
107	0.011	0.446	0.233	0.071	0.061	0.510	#21	0.076	Not Required	Pass
108	0.004	0.068	0.285	0.045	0.024	0.354	#21	0.102	Not Required	Pass
109	0.027	0.060	0.052	0.001	0.000	0.125	#21	0.206	Not Required	Pass
110	0.011	0.717	0.223	0.072	0.047	0.861	#21	0.082	Not Required	Pass
111	0.005	0.059	0.296	0.044	0.024	0.356	#21	0.102	Not Required	Pass
112	0.006	0.505	0.159	0.111	0.027	0.636	#21	0.116	Not Required	Pass
113	0.007	0.263	0.637	0.057	0.030	0.871	#21	0.306	Not Required	Pass
114	0.010	0.286	0.627	0.058	0.030	0.884	#21	0.306	Not Required	Pass
115	0.016	0.530	0.335	0.047	0.024	0.873	#21	0.644	Not Required	Pass
116	0.004	0.519	0.330	0.048	0.024	0.850	#21	0.644	Not Required	Pass
201	0.094	0.587	0.000	0.035	0.000	0.624	#13	0.504	Not Required	Pass
202	0.005	0.500	0.156	0.110	0.026	0.627	#21	0.036	Not Required	Pass
203	0.011	0.712	0.054	0.071	0.001	0.771	#21	0.046	Not Required	Pass
204	0.011	0.700	0.220	0.070	0.046	0.841	#21	0.082	Not Required	Pass
205	0.011	0.442	0.231	0.070	0.060	0.505	#21	0.076	Not Required	Pass
206	0.011	0.712	0.054	0.071	0.001	0.771	#21	0.046	Not Required	Pass
207	0.011	0.442	0.231	0.070	0.060	0.505	#21	0.076	Not Required	Pass
208	0.004	0.062	0.282	0.044	0.024	0.345	#21	0.102	Not Required	Pass
209	0.026	0.060	0.050	0.001	0.000	0.122	#21	0.206	Not Required	Pass
210	0.011	0.700	0.220	0.070	0.046	0.842	#21	0.082	Not Required	Pass
211	0.005	0.064	0.291	0.045	0.024	0.357	#21	0.102	Not Required	Pass
212	0.005	0.500	0.156	0.110	0.026	0.627	#21	0.036	Not Required	Pass
213	0.007	0.274	0.615	0.055	0.029	0.870	#21	0.306	Not Required	Pass
214	0.009	0.273	0.604	0.055	0.029	0.852	#21	0.306	Not Required	Pass
215	0.016	0.412	0.334	0.045	0.024	0.757	#21	0.644	Not Required	Pass
216	0.005	0.403	0.328	0.044	0.024	0.732	#21	0.644	Not Required	Pass
301	0.096	0.591	0.005	0.036	0.000	0.629	#13	0.504	Not Required	Pass
302	0.006	0.505	0.159	0.111	0.027	0.636	#21	0.116	Not Required	Pass
303	0.011	0.718	0.055	0.071	0.002	0.774	#21	0.046	Not Required	Pass
304	0.011	0.717	0.223	0.072	0.047	0.861	#21	0.082	Not Required	Pass
305	0.011	0.446	0.233	0.071	0.061	0.510	#21	0.076	Not Required	Pass
306	0.011	0.722	0.055	0.072	0.001	0.783	#21	0.046	Not Required	Pass
307	0.011	0.448	0.239	0.071	0.063	0.513	#21	0.076	Not Required	Pass
308	0.003	0.060	0.301	0.048	0.024	0.362	#21	0.102	Not Required	Pass
309	0.027	0.060	0.052	0.001	0.000	0.125	#21	0.206	Not Required	Pass
310	0.011	0.729	0.227	0.073	0.048	0.873	#21	0.082	Not Required	Pass
311	0.005	0.053	0.309	0.047	0.024	0.359	#21	0.102	Not Required	Pass
312	0.005	0.513	0.158	0.113	0.026	0.647	#21	0.036	Not Required	Pass
313	0.007	0.263	0.637	0.057	0.030	0.872	#21	0.306	Not Required	Pass
314	0.010	0.286	0.627	0.058	0.030	0.884	#21	0.306	Not Required	Pass

315	0.016	0.414	0.335	0.044	0.024	0.756	#21	0.644	Not Required	Pass
316	0.005	0.401	0.329	0.045	0.024	0.730	#21	0.644	Not Required	Pass
401	0.078	0.482	0.048	0.028	0.004	0.521	#13	0.504	Not Required	Pass
402	0.003	0.481	0.138	0.103	0.023	0.589	#21	0.174	Not Required	Pass
403	0.011	0.647	0.090	0.065	0.017	0.742	#21	0.046	Not Required	Pass
404	0.012	0.630	0.214	0.063	0.045	0.747	#21	0.082	Not Required	Pass
405	0.011	0.401	0.231	0.064	0.059	0.459	#21	0.076	Not Required	Pass
406	0.007	0.511	0.042	0.050	0.010	0.525	#21	0.046	Not Required	Pass
407	0.007	0.317	0.123	0.051	0.033	0.351	#21	0.076	Not Required	Pass
408	0.000	0.050	0.155	0.022	0.012	0.205	#21	Not Required	Not Required	Pass
409	0.019	0.057	0.080	0.002	0.004	0.142	#21	0.206	Not Required	Pass
410	0.006	0.508	0.135	0.051	0.031	0.611	#21	0.082	Not Required	Pass
411	0.000	0.050	0.155	0.022	0.012	0.205	#21	Not Required	Not Required	Pass
412	0.005	0.332	0.112	0.077	0.021	0.422	#21	0.036	Not Required	Pass
413	0.007	0.179	0.622	0.053	0.029	0.750	#21	0.204	Not Required	Pass
414	0.008	0.176	0.610	0.052	0.029	0.719	#21	0.306	Not Required	Pass
415	0.016	0.545	0.335	0.042	0.024	0.881	#21	0.644	Not Required	Pass
416	0.004	0.539	0.327	0.041	0.024	0.864	#21	0.644	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

