Your Project Calculations

Project Name: PopeDouglasSWM-RevA

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=PopeDouglasSWM-RevA&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/4_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=iUbOKJDFOLJ1eBMuAj2K4t3FCU2ClZahg2dAn84slUGF1RSVTPFgUvwgbHpCNTlj

Array Specification

Product:	Beam
Unique ID:	5P-22.5-8TOP-XD-57-L-4Hx16W-FCI5
Duty Classification:	XD
Module Width:	44.65 in
Module Length:	80.00in
Number of Rows:	4
Number of Columns:	16
Total Number of Modules:	64
Desired Tilt Angle:	28
Front Edge Clearance:	8
Total Array Height at Tilt:	15.03 ft
Total Frame Length:	107.00 ft
Frame Weight:	5579 lbs
Array Dimensions N/S:	15.05 ft
Array Dimensions E/W:	108.00 ft
Rail Length:	180.60 in
Rail Spacing:	3.33 ft
Rail Check:	Not Checked

Support Specifications

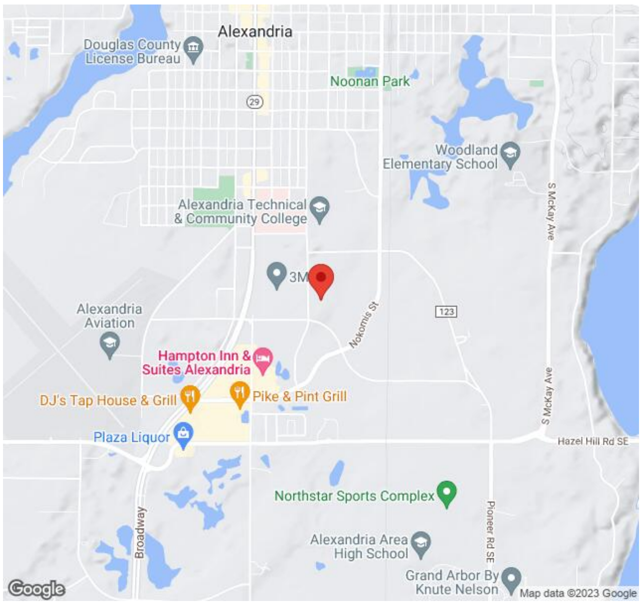
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	11.53 ft
Number of Poles:	5
Pole Spacing:	22.5 ft

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:	0.379605 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	2115 Jefferson St, Alexandria, MN 56308, USA
Wind Speed:	105 mph
Snow Load:	50 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.023092 ksf



Design Disclaimer

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

AutoDesigner Input

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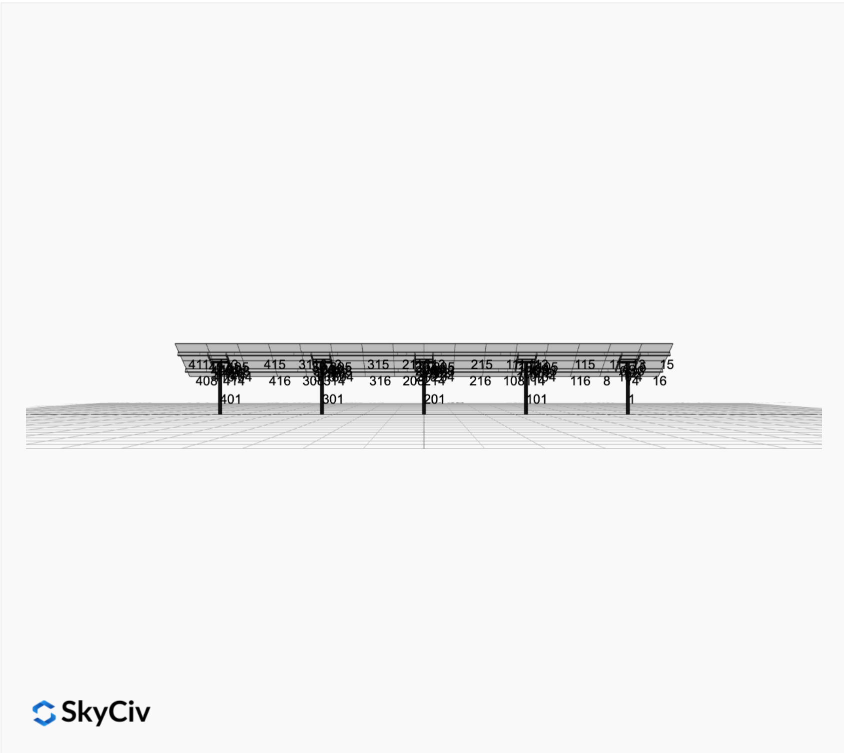
Design Notes:

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

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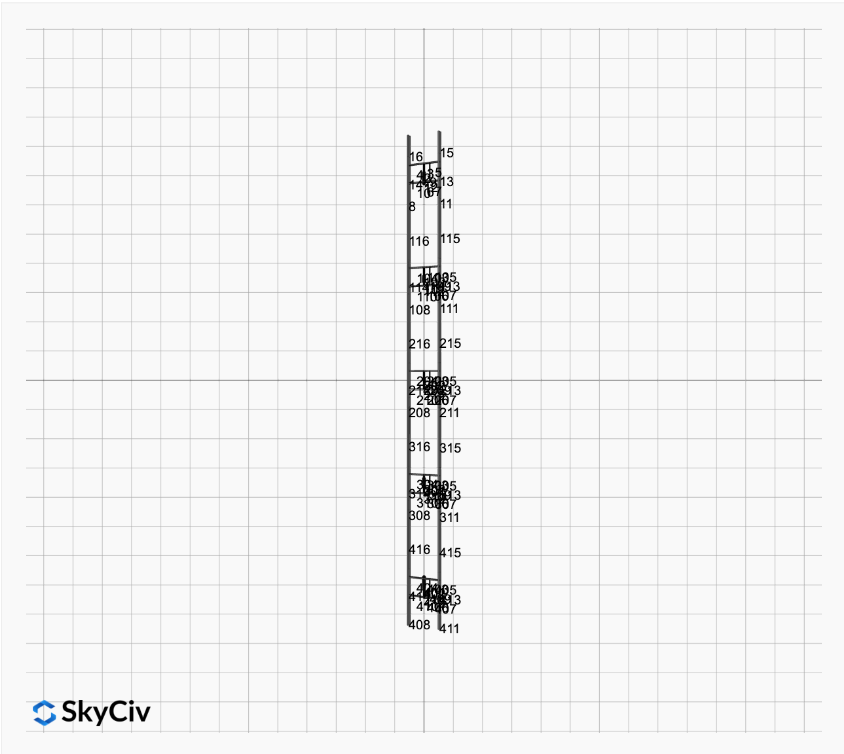
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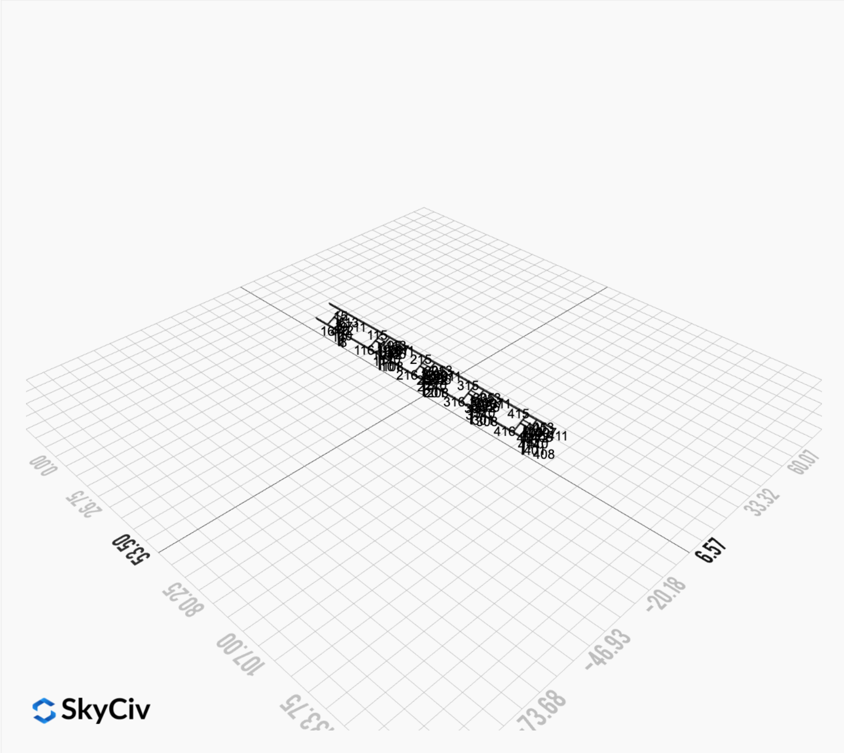
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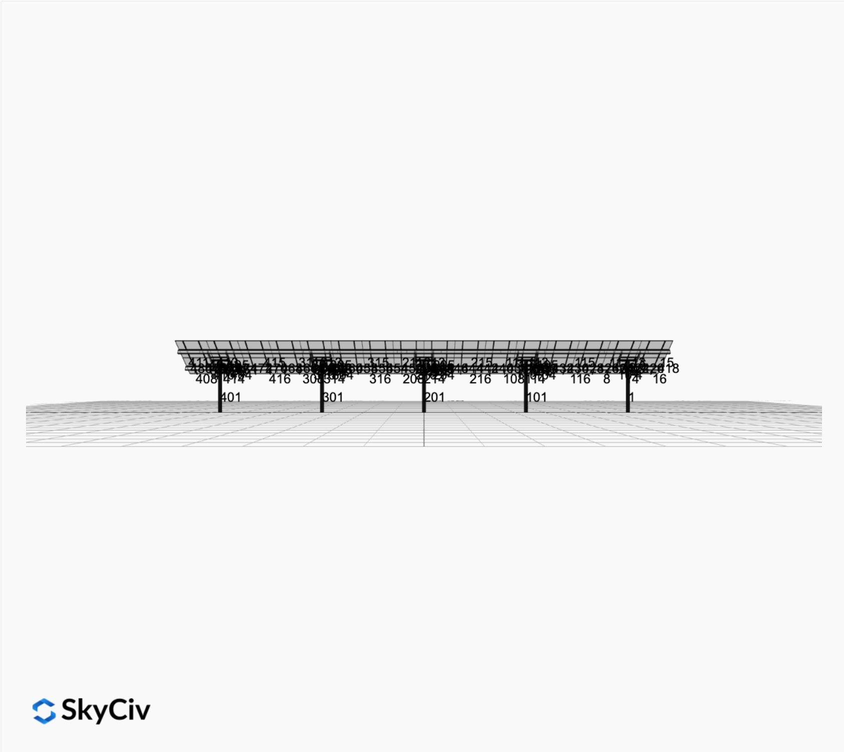
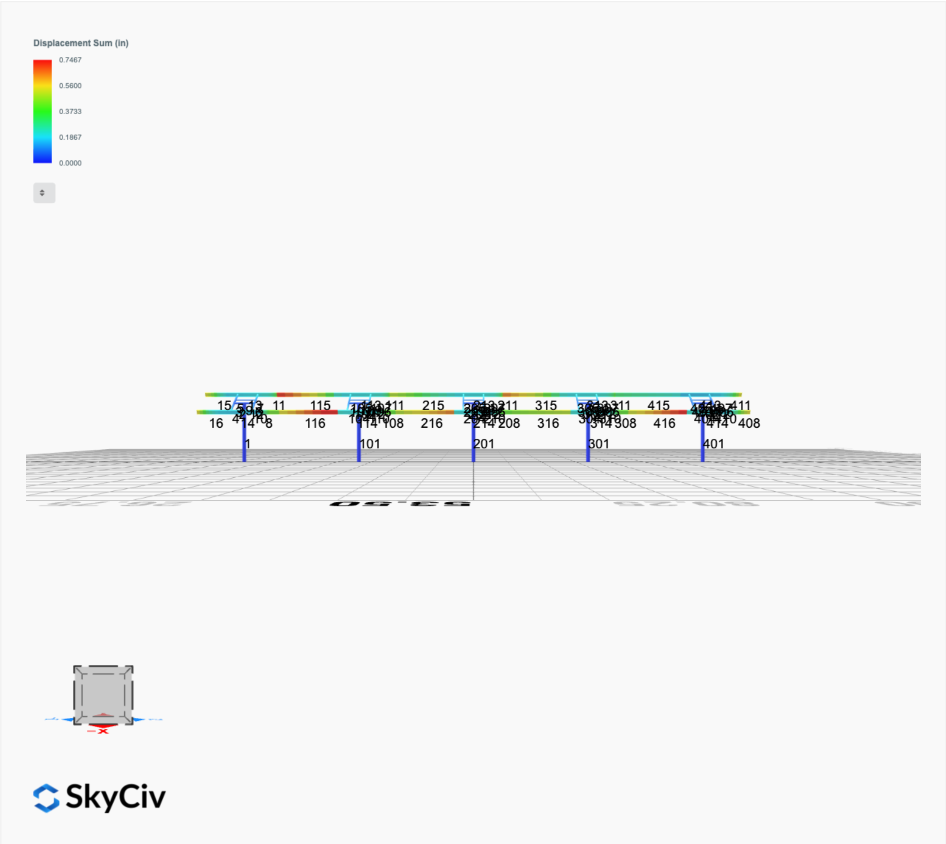
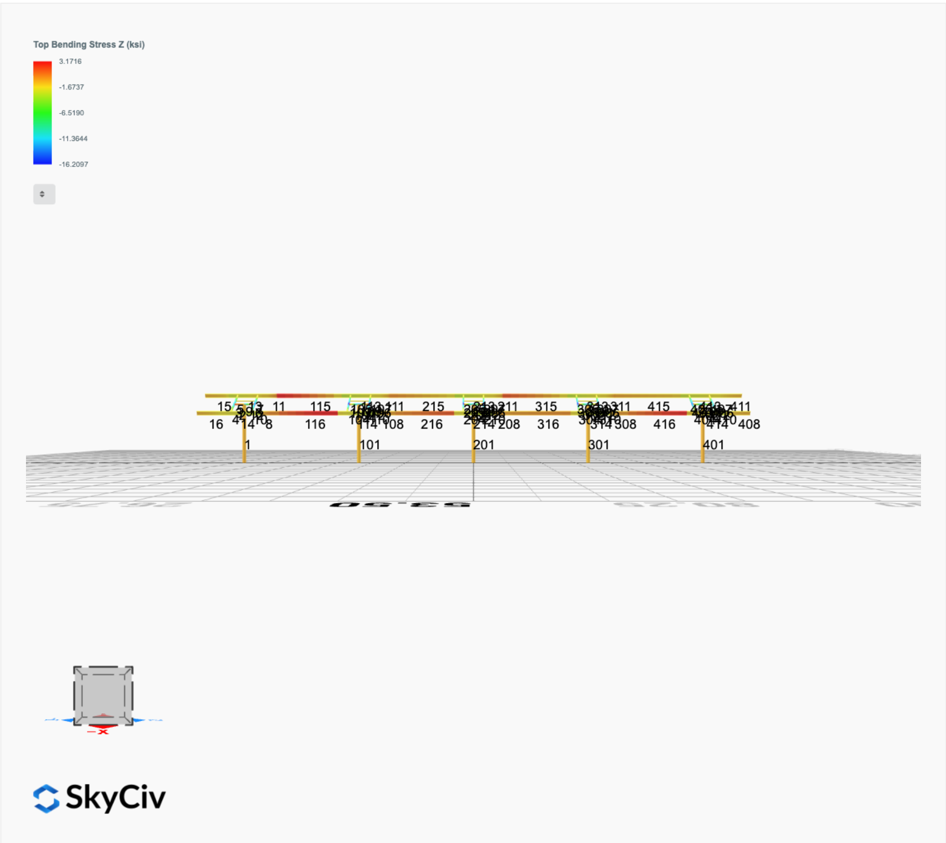
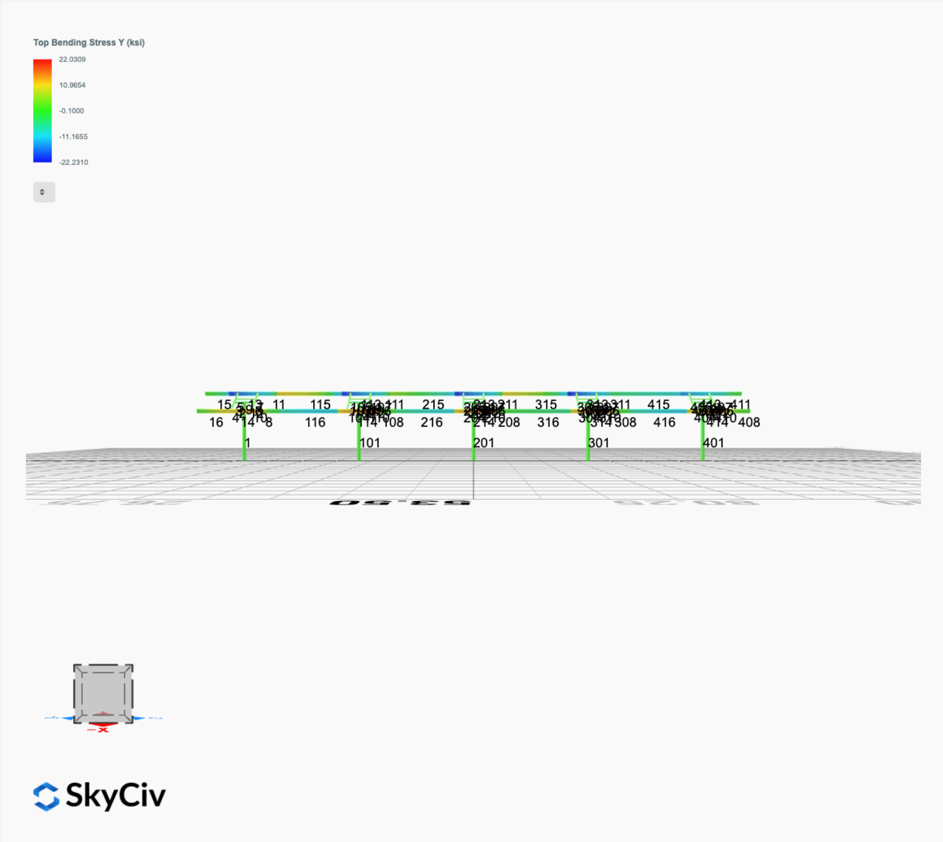
80.25
107.00
60.07
33.32
6.57
-20.18
-46.93
-73.68
SkyCiv