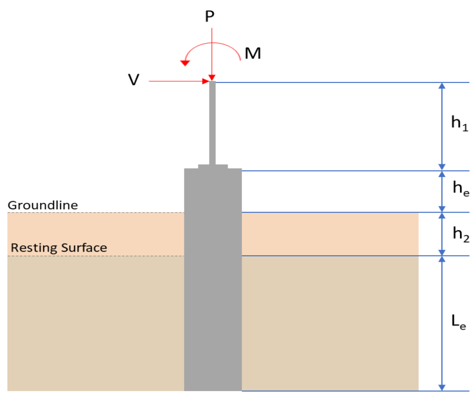
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.748	13.955
V_x (kip)	-1.936	-3.246
V_z (kip)	0.311	0.493
M_x (kipft)	1.093	1.747
M_z (kipft)	23.440	40.113

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.936\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.30828\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.44\ \text{kipft}) + ((-1.936\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.7325\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.7681\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.311\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.049522\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.093\ \text{kipft}) + ((0.311\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.17404\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.8141\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7681\ \text{ft}), (2.8141\ \text{ft})]$$

$$L_{e,req} = 5.768\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.768\ \text{ft})}{(6.25\ \text{ft})}$$

$$Ratio = 0.92288$$

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

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

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

$$q = \frac{(8.748\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.54675\ \text{kip/ft}^2$$

$$q = 0.54675\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.54675\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.27337$$

Status: **PASS**
Ratio: **0.270**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.30828\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.7325\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.7325\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (3.7325\ \mathrm{kipft/ft})) + (4 \times (-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.3\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.7325\ \mathrm{kipft/ft})) + (3 \times (-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (3.7325\ \mathrm{kipft/ft})) + (2 \times (-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.21887\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.7325\ \mathrm{kipft/ft})) + ((-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.85067\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.3\ \mathrm{ft})}{2}$$

$$p_a = 0.3225\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21887\ \mathrm{kip/ft^2}\right)}{\left(0.3225\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.67866$$

Status: **PASS**
Ratio: **0.680**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.85067\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90738$$

Status: PASS
Ratio: 0.910

Considering z-direction:

$H_o = 0.049522\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.17404\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17404\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.17404\ \mathrm{kipft/ft})) + (4 \times (0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4492\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.17404\ \mathrm{kipft/ft})) + (3 \times (0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.17404\ \mathrm{kipft/ft})) + (2 \times (0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.044413\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.17404\ \mathrm{kipft/ft})) + ((0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.10101\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4492\ \mathrm{ft})}{2}$$

$$p_a = 0.33369\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.044413\ \mathrm{kip/ft^2}\right)}{\left(0.33369\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.1331$$

Status: PASS
Ratio: 0.130

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

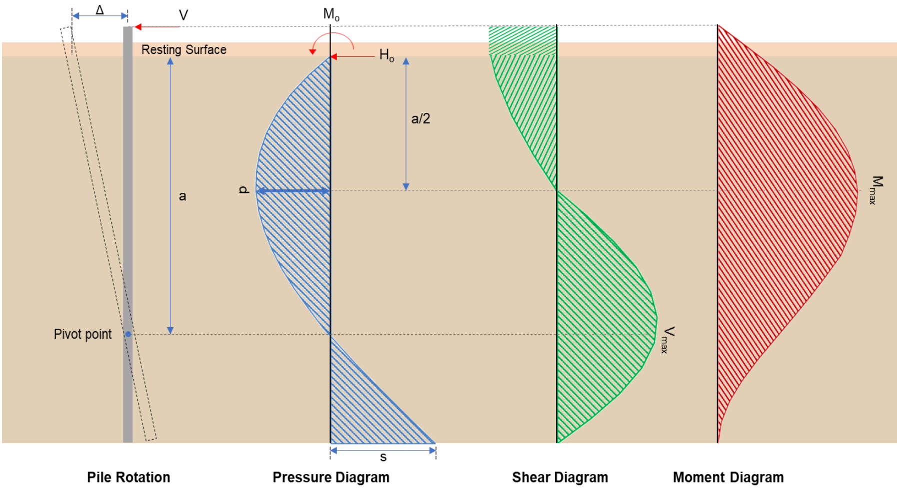
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.10101\ \text{kip/ft}^2)}{(0.9375\ \text{kip/ft}^2)}$$

$$Ratio = 0.10774$$

Status: **PASS**
Ratio: **0.110**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.246\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.51688\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(40.113\ \text{kipft}) + ((-3.246\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.3874\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.3874\ \text{kipft/ft})}{(-0.51688\ \text{kip/ft})}$$

$$E = 12.358\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.3874\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.51688\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (6.3874\ \text{kipft/ft})) + (4 \times (-0.51688\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.298\ \text{ft}$$

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

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

$$V_{max} = ((-0.51688\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.358\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.298\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.358\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.298\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.5985\ \text{kip}$$

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

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

$$M_{max} = ((-0.51688\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(12.358\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.298\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.358\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.298\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.358\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.298\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 25.695\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.493\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.078503\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.747\ \text{kipft}) + ((0.493\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.27818\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.27818\ \text{kipft/ft})}{(0.078503\ \text{kip/ft})}$$

$$E = 3.5436\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.27818\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (0.078503\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (0.27818\ \text{kipft/ft})) + (4 \times (0.078503\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.4481\ \text{ft}$$

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

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

$$V_{max} = ((0.078503\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5436\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4481\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.5436\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4481\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.52386\ \text{kip}$$

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

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

$$M_{max} = ((0.078503\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(3.5436\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.4481\ \text{ft})}{2 \times (6.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.5436\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.4481\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.5436\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.4481\ \text{ft})}{2 \times (6.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.4617 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.955 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.132 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.132 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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**	

22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(13.955\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.0052165$$	Status: **PASS** Ratio: **0.010**

	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 48\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,max} = 296.21\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 13.955\ \text{kip} \rightarrow 13955\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(13955\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 120.35\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,b} = 348.89\ \text{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \text{kip}), (120.35\ \text{kip}), (348.89\ \text{kip})\right]$$ $$V_c = 120.35\ \text{kip}$$	

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.35\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.31\ \text{kip}$$

Considering x-direction:

$V_{max} = 8.5985\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.5985\ \text{kip})}{(111.31\ \text{kip})}$$

$$Ratio = 0.077251$$

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

Considering z-direction:

$V_{max} = 0.52386\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.52386\ \text{kip})}{(111.31\ \text{kip})}$$

$$Ratio = 0.0047065$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 25.695 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(25.695 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.10294$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $M_{max} = 1.4617 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.4617 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0058562$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

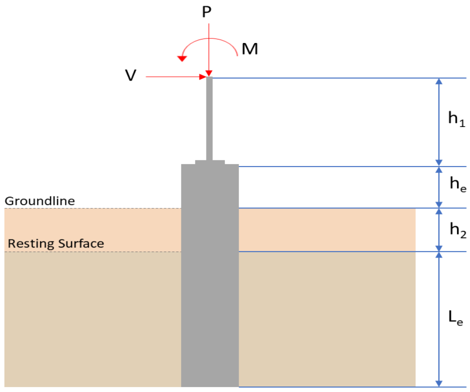
SkyCiv Foundation Design

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
$L = 6.25\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	8.748	13.955
V_x (kip)	-1.936	-3.246
V_z (kip)	-0.311	-0.493
M_x (kipft)	-1.093	-1.749
M_z (kipft)	23.440	40.113

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.936\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.30828\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.44\ \text{kipft}) + ((-1.936\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.7325\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 5.7681\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.311\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.049522\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.093\ \text{kipft}) + ((-0.311\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.17404\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.9987\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7681\ \text{ft}), (1.9987\ \text{ft})]$$

$$L_{e,req} = 5.768\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.25\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.25\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.768\ \text{ft})}{(6.25\ \text{ft})}$$

$$Ratio = 0.92288$$

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

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

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

$$q = \frac{(8.748\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.54675\ \text{kip/ft}^2$$

$q = 0.54675\ \mathrm{kip/ft^2}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.54675\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.27337$$

Status: **PASS**
Ratio: **0.270**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.30828\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.7325\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.7325\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (3.7325\ \mathrm{kipft/ft})) + (4 \times (-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.3\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times \left[(4 \times (3.7325\ \mathrm{kipft/ft})) + (3 \times (-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))\right]^2}{(6.25\ \mathrm{ft})^2 \times \left[(3 \times (3.7325\ \mathrm{kipft/ft})) + (2 \times (-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))\right]}$$

$$p = 0.21887\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times \left[(2 \times (3.7325\ \mathrm{kipft/ft})) + ((-0.30828\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))\right]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.85067\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.3\ \mathrm{ft})}{2}$$

$$p_a = 0.3225\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21887\ \mathrm{kip/ft^2}\right)}{\left(0.3225\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.67866$$

Status: **PASS**
Ratio: **0.680**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.85067\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90738$$

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

Considering z-direction:

$H_o = -0.049522\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.17404\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17404\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.17404\ \mathrm{kipft/ft})) + (4 \times (-0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4492\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.17404\ \mathrm{kipft/ft})) + (3 \times (-0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.17404\ \mathrm{kipft/ft})) + (2 \times (-0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = -0.010699\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.17404\ \mathrm{kipft/ft})) + ((-0.049522\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.0059251\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4492\ \mathrm{ft})}{2}$$

$$p_a = 0.33369\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.010699\ \mathrm{kip/ft^2}\right)}{\left(0.33369\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.032063$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.25\ \mathrm{ft})$$

$$p_s = 0.9375\ \mathrm{kip/ft^2}$$

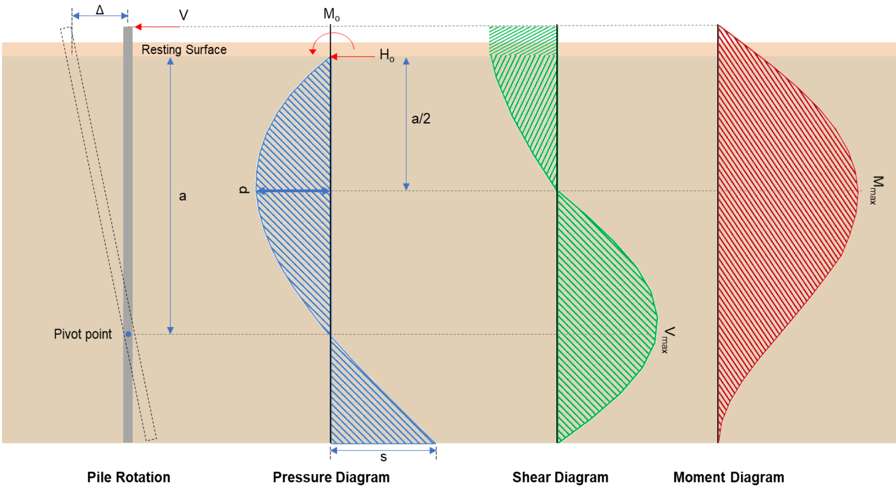
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0059251\ \text{kip/ft}^2)}{(0.9375\ \text{kip/ft}^2)}$$

$$Ratio = 0.0063201$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.246\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.51688\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(40.113\ \text{kipft}) + ((-3.246\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.3874\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.3874\ \text{kipft/ft})}{(-0.51688\ \text{kip/ft})}$$

$$E = 12.358\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.3874\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.51688\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (6.3874\ \text{kipft/ft})) + (4 \times (-0.51688\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.298\ \text{ft}$$