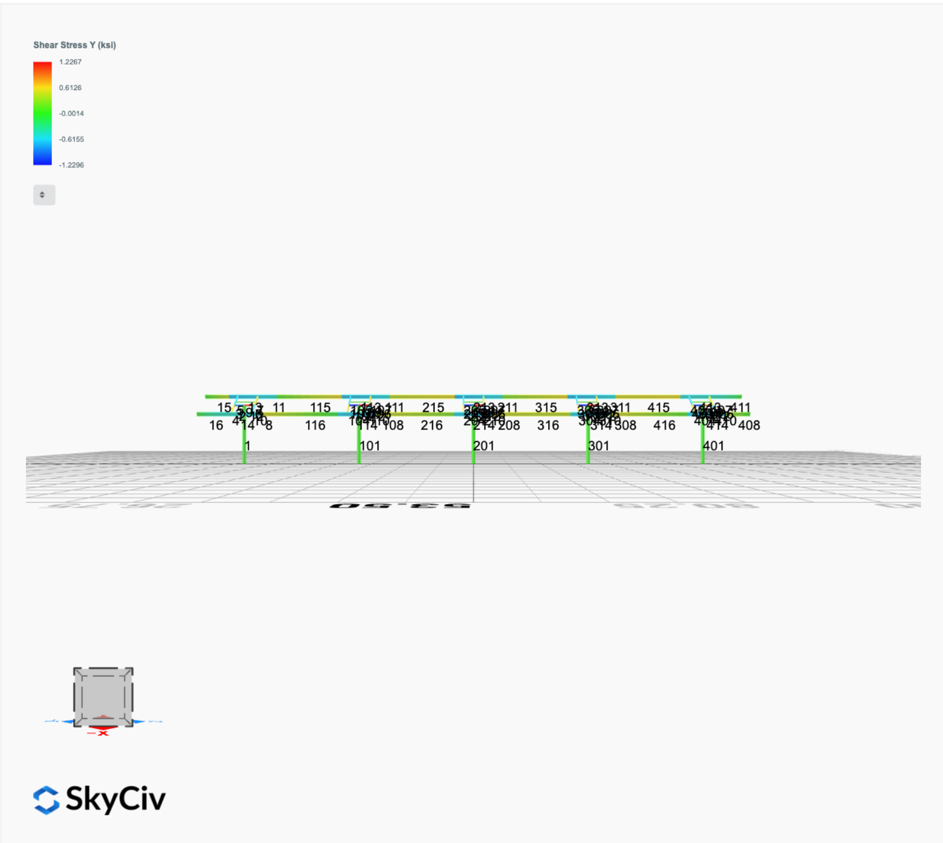

SkyCiv

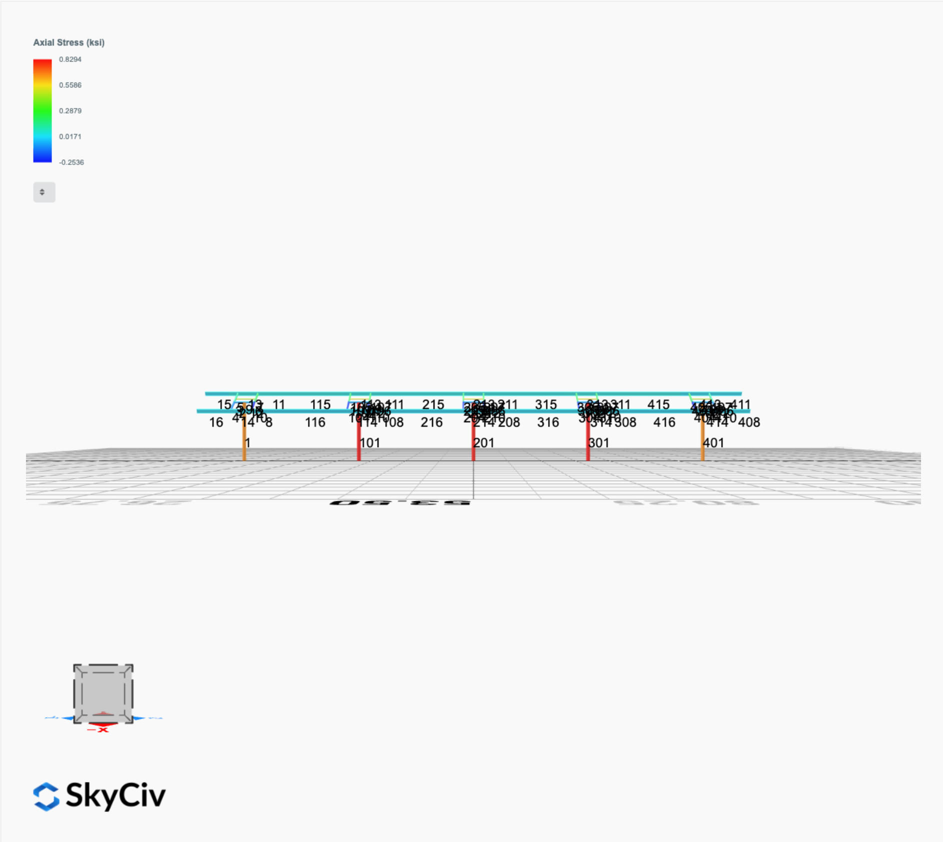
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
22.0309
10.9654
-0.1000
-11.1655
-22.2310
15
11
115
215
315
415
16
116
216
316
416
408
1
101
201
301
401
SkyCiv


Shear Stress Y (ksi)
1.2267
0.6126
-0.0014
-0.6155
-1.2296
15
11
115
215
315
415
16
116
216
316
416
408
1
101
201
301
401
SkyCiv