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

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

$$V_{max} = ((-0.51688\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.358\ \text{ft})}{(6.25\ \text{ft})} + 3\right) \times \left(\frac{(4.298\ \text{ft})}{(6.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.358\ \text{ft})}{(6.25\ \text{ft})} + 2\right) \times \left(\frac{(4.298\ \text{ft})}{(6.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.5985\ \text{kip}$$

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

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

$$M_{max} = ((-0.51688\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(12.358\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.298\ \text{ft})}{2 \times (6.25\ \text{ft})} \right) - \left[\left(\frac{4 \times (12.358\ \text{ft})}{(6.25\ \text{ft})} + 3 \right) \times \left(\frac{(4.298\ \text{ft})}{2 \times (6.25\ \text{ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.358\ \text{ft})}{(6.25\ \text{ft})} + 2 \right) \times \left(\frac{(4.298\ \text{ft})}{2 \times (6.25\ \text{ft})} \right)^4 \right] \right]$$

$$M_{max} = 25.695\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.493\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.078503\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.749\ \text{kipft}) + ((-0.493\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.2785\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.2785\ \text{kipft/ft})}{(-0.078503\ \text{kip/ft})}$$

$$E = 3.5477\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.2785\ \text{kipft/ft}) \times (6.25\ \text{ft})) + \left(3 \times (-0.078503\ \text{kip/ft}) \times (6.25\ \text{ft})^2\right)}{(6 \times (0.2785\ \text{kipft/ft})) + (4 \times (-0.078503\ \text{kip/ft}) \times (6.25\ \text{ft}))}$$

$$a = 4.448\ \text{ft}$$

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

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

$$V_{max} = ((-0.078503\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5477\ \text{ft})}{(6.25\ \text{ft})} + 3 \right) \times \left(\frac{(4.448\ \text{ft})}{(6.25\ \text{ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.5477\ \text{ft})}{(6.25\ \text{ft})} + 2 \right) \times \left(\frac{(4.448\ \text{ft})}{(6.25\ \text{ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.52422\ \text{kip}$$

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

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

$$M_{max} = ((-0.078503\ \text{kip/ft}) \times (48\ \text{in}) \times (6.25\ \text{ft})) \times \left[\left(\frac{(3.5477\ \text{ft})}{(6.25\ \text{ft})} + \frac{(4.448\ \text{ft})}{2 \times (6.25\ \text{ft})} \right) - \left[\left(\frac{4 \times (3.5477\ \text{ft})}{(6.25\ \text{ft})} + 3 \right) \times \left(\frac{(4.448\ \text{ft})}{2 \times (6.25\ \text{ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.5477\ \text{ft})}{(6.25\ \text{ft})} + 2 \right) \times \left(\frac{(4.448\ \text{ft})}{2 \times (6.25\ \text{ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.4628 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(13.955 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.132 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.132 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(13.955\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0052165$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 13.955\ \text{kip} \rightarrow 13955\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(13955\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.35\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.35\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.35\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.35\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 111.31\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 8.5985\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.5985\ \mathrm{kip})}{(111.31\ \mathrm{kip})}$$

$$Ratio = 0.077251$$

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

Considering z-direction:

$V_{max} = 0.52422\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.52422\ \mathrm{kip})}{(111.31\ \mathrm{kip})}$$

$$Ratio = 0.0047097$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 25.695 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(25.695 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.10294$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $M_{max} = 1.4628 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.4628 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0058607$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

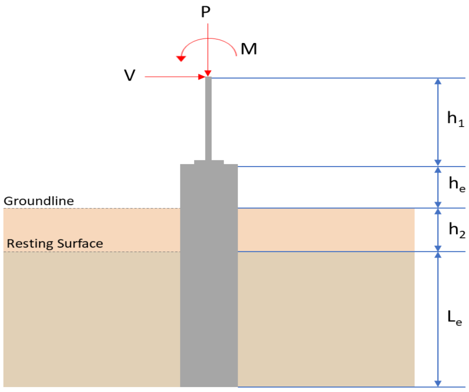
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.5$ 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)	10.779	17.247
V_x (kip)	-2.407	-4.030
V_z (kip)	-0.027	-0.046
M_x (kipft)	-0.095	-0.164
M_z (kipft)	28.733	49.184

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.407\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.38328\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.733\ \text{kipft}) + ((-2.407\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.5753\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.0908\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.027\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0042994\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.095\ \text{kipft}) + ((-0.027\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.015127\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.98519\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.0908\ \text{ft}), (0.98519\ \text{ft})]$$

$$L_{e,req} = 6.091\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.091\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.93708$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.779\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.67369\ \text{kip/ft}^2$$

$q = 0.67369\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.67369\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.33684$$