Axial Stress (ksi)
0.8294
0.5586
0.2879
0.0171
-0.2536
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	0.0078	2.4335	0.0379	0.1328	0.0352	-0.0548
ULS: 2. D + L	0.0078	2.4335	0.0379	0.1328	0.0352	-0.0548
ULS: 3. D + (S or Lr or R)	0.0336	8.4289	0.1628	0.5720	0.1492	-0.3056
ULS: 3. D + (S or Lr or R)	0.0078	2.4335	0.0379	0.1328	0.0352	-0.0548
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0272	6.9301	0.1316	0.4622	0.1207	-0.2429
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0078	2.4335	0.0379	0.1328	0.0352	-0.0548
ULS: 5b. D + 0.7E	0.0078	2.4335	0.0379	0.1328	0.0352	-0.0548
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0272	6.9301	0.1316	0.4622	0.1207	-0.2429
ULS: 8. 0.6D + 0.7E	0.0047	1.4601	0.0227	0.0797	0.0211	-0.0329
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.8735	5.9469	0.1258	0.4301	-0.1534	22.2302
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.8735	5.9469	0.1258	0.4301	-0.1534	22.2302
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6315	-0.6002	-0.0360	-0.1163	0.1933	-18.4686
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.3849	-0.1285	-0.0355	-0.1138	0.1963	-23.2441
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3838	9.5651	0.1975	0.6852	-0.0207	16.4708
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3838	9.5651	0.1975	0.6852	-0.0207	16.4708
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2449	4.6548	0.0762	0.2754	0.2393	-14.0533
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0599	5.0086	0.0765	0.2773	0.2416	-17.6349
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4031	5.0686	0.1038	0.3558	-0.1063	16.6590
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4031	5.0686	0.1038	0.3558	-0.1063	16.6590
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2256	0.1582	-0.0175	-0.0540	0.1537	-13.8651
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0406	0.5120	-0.0172	-0.0521	0.1561	-17.4468
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8766	4.9735	0.1107	0.3770	-0.1675	22.2521
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.8766	4.9735	0.1107	0.3770	-0.1675	22.2521
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6283	-1.5736	-0.0511	-0.1694	0.1792	-18.4467
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3817	-1.1019	-0.0507	-0.1669	0.1823	-23.2222

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	15.4417
Shear X	-3.1355
Shear Z	0.3217
Moment X	1.1247
Moment Y (Twist)	0.3710
Moment Z	39.6937

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	9.5651
Shear X	-1.8766
Shear Z	0.1975
Moment X	0.6852
Moment Y (Twist)	0.2416
Moment Z	23.2441

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	-0.0078	2.7302	-0.0001	0.0003	0.0305	0.1112
ULS: 2. D + L	-0.0078	2.7302	-0.0001	0.0003	0.0305	0.1112
ULS: 3. D + (S or Lr or R)	-0.0335	9.6964	-0.0005	0.0014	0.1304	0.4189
ULS: 3. D + (S or Lr or R)	-0.0078	2.7302	-0.0001	0.0003	0.0305	0.1112
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0271	7.9549	-0.0004	0.0011	0.1054	0.3420
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0078	2.7302	-0.0001	0.0003	0.0305	0.1112
ULS: 5b. D + 0.7E	-0.0078	2.7302	-0.0001	0.0003	0.0305	0.1112

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0271	7.9549	-0.0004	0.0011	0.1054	0.3420
ULS: 8. 0.6D + 0.7E	-0.0047	1.6381	-0.0001	0.0002	0.0183	0.0667
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1622	6.8046	0.0044	0.0162	0.0101	25.4859
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1622	6.8046	0.0044	0.0162	0.0101	25.4859
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8547	-0.7909	-0.0028	-0.0094	0.0449	-20.7966
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5509	-0.2256	-0.0091	-0.0296	0.0616	-25.9671
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6429	11.0107	0.0030	0.0130	0.0901	19.3731
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6429	11.0107	0.0030	0.0130	0.0901	19.3731
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3698	5.3141	-0.0024	-0.0062	0.1162	-15.3388
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1419	5.7381	-0.0071	-0.0213	0.1288	-19.2167
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6236	5.7860	0.0033	0.0122	0.0152	19.1422
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6236	5.7860	0.0033	0.0122	0.0152	19.1422
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3891	0.0894	-0.0021	-0.0069	0.0413	-15.5696
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1612	0.5134	-0.0068	-0.0221	0.0538	-19.4476
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1591	5.7125	0.0044	0.0161	-0.0022	25.4414
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.1591	5.7125	0.0044	0.0161	-0.0022	25.4414
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8578	-1.8830	-0.0028	-0.0095	0.0327	-20.8410
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5540	-1.3176	-0.0090	-0.0297	0.0494	-26.0116

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	17.8157
Shear X	-3.6113
Shear Z	-0.0165
Moment X	-0.0531
Moment Y (Twist)	0.2268
Moment Z	44.2199

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	11.0107
Shear X	-2.1622
Shear Z	-0.0091
Moment X	-0.0297
Moment Y (Twist)	0.1304
Moment Z	26.0116

Reaction Forces for Foundation 3 (Node ID#201), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0002	2.7135	0.0017	0.0075	-0.0017	0.0426
ULS: 2. D + L	-0.0002	2.7135	0.0017	0.0075	-0.0017	0.0426
ULS: 3. D + (S or Lr or R)	-0.0008	9.6249	0.0072	0.0319	-0.0070	0.1238
ULS: 3. D + (S or Lr or R)	-0.0002	2.7135	0.0017	0.0075	-0.0017	0.0426
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0006	7.8971	0.0058	0.0258	-0.0057	0.1035
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0002	2.7135	0.0017	0.0075	-0.0017	0.0426
ULS: 5b. D + 0.7E	-0.0002	2.7135	0.0017	0.0075	-0.0017	0.0426
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0006	7.8971	0.0058	0.0258	-0.0057	0.1035
ULS: 8. 0.6D + 0.7E	-0.0001	1.6281	0.0010	0.0045	-0.0010	0.0255
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1592	6.7786	0.0056	0.0242	-0.0071	25.6310
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1592	6.7786	0.0056	0.0242	-0.0071	25.6310
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8645	-0.7967	-0.0017	-0.0068	0.0031	-21.0128
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5718	-0.2500	-0.0012	-0.0046	0.0021	-26.3754
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6199	10.9458	0.0088	0.0383	-0.0098	19.2948
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6199	10.9458	0.0088	0.0383	-0.0098	19.2948
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3979	5.2644	0.0033	0.0151	-0.0021	-15.6881
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1784	5.6744	0.0036	0.0168	-0.0028	-19.7100

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	-1.6194	5.7623	0.0047	0.0200	-0.0058	19.2339
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6194	5.7623	0.0047	0.0200	-0.0058	19.2339
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3984	0.0808	-0.0008	-0.0032	0.0019	-15.7490
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1788	0.4909	-0.0005	-0.0016	0.0012	-19.7709
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1591	5.6931	0.0050	0.0212	-0.0065	25.6140
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.1591	5.6931	0.0050	0.0212	-0.0065	25.6140
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8646	-1.8821	-0.0024	-0.0098	0.0037	-21.0299
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5719	-1.3354	-0.0019	-0.0076	0.0028	-26.3924

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	17.7036
Shear X	-3.5992
Shear Z	0.0142
Moment X	0.0628
Moment Y (Twist)	0.0150
Moment Z	45.0198

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	10.9458
Shear X	-2.1592
Shear Z	0.0088
Moment X	0.0383
Moment Y (Twist)	0.0098
Moment Z	26.3924

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	-0.0075	2.7296	-0.0006	0.0007	-0.0270	0.1077
ULS: 2. D + L	-0.0075	2.7296	-0.0006	0.0007	-0.0270	0.1077
ULS: 3. D + (S or Lr or R)	-0.0321	9.6939	-0.0025	0.0033	-0.1154	0.4041
ULS: 3. D + (S or Lr or R)	-0.0075	2.7296	-0.0006	0.0007	-0.0270	0.1077
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0260	7.9528	-0.0020	0.0027	-0.0933	0.3300
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0075	2.7296	-0.0006	0.0007	-0.0270	0.1077
ULS: 5b. D + 0.7E	-0.0075	2.7296	-0.0006	0.0007	-0.0270	0.1077
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0260	7.9528	-0.0020	0.0027	-0.0933	0.3300
ULS: 8. 0.6D + 0.7E	-0.0045	1.6378	-0.0004	0.0004	-0.0162	0.0646
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1612	6.8026	-0.0073	-0.0160	0.0024	25.4756
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1612	6.8026	-0.0073	-0.0160	0.0024	25.4756
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8544	-0.7903	0.0039	0.0112	-0.0490	-20.7945
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5506	-0.2251	0.0101	0.0323	-0.0656	-25.9616
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6412	11.0076	-0.0070	-0.0099	-0.0713	19.3559
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6412	11.0076	-0.0070	-0.0099	-0.0713	19.3559
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3705	5.3129	0.0014	0.0105	-0.1098	-15.3466
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1426	5.7368	0.0060	0.0263	-0.1222	-19.2220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6228	5.7844	-0.0056	-0.0118	-0.0050	19.1336
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6228	5.7844	-0.0056	-0.0118	-0.0050	19.1336
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3889	0.0897	0.0028	0.0085	-0.0435	-15.5689
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1611	0.5136	0.0074	0.0244	-0.0559	-19.4442
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.1582	5.7108	-0.0070	-0.0163	0.0132	25.4325
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.1582	5.7108	-0.0070	-0.0163	0.0132	25.4325
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8574	-1.8821	0.0042	0.0109	-0.0382	-20.8375
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5536	-1.3169	0.0103	0.0320	-0.0548	-26.0046

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	17.8108
Shear X	-3.6093
Shear Z	0.0178
Moment X	0.0592
Moment Y (Twist)	0.2103
Moment Z	44.2141

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	11.0076
Shear X	-2.1612
Shear Z	0.0103
Moment X	0.0323
Moment Y (Twist)	0.1222
Moment Z	26.0046

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	0.0077	2.4340	-0.0389	-0.1327	-0.0358	-0.0528
ULS: 2. D + L	0.0077	2.4340	-0.0389	-0.1327	-0.0358	-0.0528
ULS: 3. D + (S or Lr or R)	0.0328	8.4311	-0.1670	-0.5716	-0.1518	-0.2971
ULS: 3. D + (S or Lr or R)	0.0077	2.4340	-0.0389	-0.1327	-0.0358	-0.0528
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0265	6.9318	-0.1350	-0.4618	-0.1228	-0.2360
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0077	2.4340	-0.0389	-0.1327	-0.0358	-0.0528
ULS: 5b. D + 0.7E	0.0077	2.4340	-0.0389	-0.1327	-0.0358	-0.0528
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0265	6.9318	-0.1350	-0.4618	-0.1228	-0.2360
ULS: 8. 0.6D + 0.7E	0.0046	1.4604	-0.0233	-0.0796	-0.0215	-0.0317
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.8743	5.9485	-0.1286	-0.4297	0.1590	22.2377
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.8743	5.9485	-0.1286	-0.4297	0.1590	22.2377
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6318	-0.6006	0.0365	0.1162	-0.1994	-18.4716
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.3852	-0.1288	0.0357	0.1140	-0.2012	-23.2347
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3850	9.5677	-0.2022	-0.6846	0.0232	16.4819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.3850	9.5677	-0.2022	-0.6846	0.0232	16.4819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2446	4.6558	-0.0784	-0.2752	-0.2455	-14.0501
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0596	5.0097	-0.0790	-0.2768	-0.2469	-17.6224
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.4038	5.0699	-0.1062	-0.3554	0.1103	16.6651
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.4038	5.0699	-0.1062	-0.3554	0.1103	16.6651
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2258	0.1581	0.0177	0.0540	-0.1585	-13.8669
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0408	0.5119	0.0171	0.0523	-0.1599	-17.4392
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8773	4.9749	-0.1130	-0.3766	0.1733	22.2588
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.8773	4.9749	-0.1130	-0.3766	0.1733	22.2588
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6287	-1.5742	0.0521	0.1693	-0.1851	-18.4504
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.3821	-1.1024	0.0513	0.1670	-0.1869	-23.2136

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	15.4458
Shear X	-3.1366
Shear Z	-0.3295
Moment X	-1.1228
Moment Y (Twist)	0.3796
Moment Z	39.6758

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	9.5677
Shear X	-1.8773
Shear Z	-0.2022
Moment X	-0.6846
Moment Y (Twist)	0.2469
Moment Z	23.2347

Project Details

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

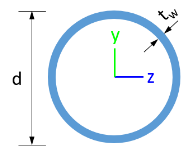
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

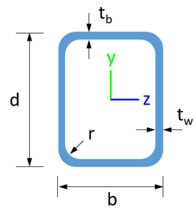
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

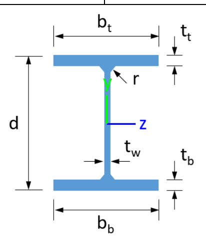
Section Dimensions



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	62.42	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	24.22	24.22	11.53	-	300	200	1
2	6	0.22	0.22	0.33	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.16,1.18,1.18,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.74,1.67,1.67,1.67,1.67,1.68,1.68,1.61,1.70,1.67,1.67,1.66,1.89	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	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.67,1.67	300	200	1
8	20	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.09,2.09,1.98,2.21,2.09,2.09,2.09,1.62,2.10,2.10,2.10,2.11,2.09,2.09,2.09,2.08,2.36,2.09,2.09,2.09,1.07	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.66,1.76,1.67,1.67,1.68,1.67,1.68,1.68,1.62,1.70,1.67,1.67,1.66,1.20	300	200	1
11	20	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.12,2.12,2.30,2.33,2.12,2.12,2.13,2.16,2.11,2.11,2.10,2.08,2.12,2.12,2.12,2.32,2.36,2.12,2.12,2.13,2.15	300	200	1
12	6	1.30	1.30	2.00	-	300	200	1
13	20	1.14	1.14	1.75	1.45,1.45,1.45,1.44,1.45,1.45,1.43,1.43,1.37,1.38,1.43,1.43,1.42,1.40,1.44,1.44,1.45,1.47,1.43,1.43,1.39,1.39,1.43,1.43,1.42,1.41	300	200	1
14	20	1.14	1.14	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
15	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
17	20	2.60	2.60	4.00	1.12,1.12,1.12,1.12,1.12,1.12,1.11,1.11,1.08,1.12,1.11,1.11,1.11,1.12,1.11,1.11,1.12,1.12,1.11,1.11,1.10,1.12,1.11,1.11,1.11,1.12	300	200	1
18	20	1.14	1.14	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
19	20	2.60	2.60	4.00	1.11,1.12,1.11,1.12,1.12,1.11,1.12,1.12,1.12,1.16,1.12,1.12,1.12,1.70,1.12,1.12,1.12,1.12,1.12,1.12,1.12,1.17,1.12,1.12,1.12,1.30	300	200	1
20	20	1.14	1.14	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.46,1.46,1.52,1.40,1.46,1.46,1.47,1.26,1.46,1.46,1.45,1.44,1.46,1.46,1.49,1.39,1.46,1.46,1.47,1.05	300	200	1
21	20	2.60	2.60	4.00	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.12,1.11,1.07,1.07,1.07,1.08,1.06,1.06,1.06,1.05,1.07,1.07,1.09,1.10,1.07,1.07,1.07,1.08	300	200	1
22	20	1.14	1.14	1.75	1.36,1.36,1.36,1.36,1.36,1.36,1.38,1.38,1.76,1.49,1.39,1.39,1.42,1.42,1.37,1.37,1.35,1.34,1.38,1.38,1.52,1.46,1.39,1.39,1.41,1.42	300	200	1
23	20	2.60	2.60	4.00	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.06,1.06,1.06,1.11,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.06,1.06,1.06,1.03	300	200	1

24	20	1.14	1.14	1.75	1.34,1.33,1.34,1.33,1.34,1.34,1.34,1.34,1.35,1.34,1.34,1.34,1.34,1.38,1.34,1.34,1.33,1.34,1.34,1.34,1.34,1.34,1.34,1.34,1.34,1.13	300	200	1
25	20	2.60	2.60	4.00	1.05,1.05,1.05,1.06,1.05,1.05,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.05,1.05,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06	300	200	1
26	20	1.14	1.14	1.75	1.33,1.33,1.33,1.33,1.33,1.33,1.34,1.34,1.38,1.35,1.34,1.34,1.34,1.34,1.33,1.33,1.33,1.33,1.34,1.34,1.36,1.34,1.34,1.34,1.34,1.34	300	200	1
27	20	2.60	2.60	4.00	1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.31,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.06,1.05,1.05,1.05,1.01	300	200	1
28	20	1.14	1.14	1.75	1.33,1.33,1.33,1.33,1.33,1.33,1.33,1.33,1.32,1.33,1.33,1.33,1.33,1.31,1.33,1.33,1.33,1.33,1.33,1.33,1.32,1.33,1.33,1.33,1.33,1.05	300	200	1
29	20	2.60	2.60	4.00	1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.13,1.11,1.07,1.07,1.08,1.08,1.07,1.07,1.06,1.05,1.07,1.07,1.10,1.10,1.07,1.07,1.07,1.08	300	200	1
30	20	1.14	1.14	1.75	1.34,1.34,1.34,1.34,1.34,1.34,1.35,1.35,1.50,1.40,1.35,1.35,1.37,1.37,1.34,1.34,1.33,1.32,1.35,1.35,1.42,1.39,1.36,1.36,1.37,1.37	300	200	1
31	20	2.60	2.60	4.00	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.07,1.06,1.06,1.07,1.09,1.06,1.06,1.06,1.06,1.06,1.06,1.07,1.07,1.06,1.06,1.06,1.03	300	200	1
32	20	1.14	1.14	1.75	1.36,1.35,1.36,1.35,1.35,1.36,1.36,1.36,1.36,1.37,1.36,1.36,1.36,1.61,1.35,1.35,1.35,1.36,1.36,1.36,1.36,1.38,1.36,1.36,1.36,1.12	300	200	1
33	20	2.60	2.60	4.00	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.08,1.12,1.11,1.11,1.10,1.12,1.11,1.11,1.12,1.11,1.11,1.11,1.09,1.12,1.11,1.11,1.11,1.12	300	200	1
34	20	1.14	1.14	1.75	1.44,1.44,1.44,1.44,1.44,1.44,1.43,1.43,1.37,1.38,1.43,1.43,1.42,1.40,1.44,1.44,1.45,1.47,1.43,1.43,1.39,1.38,1.43,1.43,1.42,1.40	300	200	1
35	20	2.60	2.60	4.00	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.16,1.11,1.11,1.11,1.69,1.11,1.11,1.11,1.12,1.11,1.11,1.12,1.17,1.11,1.11,1.11,1.30	300	200	1
36	20	1.14	1.14	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
37	20	4.60	4.60	7.08	1.58,1.58,1.58,1.58,1.58,1.58,1.58,1.58,1.58,1.53,1.58,1.58,1.58,1.28,1.58,1.58,1.58,1.58,1.58,1.58,1.58,1.52,1.58,1.58,1.58,2.21	300	200	1
38	20	4.33	4.33	6.67	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.07,1.07,1.07,1.09,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.07,1.07,1.07,1.51	300	200	1
39	20	1.90	1.90	2.92	2.35,2.36,2.35,2.36,2.35,2.35,2.39,2.39,2.37,2.41,2.40,2.40,2.41,2.35,2.38,2.38,2.34,2.37,2.39,2.39,2.39,2.41,2.40,2.40,2.41,1.01	300	200	1
40	20	4.33	4.33	6.67	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.07,1.07,1.07,1.09,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.07,1.07,1.07,1.49	300	200	1
41	20	3.52	3.52	5.42	1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.76,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.89,1.70	300	200	1
42	20	4.33	4.33	6.67	1.20,1.20,1.20,1.20,1.20,1.20,1.19,1.19,1.17,1.23,1.19,1.19,1.19,1.54,1.19,1.19,1.20,1.20,1.19,1.19,1.18,1.24,1.19,1.19,1.19,1.40	300	200	1
43	20	0.81	0.81	1.25	2.27,2.27,2.27,2.27,2.27,2.27,2.29,2.29,2.14,2.09,2.29,2.29,2.31,1.32,2.28,2.28,2.26,2.25,2.29,2.29,2.18,1.96,2.30,2.30,2.31,1.05	300	200	1
44	6	1.08	1.08	1.67	-	300	200	1
45	6	0.22	0.22	0.33	-	300	200	1
46	20	3.81	3.81	5.87	1.14,1.14,1.14,1.14,1.14,1.14,1.15,1.15,1.22,1.19,1.15,1.15,1.16,1.17,1.14,1.14,1.13,1.12,1.15,1.15,1.19,1.18,1.15,1.15,1.16,1.16	300	200	1
47	20	2.19	2.19	3.37	1.33,1.33,1.33,1.33,1.33,1.33,1.31,1.31,1.22,1.26,1.31,1.31,1.29,1.29,1.32,1.32,1.35,1.36,1.31,1.31,1.25,1.27,1.31,1.31,1.30,1.29	300	200	1
48	20	4.33	4.33	6.67	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.07,1.07,1.07,1.08,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.07,1.07,1.07,1.08	300	200	1
49	20	0.56	0.56	0.87	1.28,1.28,1.28,1.28,1.28,1.28,1.27,1.27,1.21,1.25,1.27,1.27,1.25,1.26,1.28,1.28,1.29,1.30,1.27,1.27,1.23,1.25,1.26,1.26,1.26,1.26	300	200	1

50	20	4.33	4.33	6.67	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.07,1.07,1.08,1.08,1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.08,1.07,1.07,1.08,1.08	300	200	1
51	20	3.27	3.27	5.03	1.25,1.25,1.25,1.25,1.25,1.25,1.23,1.23,1.12,1.17,1.22,1.22,1.21,1.20,1.24,1.24,1.26,1.28,1.23,1.23,1.16,1.18,1.22,1.22,1.21,1.20	300	200	1
52	20	4.33	4.33	6.67	1.20,1.20,1.20,1.20,1.20,1.20,1.21,1.21,1.30,1.27,1.21,1.21,1.22,1.24,1.21,1.21,1.19,1.18,1.21,1.21,1.26,1.26,1.22,1.22,1.22,1.23	300	200	1
101	9	24.22	24.22	11.53	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.68,1.68,1.68,1.68,1.63,1.70,1.67,1.67,1.66,1.12	300	200	1
105	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.68,1.68,1.68,1.64,1.66,1.67,1.67,1.67,1.67	300	200	1
106	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.67,1.67	300	200	1
108	20	1.33	1.33	2.05	2.23,2.23,2.23,2.23,2.23,2.23,2.23,2.23,2.25,2.24,2.23,2.23,2.24,2.33,2.23,2.23,2.23,2.23,2.23,2.23,2.24,2.25,2.23,2.23,2.24,1.20	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.68,1.67,1.68,1.68,1.63,1.70,1.67,1.67,1.66,1.12	300	200	1
111	20	1.33	1.33	2.05	2.24,2.24,2.24,2.24,2.24,2.24,2.27,2.27,2.06,2.14,2.28,2.28,2.32,2.32,2.25,2.25,2.22,2.20,2.27,2.27,2.13,2.36,2.28,2.28,2.31,2.31	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	1.14	1.14	1.75	1.34,1.34,1.34,1.34,1.34,1.34,1.35,1.35,1.50,1.41,1.36,1.36,1.37,1.37,1.34,1.34,1.33,1.32,1.35,1.35,1.42,1.39,1.36,1.36,1.37,1.37	300	200	1
114	20	1.14	1.14	1.75	1.36,1.35,1.36,1.35,1.35,1.36,1.36,1.36,1.36,1.37,1.36,1.36,1.36,1.57,1.35,1.35,1.35,1.36,1.36,1.36,1.36,1.38,1.36,1.36,1.36,1.13	300	200	1
115	20	4.60	4.60	7.08	1.57,1.57,1.57,1.57,1.57,1.57,1.52,1.52,1.28,1.38,1.51,1.51,1.46,1.46,1.55,1.55,1.60,1.64,1.52,1.52,1.37,1.41,1.50,1.50,1.47,1.46	300	200	1
116	20	3.81	3.81	5.87	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.12,1.16,1.13,1.13,1.13,1.39,1.13,1.13,1.14,1.14,1.13,1.13,1.12,1.17,1.13,1.13,1.13,1.37	300	200	1
201	9	24.22	24.22	11.53	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.68,1.68,1.64,1.68,1.68,1.68,1.66,1.75,1.68,1.68,1.68,1.68,1.68,1.68,1.63,1.70,1.68,1.68,1.67,3.08	300	200	1
205	17	1.52	1.52	2.33	1.69,1.68,1.69,1.68,1.68,1.69,1.68,1.68,1.65,1.67,1.68,1.68,1.67,1.67,1.68,1.68,1.68,1.68,1.68,1.68,1.65,1.66,1.68,1.68,1.67,1.67	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
207	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.68,1.68,1.67,1.67,1.67,1.67,1.68,1.68,1.68,1.68,1.65,1.66,1.67,1.67,1.67,1.67	300	200	1