Status: **PASS**
Ratio: **0.340**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.38328\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.5753\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5753\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.38328\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (4.5753\ \text{kipft/ft})) + (4 \times (-0.38328\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4776\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.5753\ \text{kipft/ft})) + (3 \times (-0.38328\ \text{kip/ft}) \times (6.5\ \text{ft}))]^{\,2}}{(6.5\ \text{ft})^2 \times [(3 \times (4.5753\ \text{kipft/ft})) + (2 \times (-0.38328\ \text{kip/ft}) \times (6.5\ \text{ft}))]}$$

$$p = 0.23801\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.5753\ \text{kipft/ft})) + ((-0.38328\ \text{kip/ft}) \times (6.5\ \text{ft}))]}{(6.5\ \text{ft})^2}$$

$$s = 0.9457\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.4776\ \text{ft})}{2}$$

$$p_a = 0.33582\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.23801\ \text{kip/ft}^2)}{(0.33582\ \text{kip/ft}^2)}$$

$$Ratio = 0.70875$$

Status: **PASS**
Ratio: **0.710**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 0.975\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.9457\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.96995$$

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

Considering z-direction:

$H_o = -0.0042994\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.015127\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015127\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.0042994\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.015127\ \mathrm{kipft/ft})) + (4 \times (-0.0042994\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6323\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.015127\ \mathrm{kipft/ft})) + (3 \times (-0.0042994\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.015127\ \mathrm{kipft/ft})) + (2 \times (-0.0042994\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = -0.0009192\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.015127\ \mathrm{kipft/ft})) + ((-0.0042994\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.00032789\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6323\ \mathrm{ft})}{2}$$

$$p_a = 0.34742\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0009192\ \mathrm{kip/ft^2}\right)}{\left(0.34742\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0026458$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 0.975\ \mathrm{kip/ft^2}$$

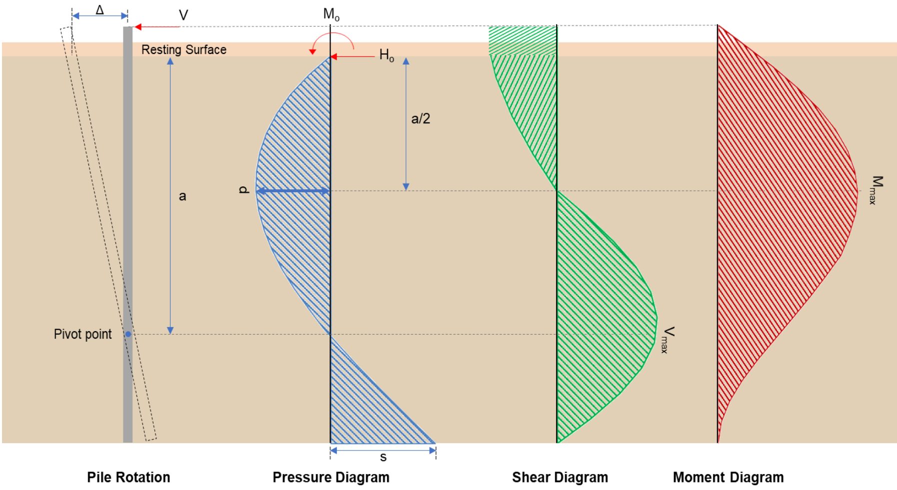
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00032789 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$Ratio = 0.0003363$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.03 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.64172 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(49.184 \text{ kipft}) + ((-4.03 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.8318 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.8318 \text{ kipft/ft})}{(-0.64172 \text{ kip/ft})}$$

$$E = 12.204 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.8318 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.64172 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (7.8318 \text{ kipft/ft})) + (4 \times (-0.64172 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4753 \text{ ft}$$

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

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

$$V_{max} = ((-0.64172 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.204 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.4753 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.204 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.4753 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 10.222 \text{ kip}$$

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

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

$$M_{max} = ((-0.64172\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(12.204\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.4753\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (12.204\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4753\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.204\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4753\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 31.705\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.046\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0073248\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.164\ \text{kipft}) + ((-0.046\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.026115\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.026115\ \text{kipft/ft})}{(-0.0073248\ \text{kip/ft})}$$

$$E = 3.5652\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.026115\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.0073248\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (0.026115\ \text{kipft/ft})) + (4 \times (-0.0073248\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.6305\ \text{ft}$$

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

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

$$V_{max} = ((-0.0073248\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5652\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.6305\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.5652\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.6305\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.047931\ \text{kip}$$

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

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

$$M_{max} = ((-0.0073248\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(3.5652\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.6305\ \text{ft})}{2 \times (6.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (3.5652\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.6305\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.5652\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.6305\ \text{ft})}{2 \times (6.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.13877 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(17.247 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.023 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.023 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(17.247\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.006447$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 17.247\ \mathrm{kip} \rightarrow 17247\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(17247\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 120.78\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (120.78\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 120.78\ \mathrm{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 737.28\ \text{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((120.78\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 111.59\ \text{kip}$$ **Considering x-direction:** $V_{max} = 10.222\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(10.222\ \text{kip})}{(111.59\ \text{kip})}$$ $$Ratio = 0.091603$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $V_{max} = 0.047931\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.047931\ \text{kip})}{(111.59\ \text{kip})}$$ $$Ratio = 0.00042952$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$	

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 31.705\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(31.705\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.12702$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $M_{max} = 0.13877\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.13877\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.00055596$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

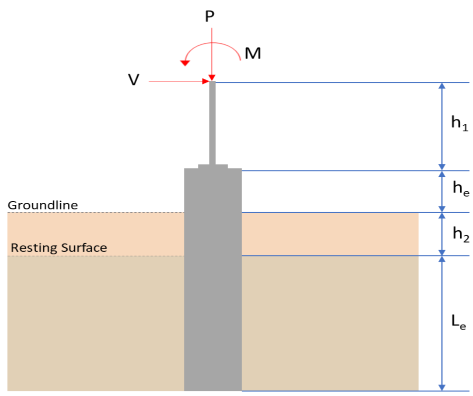
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48 \text{ in}$ - Pile width
$D = 48 \text{ in}$ - Pile depth
$L = 6.5 \text{ ft}$ - 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)	10.590	16.939
V_x (kip)	-2.370	-3.951
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	-0.001
M_z (kipft)	28.639	48.867