208	20	1.33	1.33	2.05	2.23,2.23,2.23,2.23,2.23,2.23,2.22,2.22,2.13,2.22,2.22,2.22,2.22,2.07,2.23,2.23,2.23,2.23,2.22,2.22,2.20,2.22,2.22,2.22,2.22,1.00	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.64,1.68,1.68,1.68,1.66,1.75,1.67,1.67,1.68,1.68,1.68,1.68,1.63,1.70,1.67,1.67,1.66,2.55	300	200	1
211	20	1.33	1.33	2.05	2.22,2.22,2.22,2.22,2.22,2.22,2.23,2.23,2.33,2.25,2.24,2.24,2.25,2.24,2.23,2.23,2.21,2.21,2.23,2.23,2.28,2.24,2.24,2.24,2.24,2.24	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	1.14	1.14	1.75	1.33,1.33,1.33,1.33,1.33,1.33,1.34,1.34,1.38,1.34,1.34,1.34,1.34,1.34,1.33,1.33,1.33,1.33,1.34,1.34,1.36,1.34,1.34,1.34,1.34,1.34	300	200	1
214	20	1.14	1.14	1.75	1.34,1.34,1.34,1.34,1.34,1.34,1.33,1.33,1.32,1.33,1.33,1.33,1.33,1.31,1.33,1.33,1.34,1.34,1.33,1.33,1.32,1.33,1.33,1.33,1.33,1.04	300	200	1
215	20	1.90	1.90	2.92	2.41,2.41,2.41,2.41,2.41,2.41,2.32,2.32,2.07,2.16,2.29,2.29,2.20,2.27,2.37,2.37,2.40,2.40,2.31,2.31,2.09,2.21,2.28,2.28,2.23,2.28	300	200	1
216	20	2.19	2.19	3.37	1.34,1.34,1.34,1.34,1.34,1.34,1.34,1.34,1.32,1.33,1.34,1.34,1.33,1.28,1.34,1.34,1.34,1.34,1.34,1.34,1.33,1.33,1.34,1.34,1.33,1.60	300	200	1
301	9	24.22	24.22	11.53	-	300	200	1
302	6	1.30	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.68,1.68,1.68,1.68,1.63,1.70,1.67,1.67,1.66,1.13	300	200	1
305	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.67,1.68,1.68,1.67,1.67,1.67,1.67,1.68,1.68,1.68,1.68,1.65,1.66,1.67,1.67,1.67,1.67	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.18	300	200	1
307	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.67	300	200	1
308	20	1.33	1.33	2.05	2.28,2.27,2.28,2.27,2.27,2.28,2.28,2.28,2.29,2.32,2.28,2.28,2.28,1.73,2.27,2.27,2.27,2.28,2.28,2.28,2.28,2.34,2.28,2.28,2.28,1.20	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.64,1.68,1.67,1.67,1.66,1.75,1.67,1.67,1.67,1.67,1.68,1.68,1.63,1.70,1.67,1.67,1.66,1.12	300	200	1
311	20	1.33	1.33	2.05	2.29,2.29,2.29,2.29,2.29,2.29,2.35,2.35,1.55,2.07,2.34,2.34,2.13,2.12,2.31,2.31,2.26,2.23,2.35,2.35,1.99,2.09,2.31,2.31,2.14,2.13	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	1.14	1.14	1.75	1.36,1.36,1.36,1.36,1.36,1.36,1.38,1.38,1.77,1.50,1.39,1.39,1.42,1.42,1.37,1.37,1.35,1.33,1.38,1.38,1.52,1.46,1.39,1.39,1.41,1.42	300	200	1
314	20	1.14	1.14	1.75	1.33,1.33,1.33,1.33,1.33,1.33,1.33,1.33,1.34,1.34,1.33,1.33,1.34,1.37,1.33,1.33,1.33,1.33,1.33,1.33,1.34,1.34,1.33,1.33,1.34,1.13	300	200	1
315	20	3.52	3.52	5.42	1.89,1.89,1.89,1.89,1.89,1.89,1.86,1.86,1.54,1.69,1.84,1.84,1.78,1.78,1.89,1.89,1.89,1.89,1.86,1.86,1.66,1.72,1.84,1.84,1.80,1.79	300	200	1
316	20	0.56	0.56	0.87	1.27,1.27,1.27,1.27,1.27,1.27,1.28,1.28,1.32,1.28,1.28,1.28,1.29,1.34,1.28,1.28,1.27,1.28,1.28,1.28,1.30,1.28,1.28,1.28,1.28,1.02	300	200	1
401	9	24.22	24.22	11.53	-	300	200	1
402	6	1.30	1.30	2.0		3	2	1

402	6	1.30	1.30	0	-	00	00	1
403	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.17,1.18,1.18,1.18,1.18	300	200	1
404	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.68,1.68,1.64,1.69,1.68,1.68,1.66,1.77,1.68,1.68,1.68,1.68,1.68,1.68,1.63,1.71,1.68,1.68,1.67,1.21	300	200	1
405	17	1.52	1.52	2.33	1.69,1.68,1.69,1.68,1.69,1.69,1.68,1.68,1.66,1.67,1.68,1.68,1.67,1.67,1.68,1.68,1.68,1.68,1.68,1.68,1.65,1.67,1.68,1.68,1.67,1.67	300	200	1
406	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.15,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.15,1.16,1.18,1.18,1.17,1.17	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	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	3	2.60	2.60	4.00	-	300	200	1
410	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.63,1.68,1.67,1.67,1.65,1.74,1.67,1.67,1.67,1.67,1.68,1.68,1.61,1.70,1.67,1.67,1.66,1.89	300	200	1
411	20	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
412	6	1.08	1.08	1.67	-	300	200	1
413	20	1.14	1.14	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
414	20	1.14	1.14	1.75	1.45,1.45,1.45,1.45,1.45,1.45,1.46,1.46,1.52,1.40,1.46,1.46,1.47,1.26,1.45,1.45,1.44,1.44,1.46,1.46,1.49,1.39,1.46,1.46,1.46,1.05	300	200	1
415	20	0.81	0.81	1.25	2.25,2.25,2.25,2.25,2.25,2.25,2.23,2.23,1.80,1.87,2.22,2.22,2.20,2.14,2.24,2.24,2.27,2.32,2.23,2.23,2.02,1.95,2.22,2.22,2.21,2.17	300	200	1
416	20	3.27	3.27	5.03	1.26,1.26,1.26,1.26,1.26,1.26,1.26,1.26,1.23,1.26,1.26,1.26,1.10,1.26,1.26,1.26,1.25,1.26,1.26,1.26,1.26,1.22,1.26,1.26,1.26,2.23	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	184.79	83.29	83.29	113.39	113.39
2	251.01	250.95	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	248.88	27.16	27.16	75.30	75.30
13	159.30	143.45	46.90	6.46	56.26	44.91
14	159.30	143.45	46.90	6.46	56.26	44.91
15	159.30	34.37	46.90	6.46	56.26	44.91
16	159.30	34.37	46.90	6.46	56.26	44.91
17	159.30	132.71	46.35	6.46	56.26	44.91
18	159.30	143.45	46.90	6.46	56.26	44.91
19	159.30	132.71	46.90	6.46	56.26	44.91

20	159.30	143.45	46.90	6.46	56.26	44.91
21	159.30	132.71	45.06	6.46	56.26	44.91
22	159.30	143.45	46.90	6.46	56.26	44.91
23	159.30	132.71	44.20	6.46	56.26	44.91
24	159.30	143.45	46.90	6.46	56.26	44.91
25	159.30	132.71	45.06	6.46	56.26	44.91
26	159.30	143.45	46.90	6.46	56.26	44.91
27	159.30	132.71	43.34	6.46	56.26	44.91
28	159.30	143.45	46.90	6.46	56.26	44.91
29	159.30	132.71	45.06	6.46	56.26	44.91
30	159.30	143.45	46.90	6.46	56.26	44.91
31	159.30	132.71	44.20	6.46	56.26	44.91
32	159.30	143.45	46.90	6.46	56.26	44.91
33	159.30	132.71	46.35	6.46	56.26	44.91
34	159.30	143.45	46.90	6.46	56.26	44.91
35	159.30	132.71	46.90	6.46	56.26	44.91
36	159.30	143.45	46.90	6.46	56.26	44.91
37	159.30	108.04	41.00	6.46	56.26	44.91
38	159.30	111.83	35.85	6.46	56.26	44.91
39	159.30	138.83	46.90	6.46	56.26	44.91
40	159.30	111.83	35.85	6.46	56.26	44.91
41	159.30	122.47	46.90	6.46	56.26	44.91
42	159.30	111.83	39.20	6.46	56.26	44.91
43	159.30	144.76	46.90	6.46	56.26	44.91
44	251.01	249.53	27.16	27.16	75.30	75.30
45	251.01	250.95	27.16	27.16	75.30	75.30
46	159.30	118.79	40.68	6.46	56.26	44.91
47	159.30	136.49	46.90	6.46	56.26	44.91
48	159.30	111.83	35.85	6.46	56.26	44.91
49	159.30	145.46	46.90	6.46	56.26	44.91
50	159.30	111.83	35.85	6.46	56.26	44.91
51	159.30	125.46	43.98	6.46	56.26	44.91
52	159.30	111.83	39.53	6.46	56.26	44.91
101	377.97	184.79	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	248.88	27.16	27.16	75.30	75.30
113	159.30	143.45	46.90	6.46	56.26	44.91
114	159.30	143.45	46.90	6.46	56.26	44.91
115	159.30	108.04	41.00	6.46	56.26	44.91
116	159.30	118.79	40.68	6.46	56.26	44.91
201	377.97	184.79	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	143.45	46.90	6.46	56.26	44.91
214	159.30	143.45	46.90	6.46	56.26	44.91
215	159.30	138.83	46.90	6.46	56.26	44.91
216	159.30	136.49	46.90	6.46	56.26	44.91
301	377.97	184.79	83.29	83.29	113.39	113.39
302	251.01	248.88	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	143.45	46.90	6.46	56.26	44.91
314	159.30	143.45	46.90	6.46	56.26	44.91
315	159.30	122.47	46.90	6.46	56.26	44.91
316	159.30	145.46	46.90	6.46	56.26	44.91
401	377.97	184.79	83.29	83.29	113.39	113.39
402	251.01	248.88	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	34.37	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	34.37	46.90	6.46	56.26	44.91
412	251.01	249.53	27.16	27.16	75.30	75.30
413	159.30	143.45	46.90	6.46	56.26	44.91
414	159.30	143.45	46.90	6.46	56.26	44.91
415	159.30	144.76	46.90	6.46	56.26	44.91
416	159.30	125.46	43.19	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	0.084	0.477	0.031	0.028	0.003	0.495	#13	0.495	Not Required	Pass
2	0.005	0.096	0.045	0.091	0.021	0.132	#21	0.006	Not Required	Pass
3	0.008	0.608	0.046	0.060	0.007	0.637	#21	0.046	Not Required	Pass
4	0.008	0.602	0.177	0.060	0.038	0.724	#21	0.082	Not Required	Pass
5	0.008	0.377	0.172	0.060	0.045	0.423	#21	0.076	Not Required	Pass
6	0.011	0.689	0.070	0.069	0.008	0.764	#21	0.046	Not Required	Pass

7	0.011	0.427	0.228	0.068	0.059	0.488	#21	0.076	Not Required	Pass
8	0.001	0.059	0.280	0.045	0.024	0.308	#24	0.102	Not Required	Pass
9	0.023	0.062	0.065	0.001	0.002	0.138	#21	0.206	Not Required	Pass
10	0.011	0.675	0.212	0.068	0.044	0.798	#21	0.082	Not Required	Pass
11	0.003	0.057	0.288	0.046	0.024	0.317	#21	0.102	Not Required	Pass
12	0.004	0.505	0.129	0.108	0.022	0.609	#21	0.036	Not Required	Pass
13	0.003	0.147	0.610	0.057	0.029	0.744	#21	0.087	Not Required	Pass
14	0.000	0.158	0.463	0.041	0.021	0.621	#21	Not Required	Not Required	Pass
15	0.000	0.085	0.248	0.030	0.015	0.332	#21	Not Required	Not Required	Pass
16	0.000	0.084	0.248	0.030	0.015	0.332	#21	Not Required	Not Required	Pass
17	0.008	0.176	0.110	0.017	0.007	0.270	#21	0.133	Not Required	Pass
18	0.000	0.158	0.463	0.041	0.021	0.622	#21	Not Required	Not Required	Pass
19	0.008	0.176	0.144	0.017	0.009	0.303	#21	0.199	Not Required	Pass
20	0.001	0.142	0.600	0.056	0.029	0.726	#21	0.087	Not Required	Pass
21	0.009	0.199	0.111	0.013	0.006	0.313	#21	0.133	Not Required	Pass
22	0.003	0.174	0.631	0.059	0.029	0.806	#21	0.087	Not Required	Pass
23	0.010	0.207	0.125	0.013	0.006	0.337	#21	0.199	Not Required	Pass
24	0.001	0.182	0.602	0.058	0.029	0.784	#21	0.087	Not Required	Pass
25	0.009	0.208	0.109	0.013	0.006	0.320	#21	0.133	Not Required	Pass
26	0.003	0.184	0.615	0.058	0.029	0.800	#21	0.087	Not Required	Pass
27	0.010	0.209	0.125	0.013	0.006	0.339	#21	0.199	Not Required	Pass
28	0.001	0.184	0.607	0.058	0.029	0.790	#21	0.087	Not Required	Pass
29	0.009	0.200	0.111	0.013	0.006	0.312	#21	0.133	Not Required	Pass
30	0.003	0.179	0.611	0.058	0.029	0.790	#21	0.087	Not Required	Pass
31	0.010	0.208	0.126	0.013	0.006	0.339	#21	0.199	Not Required	Pass
32	0.001	0.180	0.624	0.059	0.029	0.804	#21	0.087	Not Required	Pass
33	0.008	0.176	0.111	0.017	0.007	0.270	#21	0.133	Not Required	Pass
34	0.003	0.148	0.611	0.057	0.029	0.745	#21	0.087	Not Required	Pass
35	0.008	0.176	0.145	0.016	0.009	0.305	#21	0.199	Not Required	Pass
36	0.000	0.158	0.463	0.041	0.021	0.621	#21	Not Required	Not Required	Pass
37	0.001	0.157	0.331	0.049	0.024	0.489	#21	0.352	Not Required	Pass
38	0.001	0.179	0.332	0.029	0.015	0.511	#21	0.331	Not Required	Pass
39	0.001	0.073	0.285	0.047	0.024	0.358	#21	0.145	Not Required	Pass
40	0.002	0.178	0.332	0.029	0.015	0.510	#21	0.331	Not Required	Pass
41	0.001	0.120	0.287	0.047	0.024	0.408	#21	0.269	Not Required	Pass
42	0.001	0.185	0.333	0.037	0.020	0.520	#21	0.331	Not Required	Pass
43	0.001	0.036	0.280	0.045	0.024	0.308	#24	0.062	Not Required	Pass
44	0.005	0.410	0.121	0.092	0.021	0.517	#21	0.030	Not Required	Pass
45	0.005	0.096	0.045	0.091	0.021	0.133	#21	0.006	Not Required	Pass
46	0.003	0.182	0.334	0.033	0.017	0.518	#21	0.292	Not Required	Pass
47	0.003	0.124	0.287	0.034	0.017	0.412	#21	0.167	Not Required	Pass
48	0.003	0.182	0.333	0.029	0.015	0.516	#21	0.331	Not Required	Pass
49	0.002	0.059	0.101	0.034	0.017	0.160	#21	0.043	Not Required	Pass
50	0.003	0.181	0.333	0.029	0.014	0.515	#21	0.331	Not Required	Pass
51	0.003	0.159	0.333	0.035	0.018	0.492	#21	0.250	Not Required	Pass
52	0.004	0.187	0.333	0.038	0.020	0.520	#21	0.331	Not Required	Pass
101	0.096	0.531	0.002	0.032	0.000	0.560	#13	0.495	Not Required	Pass
102	0.005	0.530	0.146	0.116	0.024	0.658	#21	0.036	Not Required	Pass
103	0.011	0.749	0.056	0.075	0.001	0.810	#21	0.046	Not Required	Pass
104	0.011	0.747	0.228	0.075	0.048	0.894	#21	0.082	Not Required	Pass
105	0.011	0.464	0.238	0.074	0.062	0.528	#21	0.076	Not Required	Pass
106	0.011	0.749	0.055	0.075	0.002	0.805	#21	0.046	Not Required	Pass
107	0.011	0.465	0.228	0.074	0.060	0.528	#21	0.076	Not Required	Pass
108	0.001	0.073	0.281	0.047	0.024	0.353	#21	0.102	Not Required	Pass

108	0.001	0.075	0.281	0.047	0.024	0.355	#21	0.102	Not Required	Pass
109	0.027	0.067	0.053	0.001	0.000	0.129	#21	0.206	Not Required	Pass
110	0.011	0.743	0.218	0.074	0.046	0.882	#21	0.082	Not Required	Pass
111	0.003	0.069	0.289	0.047	0.024	0.357	#21	0.102	Not Required	Pass
112	0.005	0.531	0.144	0.115	0.024	0.653	#21	0.036	Not Required	Pass
113	0.003	0.178	0.611	0.058	0.029	0.789	#21	0.087	Not Required	Pass
114	0.001	0.181	0.624	0.059	0.029	0.804	#21	0.087	Not Required	Pass
115	0.004	0.159	0.333	0.048	0.024	0.493	#21	0.352	Not Required	Pass
116	0.001	0.182	0.333	0.032	0.017	0.515	#21	0.292	Not Required	Pass
201	0.096	0.541	0.001	0.032	0.000	0.562	#13	0.495	Not Required	Pass
202	0.005	0.526	0.145	0.115	0.024	0.649	#21	0.036	Not Required	Pass
203	0.011	0.744	0.053	0.074	0.001	0.802	#21	0.046	Not Required	Pass
204	0.011	0.733	0.221	0.074	0.047	0.876	#21	0.082	Not Required	Pass
205	0.011	0.461	0.231	0.074	0.060	0.524	#21	0.076	Not Required	Pass
206	0.011	0.748	0.054	0.075	0.001	0.807	#21	0.046	Not Required	Pass
207	0.011	0.463	0.231	0.074	0.060	0.526	#21	0.076	Not Required	Pass
208	0.001	0.074	0.285	0.047	0.024	0.359	#21	0.102	Not Required	Pass
209	0.026	0.066	0.050	0.001	0.000	0.129	#21	0.206	Not Required	Pass
210	0.011	0.737	0.220	0.074	0.046	0.878	#21	0.082	Not Required	Pass
211	0.003	0.075	0.291	0.047	0.024	0.367	#21	0.102	Not Required	Pass
212	0.005	0.530	0.145	0.115	0.024	0.653	#21	0.036	Not Required	Pass
213	0.003	0.185	0.614	0.058	0.029	0.801	#21	0.087	Not Required	Pass
214	0.001	0.183	0.607	0.058	0.029	0.790	#21	0.087	Not Required	Pass
215	0.003	0.074	0.292	0.047	0.024	0.366	#21	0.145	Not Required	Pass
216	0.001	0.121	0.287	0.034	0.017	0.408	#21	0.167	Not Required	Pass
301	0.096	0.531	0.002	0.032	0.000	0.559	#13	0.495	Not Required	Pass
302	0.005	0.533	0.145	0.116	0.024	0.655	#21	0.036	Not Required	Pass
303	0.011	0.750	0.055	0.075	0.002	0.806	#21	0.046	Not Required	Pass
304	0.011	0.744	0.218	0.075	0.046	0.882	#21	0.082	Not Required	Pass
305	0.011	0.465	0.228	0.074	0.060	0.528	#21	0.076	Not Required	Pass
306	0.011	0.748	0.055	0.074	0.001	0.809	#21	0.046	Not Required	Pass
307	0.011	0.464	0.238	0.074	0.062	0.528	#21	0.076	Not Required	Pass
308	0.001	0.067	0.298	0.048	0.024	0.366	#21	0.102	Not Required	Pass
309	0.027	0.067	0.053	0.001	0.000	0.129	#21	0.206	Not Required	Pass
310	0.011	0.746	0.228	0.075	0.048	0.893	#21	0.082	Not Required	Pass
311	0.003	0.061	0.304	0.048	0.024	0.367	#21	0.102	Not Required	Pass
312	0.005	0.529	0.146	0.116	0.024	0.656	#21	0.036	Not Required	Pass
313	0.003	0.174	0.630	0.059	0.029	0.805	#21	0.087	Not Required	Pass
314	0.001	0.183	0.603	0.058	0.029	0.785	#21	0.087	Not Required	Pass
315	0.003	0.123	0.289	0.047	0.024	0.411	#21	0.269	Not Required	Pass
316	0.001	0.058	0.104	0.034	0.017	0.161	#21	0.043	Not Required	Pass
401	0.084	0.476	0.032	0.028	0.003	0.496	#13	0.495	Not Required	Pass
402	0.004	0.507	0.129	0.108	0.022	0.611	#21	0.036	Not Required	Pass
403	0.011	0.688	0.070	0.069	0.008	0.764	#21	0.046	Not Required	Pass
404	0.011	0.674	0.212	0.068	0.044	0.797	#21	0.082	Not Required	Pass
405	0.011	0.425	0.228	0.068	0.059	0.487	#21	0.076	Not Required	Pass
406	0.008	0.606	0.046	0.060	0.007	0.635	#21	0.046	Not Required	Pass
407	0.008	0.376	0.172	0.060	0.045	0.422	#21	0.076	Not Required	Pass
408	0.000	0.084	0.248	0.030	0.015	0.332	#21	Not Required	Not Required	Pass
409	0.023	0.062	0.064	0.001	0.002	0.138	#21	0.206	Not Required	Pass
410	0.008	0.600	0.177	0.060	0.039	0.722	#21	0.082	Not Required	Pass
411	0.000	0.085	0.248	0.030	0.015	0.332	#21	Not Required	Not Required	Pass
412	0.005	0.409	0.121	0.091	0.021	0.516	#21	0.030	Not Required	Pass
413	0.000	0.158	0.463	0.041	0.021	0.622	#21	Not Required	Not Required	Pass

414	0.001	0.142	0.600	0.056	0.029	0.727	#21	0.087	Not Required	Pass
415	0.003	0.041	0.289	0.046	0.024	0.318	#21	0.062	Not Required	Pass
416	0.001	0.157	0.331	0.036	0.018	0.488	#21	0.250	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

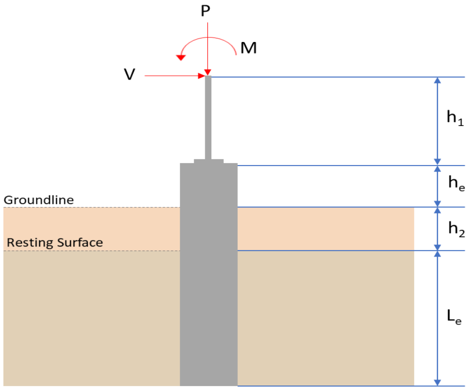
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 6.25$ 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)	9.565	15.442
V_x (kip)	-1.877	-3.136
V_z (kip)	0.198	0.322
M_x (kipft)	0.685	1.125
M_z (kipft)	23.244	39.694

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.877 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.29889 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.244 \text{ kipft}) + ((-1.877 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.7013 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.7745 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.198 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.031529 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.685 \text{ kipft}) + ((0.198 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.10908 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.3632 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7745 \text{ ft}), (2.3632 \text{ ft})]$$

$$L_{e,req} = 5.774 \text{ ft}$$

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

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

$$Ratio = \frac{(5.774 \text{ ft})}{(6.25 \text{ ft})}$$

$$Ratio = 0.92384$$

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

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

$$q = \frac{(9.565 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.59781 \text{ kip/ft}^2$$

$q = 0.59781\ \mathrm{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.59781\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.29891$$