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.37 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.37739 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.639\ \text{kipft}) + ((-2.37\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.5604\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.0979\ \text{ft}$ - 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,

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

$$L_{e,req} = MAX[(6.0979\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 6.098\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.098\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.93815$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.59\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.66188\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.66188\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.33094$$

Status: **PASS**
Ratio: **0.330**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.37739\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.5604\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5604\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.37739\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (4.5604\ \mathrm{kipft/ft})) + (4 \times (-0.37739\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.4763\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.5604\ \mathrm{kipft/ft})) + (3 \times (-0.37739\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\,2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (4.5604\ \mathrm{kipft/ft})) + (2 \times (-0.37739\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.23957\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.5604\ \mathrm{kipft/ft})) + ((-0.37739\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.94689\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4763\ \mathrm{ft})}{2}$$

$$p_a = 0.33572\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.23957\ \mathrm{kip/ft^2}\right)}{\left(0.33572\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.71359$$

Status: **PASS**
Ratio: **0.710**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 0.975\ \mathrm{kip/ft^2}$$

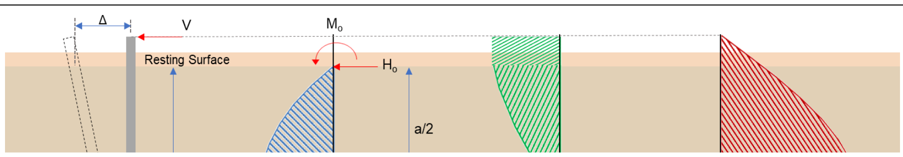
$Ratio$ - Lateral soil capacity

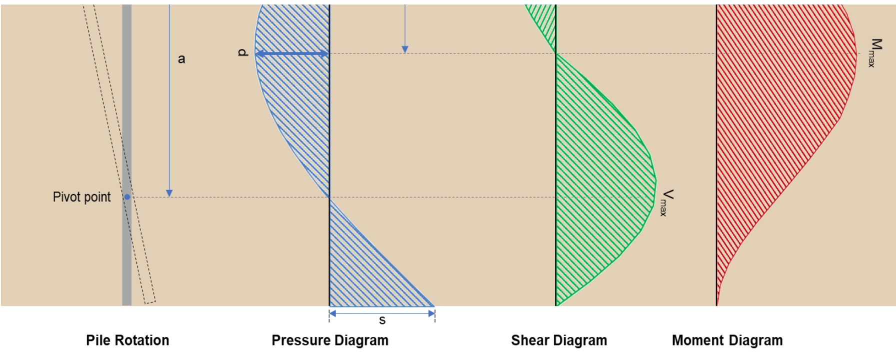
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(0.94689\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.97117$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.951\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.62914\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(48.867\text{ kipft}) + ((-3.951\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 7.7814\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.7814\text{ kipft/ft})}{(-0.62914\text{ kip/ft})}$$

$$E = 12.368\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.7814\text{ kipft/ft}) \times (6.5\text{ ft})) + \left(3 \times (-0.62914\text{ kip/ft}) \times (6.5\text{ ft})^2\right)}{(6 \times (7.7814\text{ kipft/ft})) + (4 \times (-0.62914\text{ kip/ft}) \times (6.5\text{ ft}))}$$

$$a = 4.4739\text{ ft}$$

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

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

$$V_{max} = ((-0.62914\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.368\text{ ft})}{(6.5\text{ ft})} + 3\right) \times \left(\frac{(4.4739\text{ ft})}{(6.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.368\text{ ft})}{(6.5\text{ ft})} + 2\right) \times \left(\frac{(4.4739\text{ ft})}{(6.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 10.134\text{ kip}$$

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

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

$$M_{max} = ((-0.62914\text{ kip/ft}) \times (48\text{ in}) \times (6.5\text{ ft})) \times \left[\left(\frac{(12.368\text{ ft})}{(6.5\text{ ft})} + \frac{(4.4739\text{ ft})}{2 \times (6.5\text{ ft})}\right) - \left[\left(\frac{4 \times (12.368\text{ ft})}{(6.5\text{ ft})} + 3\right) \times \left(\frac{(4.4739\text{ ft})}{2 \times (6.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.368\text{ ft})}{(6.5\text{ ft})} + 2\right) \times \left(\frac{(4.4739\text{ ft})}{2 \times (6.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 31.449 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.001 \text{ kipft}) + ((0 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.00015924 \text{ kipft/ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.00015924 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (0 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.00015924 \text{ kipft/ft})) + (4 \times (0 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.3333 \text{ ft}$$

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

$$V_{max} = 12 \left(\frac{M_o\, b}{L_e}\right) \left(\frac{a}{L_e} - 1\right) \left(\frac{a}{L_e}\right)^2$$

$$V_{max} = 12 \times \left(\frac{(0.00015924 \text{ kipft/ft}) \times (48 \text{ in})}{(6.5 \text{ ft})}\right) \times \left(\frac{(4.3333 \text{ ft})}{(6.5 \text{ ft})} - 1\right) \times \left(\frac{(4.3333 \text{ ft})}{(6.5 \text{ ft})}\right)^2$$

$$V_{max} = 0.00017421 \text{ kip}$$

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

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

$$M_{max} = ((0.00015924 \text{ kipft/ft}) \times (48 \text{ in})) \times \left[1 - \left(4 \times \frac{(4.3333 \text{ ft})}{2 \times (6.5 \text{ ft})}^3\right) + \left(3 \times \frac{(4.3333 \text{ ft})}{2 \times (6.5 \text{ ft})}^4\right)\right]$$

$$M_{max} = 0.00056617 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(16.939 \text{ kip})}{(0.65) \times (0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.033 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.033 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(16.939 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0063319$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 16.939\ \text{kip} \rightarrow 16939\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(16939\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120.74\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120.74\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120.74\ \text{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120.74\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.56\ \text{kip}$$