Status: **PASS**
Ratio: **0.300**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.29889\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.7013\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(3.7013\ \mathrm{kipft/ft}\right) \times \left(6.25\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.29889\ \mathrm{kip/ft}\right) \times \left(6.25\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(3.7013\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.29889\ \mathrm{kip/ft}\right) \times \left(6.25\ \mathrm{ft}\right)\right)}$$

$$a = 4.2978\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times \left[\left(4 \times \left(3.7013\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(-0.29889\ \mathrm{kip/ft}\right) \times \left(6.25\ \mathrm{ft}\right)\right)\right]^2}{\left(6.25\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(3.7013\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(-0.29889\ \mathrm{kip/ft}\right) \times \left(6.25\ \mathrm{ft}\right)\right)\right]}$$

$$p = 0.22062\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times \left[\left(2 \times \left(3.7013\ \mathrm{kipft/ft}\right)\right) + \left(\left(-0.29889\ \mathrm{kip/ft}\right) \times \left(6.25\ \mathrm{ft}\right)\right)\right]}{\left(6.25\ \mathrm{ft}\right)^2}$$

$$s = 0.8501\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = \left(150\ \mathrm{psf/ft}\right) \times \frac{\left(4.2978\ \mathrm{ft}\right)}{2}$$

$$p_a = 0.32233\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.22062\ \mathrm{kip/ft^2}\right)}{\left(0.32233\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.68443$$

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

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

$$Ratio = \frac{\left(0.8501\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90677$$

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

Considering z-direction:

$H_o = 0.031529\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.10908\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10908\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (0.031529\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.10908\ \mathrm{kipft/ft})) + (4 \times (0.031529\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4512\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.10908\ \mathrm{kipft/ft})) + (3 \times (0.031529\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^2}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.10908\ \mathrm{kipft/ft})) + (2 \times (0.031529\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = 0.0281\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.10908\ \mathrm{kipft/ft})) + ((0.031529\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.063776\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4512\ \mathrm{ft})}{2}$$

$$p_a = 0.33384\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0281\ \mathrm{kip/ft^2}\right)}{\left(0.33384\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.08417$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

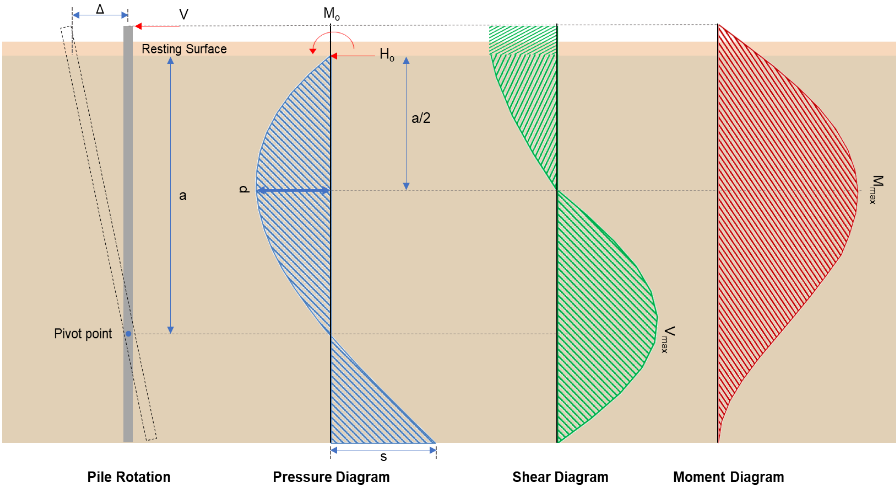
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.063776 \text{ kip/ft}^2)}{(0.9375 \text{ kip/ft}^2)}$$

$$Ratio = 0.068028$$

Status: **PASS**
Ratio: **0.070**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.136 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.49936 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.694 \text{ kipft}) + ((-3.136 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.3207 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.3207 \text{ kipft/ft})}{(-0.49936 \text{ kip/ft})}$$

$$E = 12.658 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.3207 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.49936 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (6.3207 \text{ kipft/ft})) + (4 \times (-0.49936 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2957 \text{ ft}$$

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

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

$$V_{max} = ((-0.49936 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.658 \text{ ft})}{(6.25 \text{ ft})} + 3\right) \times \left(\frac{(4.2957 \text{ ft})}{(6.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.658 \text{ ft})}{(6.25 \text{ ft})} + 2\right) \times \left(\frac{(4.2957 \text{ ft})}{(6.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 8.477 \text{ kip}$$

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

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

$$M_{max} = ((-0.49936\text{ kip/ft}) \times (48\text{ in}) \times (6.25\text{ ft})) \times \left[\left(\frac{(12.658\text{ ft})}{(6.25\text{ ft})} + \frac{(4.2957\text{ ft})}{2 \times (6.25\text{ ft})}\right) - \left[\left(\frac{4 \times (12.658\text{ ft})}{(6.25\text{ ft})} + 3\right) \times \left(\frac{(4.2957\text{ ft})}{2 \times (6.25\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.658\text{ ft})}{(6.25\text{ ft})} + 2\right) \times \left(\frac{(4.2957\text{ ft})}{2 \times (6.25\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 25.355\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.322\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = 0.051274\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.125\text{ kipft}) + ((0.322\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 0.17914\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.17914\text{ kipft/ft})}{(0.051274\text{ kip/ft})}$$

$$E = 3.4938\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17914\text{ kipft/ft}) \times (6.25\text{ ft})) + \left(3 \times (0.051274\text{ kip/ft}) \times (6.25\text{ ft})^2\right)}{(6 \times (0.17914\text{ kipft/ft})) + (4 \times (0.051274\text{ kip/ft}) \times (6.25\text{ ft}))}$$

$$a = 4.45\text{ ft}$$

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

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

$$V_{max} = ((0.051274\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4938\text{ ft})}{(6.25\text{ ft})} + 3\right) \times \left(\frac{(4.45\text{ ft})}{(6.25\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.4938\text{ ft})}{(6.25\text{ ft})} + 2\right) \times \left(\frac{(4.45\text{ ft})}{(6.25\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.33929\text{ kip}$$

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

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

$$M_{max} = ((0.051274\text{ kip/ft}) \times (48\text{ in}) \times (6.25\text{ ft})) \times \left[\left(\frac{(3.4938\text{ ft})}{(6.25\text{ ft})} + \frac{(4.45\text{ ft})}{2 \times (6.25\text{ ft})}\right) - \left[\left(\frac{4 \times (3.4938\text{ ft})}{(6.25\text{ ft})} + 3\right) \times \left(\frac{(4.45\text{ ft})}{2 \times (6.25\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.4938\text{ ft})}{(6.25\text{ ft})} + 2\right) \times \left(\frac{(4.45\text{ ft})}{2 \times (6.25\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.94578 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(15.442 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.75 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.75 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.442\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0048508$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,$P = 15.442\ \text{kip} \rightarrow 15442\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(15442\ \text{lbf})}{6 \times \left(2304\ \text{in}^2\right)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 131.85\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \text{kip}), (131.85\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 131.85\ \text{kip}$$

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

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

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

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

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

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

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.85\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 118.79\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 8.477\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.477\ \mathrm{kip})}{(118.79\ \mathrm{kip})}$$

$$Ratio = 0.071364$$

Status: **PASS**
Ratio: **0.070**

Considering z-direction:

$V_{max} = 0.33929\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.33929\ \mathrm{kip})}{(118.79\ \mathrm{kip})}$$

$$Ratio = 0.0028564$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\text{ kipft}), (2545.9\text{ kipft})]$$ $$\phi M_n = 273.42\text{ kipft}$$ **Considering x-direction:** $M_{max} = 25.355\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(25.355\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.092731$$	Status: **PASS** Ratio: **0.090**
	Considering z-direction: $M_{max} = 0.94578\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.94578\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.003459$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

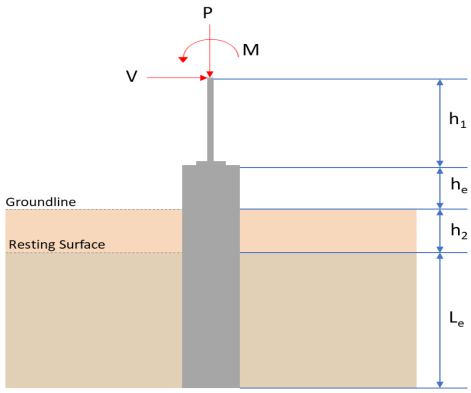
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.25\ \mathrm{ft}$ - 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)	9.568	15.446
V_x (kip)	-1.877	-3.137
V_z (kip)	-0.202	-0.329
M_x (kipft)	-0.685	-1.123
M_z (kipft)	23.235	39.676

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.877\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.29889\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.235\ \text{kipft}) + ((-1.877\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 3.6998\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.7735\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.202\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.032166\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.685\ \text{kipft}) + ((-0.202\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.10908\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.749\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.7735\ \text{ft}), (1.749\ \text{ft})]$$

$$L_{e,req} = 5.773\ \text{ft}$$

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

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

$$Ratio = \frac{(5.773\ \text{ft})}{(6.25\ \text{ft})}$$

$$Ratio = 0.92368$$

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

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

$$q = \frac{(9.568\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.598\ \text{kip/ft}^2$$

$q = 0.598 \text{ kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.598 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.299$$

Status: **PASS**
Ratio: **0.300**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.5625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.29889 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 3.6998 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.6998 \text{ kipft/ft}) \times (6.25 \text{ ft})) + \left(3 \times (-0.29889 \text{ kip/ft}) \times (6.25 \text{ ft})^2\right)}{(6 \times (3.6998 \text{ kipft/ft})) + (4 \times (-0.29889 \text{ kip/ft}) \times (6.25 \text{ ft}))}$$

$$a = 4.2978 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.6998 \text{ kipft/ft})) + (3 \times (-0.29889 \text{ kip/ft}) \times (6.25 \text{ ft}))]^2}{(6.25 \text{ ft})^2 \times [(3 \times (3.6998 \text{ kipft/ft})) + (2 \times (-0.29889 \text{ kip/ft}) \times (6.25 \text{ ft}))]}$$

$$p = 0.22047 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.6998 \text{ kipft/ft})) + ((-0.29889 \text{ kip/ft}) \times (6.25 \text{ ft}))]}{(6.25 \text{ ft})^2}$$

$$s = 0.84966 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.2978 \text{ ft})}{2}$$

$$p_a = 0.32234 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.22047 \text{ kip/ft}^2)}{(0.32234 \text{ kip/ft}^2)}$$

$$Ratio = 0.68397$$

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

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

$$Ratio = \frac{\left(0.84966\ \mathrm{kip/ft^2}\right)}{\left(0.9375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90631$$

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

Considering z-direction:

$H_o = -0.032166\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.10908\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.10908\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.032166\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (0.10908\ \mathrm{kipft/ft})) + (4 \times (-0.032166\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.4538\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.10908\ \mathrm{kipft/ft})) + (3 \times (-0.032166\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]^{\ 2}}{(6.25\ \mathrm{ft})^2 \times [(3 \times (0.10908\ \mathrm{kipft/ft})) + (2 \times (-0.032166\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}$$

$$p = -0.0071376\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.10908\ \mathrm{kipft/ft})) + ((-0.032166\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))]}{(6.25\ \mathrm{ft})^2}$$

$$s = 0.0026293\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4538\ \mathrm{ft})}{2}$$

$$p_a = 0.33404\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.0071376\ \mathrm{kip/ft^2}\right)}{\left(0.33404\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.021368$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