Considering x-direction:

$V_{max} = 10.134\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(10.134\ \text{kip})}{(111.56\ \text{kip})}$$

$$Ratio = 0.090836$$

Status: **PASS**
Ratio: **0.090**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 31.449\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(31.449\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.126$$

Status: **PASS**
Ratio: **0.130**

Considering z-direction:

$M_{max} = 0.00056617\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$\phi M_n$$ $$Ratio = \frac{(0.00056617 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 2.2683 \times 10^{-6}$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

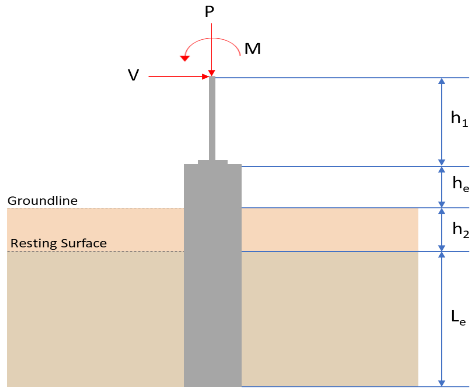
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 6.5\ \text{ft}$ - 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)	10.779	17.247
V_x (kip)	-2.407	-4.030
V_z (kip)	0.027	0.046
M_x (kipft)	0.095	0.164
M_z (kipft)	28.733	49.184

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.407\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.38328\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.733 \text{ kipft}) + ((-2.407 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.5753 \text{ kipft/ft}$$

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:
$L_{e,x} = 6.0908 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.027 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0042994 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.095 \text{ kipft}) + ((0.027 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.015127 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.1463 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.0908 \text{ ft}), (1.1463 \text{ ft})]$$

$$L_{e,req} = 6.091 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.091 \text{ ft})}{(6.5 \text{ ft})}$$

$$Ratio = 0.93708$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(10.779 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.67369 \text{ kip/ft}^2$$

$q = 0.67369\ \mathrm{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.67369\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.33684$$

Status: **PASS**
Ratio: **0.340**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.38328\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.5753\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5753\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.38328\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (4.5753\ \mathrm{kipft/ft})) + (4 \times (-0.38328\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.4776\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.5753\ \mathrm{kipft/ft})) + (3 \times (-0.38328\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\ 2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (4.5753\ \mathrm{kipft/ft})) + (2 \times (-0.38328\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.23801\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.5753\ \mathrm{kipft/ft})) + ((-0.38328\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.9457\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4776\ \mathrm{ft})}{2}$$

$$p_a = 0.33582\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.23801\ \mathrm{kip/ft^2})}{(0.33582\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.70875$$

Status: **PASS**
Ratio: **0.710**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (6.5\ \text{ft})$$

$$p_s = 0.975\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.9457\ \text{kip/ft}^2\right)}{\left(0.975\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.96995$$

Status: PASS
Ratio: 0.970

Considering z-direction:

$H_o = 0.0042994\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.015127\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.015127\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (0.0042994\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (0.015127\ \text{kipft/ft})) + (4 \times (0.0042994\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.6323\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.015127\ \text{kipft/ft})) + (3 \times (0.0042994\ \text{kip/ft}) \times (6.5\ \text{ft}))]^{\,2}}{(6.5\ \text{ft})^2 \times [(3 \times (0.015127\ \text{kipft/ft})) + (2 \times (0.0042994\ \text{kip/ft}) \times (6.5\ \text{ft}))]}$$

$$p = 0.0036522\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.015127\ \text{kipft/ft})) + ((0.0042994\ \text{kip/ft}) \times (6.5\ \text{ft}))]}{(6.5\ \text{ft})^2}$$

$$s = 0.0082652\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.6323\ \text{ft})}{2}$$

$$p_a = 0.34742\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0036522\ \text{kip/ft}^2\right)}{\left(0.34742\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.010512$$

Status: PASS
Ratio: 0.010

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (6.5\ \text{ft})$$

$$p_s = 0.975\ \text{kip/ft}^2$$

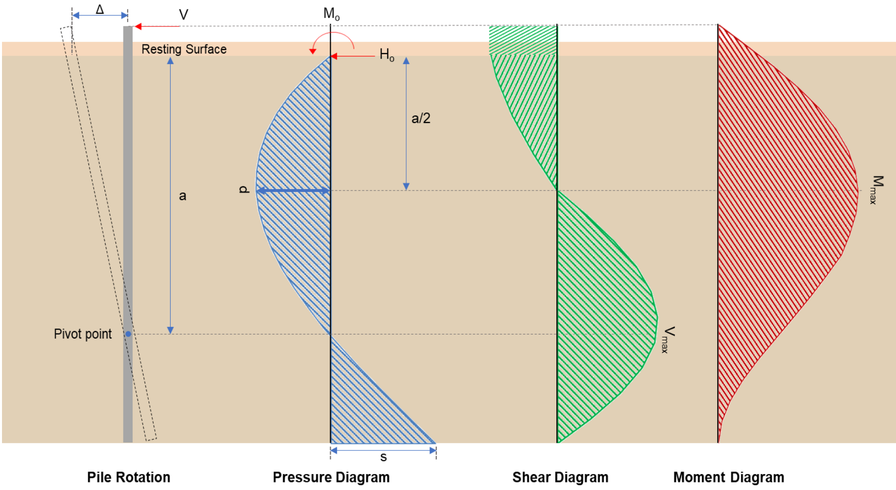
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0082652\ \text{kip/ft}^2)}{(0.975\ \text{kip/ft}^2)}$$

$$Ratio = 0.0084771$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.03\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.64172\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(49.184\ \text{kipft}) + ((-4.03\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 7.8318\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.8318\ \text{kipft/ft})}{(-0.64172\ \text{kip/ft})}$$

$$E = 12.204\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.8318\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.64172\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (7.8318\ \text{kipft/ft})) + (4 \times (-0.64172\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4753\ \text{ft}$$

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

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

$$V_{max} = ((-0.64172\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.204\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4753\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.204\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4753\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 10.222\ \text{kip}$$

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

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

$$M_{max} = ((-0.64172\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(12.204\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.4753\ \text{ft})}{2 \times (6.5\ \text{ft})} \right) - \left[\left(\frac{4 \times (12.204\ \text{ft})}{(6.5\ \text{ft})} + 3 \right) \times \left(\frac{(4.4753\ \text{ft})}{2 \times (6.5\ \text{ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.204\ \text{ft})}{(6.5\ \text{ft})} + 2 \right) \times \left(\frac{(4.4753\ \text{ft})}{2 \times (6.5\ \text{ft})} \right)^4 \right] \right]$$

$$M_{max} = 31.705\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.046\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0073248\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.164\ \text{kipft}) + ((0.046\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.026115\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.026115\ \text{kipft/ft})}{(0.0073248\ \text{kip/ft})}$$

$$E = 3.5652\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.026115\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (0.0073248\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (0.026115\ \text{kipft/ft})) + (4 \times (0.0073248\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.6305\ \text{ft}$$

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

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

$$V_{max} = ((0.0073248\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5652\ \text{ft})}{(6.5\ \text{ft})} + 3 \right) \times \left(\frac{(4.6305\ \text{ft})}{(6.5\ \text{ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.5652\ \text{ft})}{(6.5\ \text{ft})} + 2 \right) \times \left(\frac{(4.6305\ \text{ft})}{(6.5\ \text{ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.047931\ \text{kip}$$

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

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

$$M_{max} = ((0.0073248\ \text{kip/ft}) \times (48\ \text{in}) \times (6.5\ \text{ft})) \times \left[\left(\frac{(3.5652\ \text{ft})}{(6.5\ \text{ft})} + \frac{(4.6305\ \text{ft})}{2 \times (6.5\ \text{ft})} \right) - \left[\left(\frac{4 \times (3.5652\ \text{ft})}{(6.5\ \text{ft})} + 3 \right) \times \left(\frac{(4.6305\ \text{ft})}{2 \times (6.5\ \text{ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.5652\ \text{ft})}{(6.5\ \text{ft})} + 2 \right) \times \left(\frac{(4.6305\ \text{ft})}{2 \times (6.5\ \text{ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.13877 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(17.247\text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\text{ ksi}) \times \left(2304\text{ in}^2\right)\right)}{(60\text{ ksi}) - (0.85 \times (2.5\text{ ksi}))}, \left(0.08 \times \left(2304\text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.023 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.023\text{ in}^2\right), \left(0.0018 \times \left(2304\text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

	Ties: **#3(0.375 in) - 10 in**	
	Axial Compression Strength (ACI 318-19, LRFD)	
22.4.2.2	ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\ 0.80\ \left[\left(0.85\ f'_{ck}\ \left[A_g - A_{st}\right]\right) + \left(f_{yk}\ A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \text{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(17.247\ \text{kip})}{(2675.2\ \text{kip})}$$ $$Ratio = 0.006447$$	Status: **PASS** Ratio: **0.010**
	Shear Strength (ACI 318-19, LRFD) **Parameters:** $b_w = 48\ \text{in}$ - Effective width,	
22.5.2.2	d - Effective depth $$d = 0.80\ D$$ $$d = 0.80 \times (48\ \text{in})$$ $$d = 38.4\ \text{in}$$	
22.5.5.1.3	λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(38.4\ \text{in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\ \lambda_s\ \sqrt{f'_{ck}}\ b_w\ d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,max} = 296.21\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 17.247\ \text{kip} \rightarrow 17247\ \text{lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \frac{P}{6\ A_g}\right]\ b_w\ d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(17247\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,a} = 120.78\ \text{kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\ \lambda_s\ \sqrt{f'_{ck}} + \left(0.05\ f'_{ck}\right)\right]\ b_w\ d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{c,b} = 348.89\ \text{kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\ \text{kip}), (120.78\ \text{kip}), (348.89\ \text{kip})\right]$$ $$V_c = 120.78\ \text{kip}$$	

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 737.28\ \text{kip}$$	
	A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times (0.11045\ \text{in}^2) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$	
	V_s - Governing shear strength of steel $$V_s = MIN\,[V_{s,a}, V_{s,b}]$$ $$V_s = MIN\,[(737.28\ \text{kip}), (50.894\ \text{kip})]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((120.78\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 111.59\ \text{kip}$$	
	Considering x-direction: $V_{max} = 10.222\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(10.222\ \text{kip})}{(111.59\ \text{kip})}$$ $$Ratio = 0.091603$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $V_{max} = 0.047931\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.047931\ \text{kip})}{(111.59\ \text{kip})}$$ $$Ratio = 0.00042952$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$	

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 31.705 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(31.705 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.12702$$	Status: **PASS** Ratio: **0.130**
	Considering z-direction: $M_{max} = 0.13877 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.13877 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.00055596$$	Status: **PASS** Ratio: **0.000**