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

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

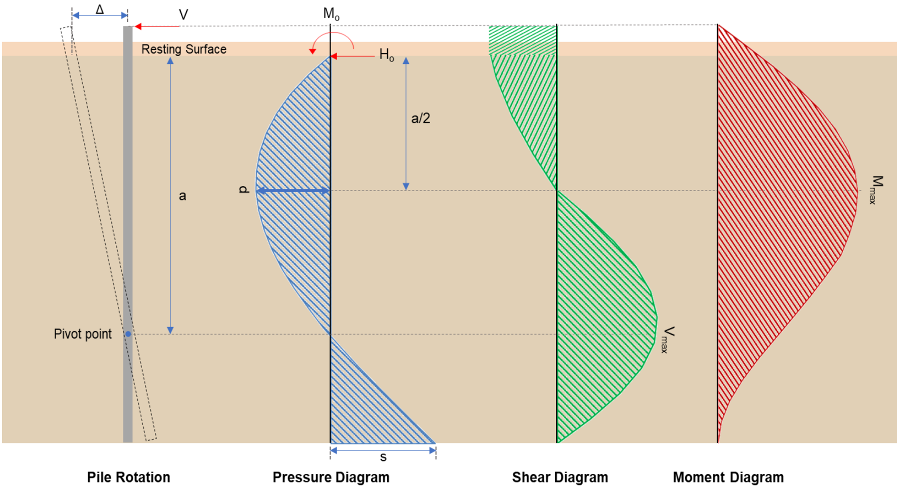
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0026293\ \mathrm{kip/ft^2})}{(0.9375\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0028046$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.137\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.49952\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.676\ \mathrm{kipft}) + ((-3.137\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.3178\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.3178\ \mathrm{kipft/ft})}{(-0.49952\ \mathrm{kip/ft})}$$

$$E = 12.648\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.3178\ \mathrm{kipft/ft}) \times (6.25\ \mathrm{ft})) + \left(3 \times (-0.49952\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft})^2\right)}{(6 \times (6.3178\ \mathrm{kipft/ft})) + (4 \times (-0.49952\ \mathrm{kip/ft}) \times (6.25\ \mathrm{ft}))}$$

$$a = 4.2957\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.49952\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.648\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.2957\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.648\ \mathrm{ft})}{(6.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.2957\ \mathrm{ft})}{(6.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 8.4741\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.49952\text{ kip/ft})\times(48\text{ in})\times(6.25\text{ ft}))\times\left[\left(\frac{(12.648\text{ ft})}{(6.25\text{ ft})}+\frac{(4.2957\text{ ft})}{2\times(6.25\text{ ft})}\right) - \left[\left(\frac{4\times(12.648\text{ ft})}{(6.25\text{ ft})}+3\right)\times\left(\frac{(4.2957\text{ ft})}{2\times(6.25\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(12.648\text{ ft})}{(6.25\text{ ft})}+2\right)\times\left(\frac{(4.2957\text{ ft})}{2\times(6.25\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 25.346\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.329\text{ kip})}{1.57\times(48\text{ in})}$$

$$H_o = -0.052389\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.123\text{ kipft})+((-0.329\text{ kip})\times(0\text{ ft}))}{1.57\times(48\text{ in})}$$

$$M_o = 0.17882\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.17882\text{ kipft/ft})}{(-0.052389\text{ kip/ft})}$$

$$E = 3.4134\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4\times(0.17882\text{ kipft/ft})\times(6.25\text{ ft}))+\left(3\times(-0.052389\text{ kip/ft})\times(6.25\text{ ft})^2\right)}{(6\times(0.17882\text{ kipft/ft}))+(4\times(-0.052389\text{ kip/ft})\times(6.25\text{ ft}))}$$

$$a = 4.453\text{ ft}$$

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

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

$$V_{max} = ((-0.052389\text{ kip/ft})\times(48\text{ in}))\times\left[1-\left[3\times\left(\frac{4\times(3.4134\text{ ft})}{(6.25\text{ ft})}+3\right)\times\left(\frac{(4.453\text{ ft})}{(6.25\text{ ft})}\right)^2\right]+\left[4\times\left(\frac{3\times(3.4134\text{ ft})}{(6.25\text{ ft})}+2\right)\times\left(\frac{(4.453\text{ ft})}{(6.25\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.34195\text{ kip}$$

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

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

$$M_{max} = ((-0.052389\text{ kip/ft})\times(48\text{ in})\times(6.25\text{ ft}))\times\left[\left(\frac{(3.4134\text{ ft})}{(6.25\text{ ft})}+\frac{(4.453\text{ ft})}{2\times(6.25\text{ ft})}\right) - \left[\left(\frac{4\times(3.4134\text{ ft})}{(6.25\text{ ft})}+3\right)\times\left(\frac{(4.453\text{ ft})}{2\times(6.25\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(3.4134\text{ ft})}{(6.25\text{ ft})}+2\right)\times\left(\frac{(4.453\text{ ft})}{2\times(6.25\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.95162 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(15.446 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.75 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.75 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(15.446\text{ kip})}{(3183.4\text{ kip})}$$

$$Ratio = 0.004852$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$, $P = 15.446\text{ kip} \rightarrow 15446\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\text{ psi})} + \frac{(15446\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 131.85\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\text{ kip}), (131.85\text{ kip}), (406.27\text{ kip})\right]$$

$$V_c = 131.85\text{ kip}$$

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

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

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

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

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

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

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((131.85\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 118.79\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 8.4741\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(8.4741\ \mathrm{kip})}{(118.79\ \mathrm{kip})}$$

$$Ratio = 0.07134$$

Status: **PASS**
Ratio: **0.070**

Considering z-direction:

$V_{max} = 0.34195\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.34195\ \mathrm{kip})}{(118.79\ \mathrm{kip})}$$

$$Ratio = 0.0028787$$

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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$		
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$ $$\phi M_n = 273.42 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 25.346 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(25.346 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.092697$$		Status: **PASS** Ratio: **0.090**
	Considering z-direction: $M_{max} = 0.95162 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.95162 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.0034804$$		Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

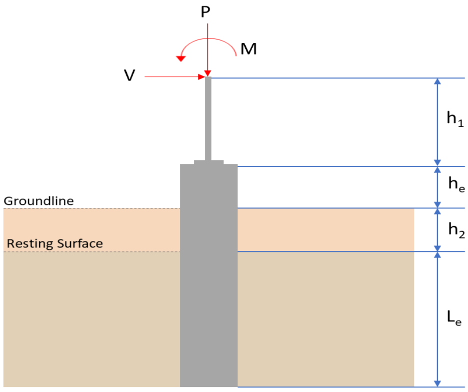
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.011	17.816
V_x (kip)	-2.162	-3.611
V_z (kip)	-0.009	-0.017
M_x (kipft)	-0.030	-0.053
M_z (kipft)	26.012	44.220

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.162\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.34427\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.012 \text{ kipft}) + ((-2.162 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.142 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.9327 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.03 \text{ kipft}) + ((-0.009 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0047771 \text{ kipft/ft}$$

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:
$L_{e,z} = 0.68648 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.9327 \text{ ft}), (0.68648 \text{ ft})]$$

$$L_{e,req} = 5.933 \text{ ft}$$

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

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

$$Ratio = \frac{(5.933 \text{ ft})}{(6.5 \text{ ft})}$$

$$Ratio = 0.91277$$

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

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

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

$$q = \frac{(11.011 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.68819 \text{ kip/ft}^2$$

$q = 0.68819\ \mathrm{kip/ft^2}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.68819\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.34409$$

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:

$H_o = -0.34427\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.142\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.142\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.34427\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (4.142\ \mathrm{kipft/ft})) + (4 \times (-0.34427\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.4768\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.142\ \mathrm{kipft/ft})) + (3 \times (-0.34427\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (4.142\ \mathrm{kipft/ft})) + (2 \times (-0.34427\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.21684\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.142\ \mathrm{kipft/ft})) + ((-0.34427\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.85865\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4768\ \mathrm{ft})}{2}$$

$$p_a = 0.33576\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21684\ \mathrm{kip/ft^2}\right)}{\left(0.33576\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.64582$$

Status: **PASS**
Ratio: **0.650**

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

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

$$Ratio = \frac{\left(0.85865\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.88067$$

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

Considering z-direction:

$H_o = -0.0014331\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0047771\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0047771\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.0047771\ \mathrm{kipft/ft})) + (4 \times (-0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6395\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0047771\ \mathrm{kipft/ft})) + (3 \times (-0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.0047771\ \mathrm{kipft/ft})) + (2 \times (-0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = -0.00032248\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0047771\ \mathrm{kipft/ft})) + ((-0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.00003392\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6395\ \mathrm{ft})}{2}$$

$$p_a = 0.34796\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00032248\ \mathrm{kip/ft^2}\right)}{\left(0.34796\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00092676$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

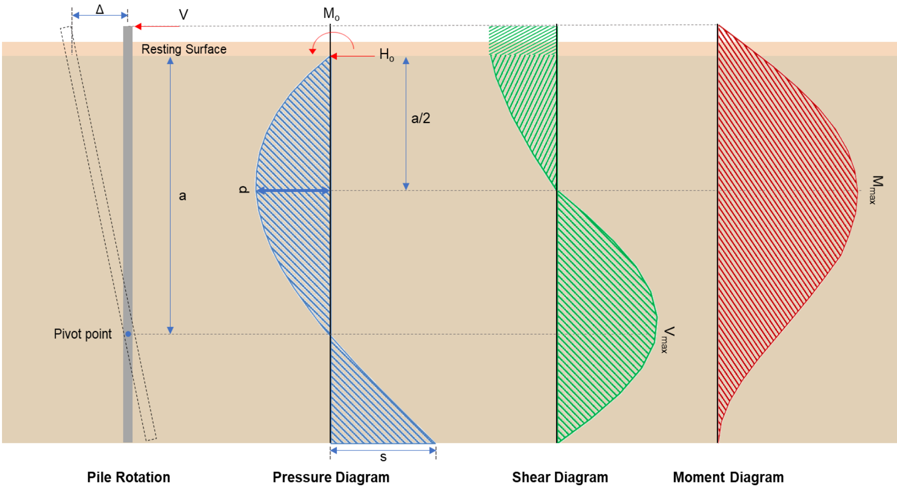
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.00003392\ \text{kip/ft}^2)}{(0.975\ \text{kip/ft}^2)}$$

$$Ratio = 0.00003479$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.611\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.575\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.22\ \text{kipft}) + ((-3.611\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 7.0414\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.0414\ \text{kipft/ft})}{(-0.575\ \text{kip/ft})}$$

$$E = 12.246\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.0414\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.575\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (7.0414\ \text{kipft/ft})) + (4 \times (-0.575\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4749\ \text{ft}$$

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

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

$$V_{max} = ((-0.575\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.246\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4749\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.246\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4749\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.1853\ \text{kip}$$

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

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

$$M_{max} = ((-0.575 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(12.246 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.4749 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.246 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.4749 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.246 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.4749 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 28.493 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.053 \text{ kipft}) + ((-0.017 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0084395 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.0084395 \text{ kipft/ft})}{(-0.002707 \text{ kip/ft})}$$

$$E = 3.1176 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0084395 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.002707 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.0084395 \text{ kipft/ft})) + (4 \times (-0.002707 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6484 \text{ ft}$$

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

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

$$V_{max} = ((-0.002707 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.1176 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.6484 \text{ ft})}{(6.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.1176 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.6484 \text{ ft})}{(6.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.016409 \text{ kip}$$

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

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

$$M_{max} = ((-0.002707 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(3.1176 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6484 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.1176 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.6484 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.1176 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.6484 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.047055 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(17.816 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.67 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.67 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(17.816\text{ kip})}{(3183.4\text{ kip})}$$

$$Ratio = 0.0055965$$

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 $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$, $P = 17.816\text{ kip} \rightarrow 17816\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\text{ psi})} + \frac{(17816\text{ lbf})}{6 \times \left(2304\text{ in}^2\right)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 132.17\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\text{ kip}), (132.17\text{ kip}), (406.27\text{ kip})\right]$$

$$V_c = 132.17\text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((132.17\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 118.99\ \text{kip}$$

Considering x-direction:

$V_{max} = 9.1853\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(9.1853\ \text{kip})}{(118.99\ \text{kip})}$$

$$Ratio = 0.077193$$

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

Considering z-direction:

$V_{max} = 0.016409\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.016409\ \text{kip})}{(118.99\ \text{kip})}$$

$$Ratio = 0.0001379$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$ $$\phi M_n = 273.42 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 28.493 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(28.493 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.10421$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $M_{max} = 0.047055 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.047055 \text{ kipft})}{(273.42 \text{ kipft})}$$ $$Ratio = 0.0001721$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

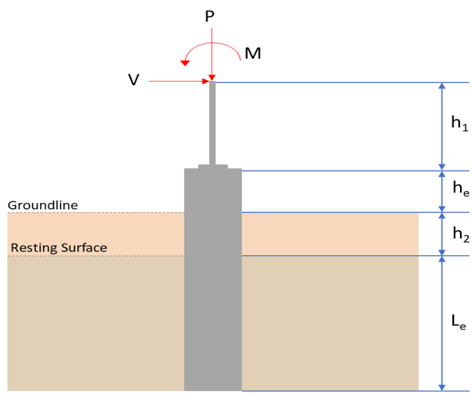
SkyCiv Foundation Design

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)	10.946	17.704
V_x (kip)	-2.159	-3.599
V_z (kip)	0.009	0.014
M_x (kipft)	0.038	0.063
M_z (kipft)	26.392	45.020

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.159\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.34379\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.392\ \text{kipft}) + ((-2.159\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.2025\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.9722\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.038\ \text{kipft}) + ((0.009\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

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

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.82154\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.9722\ \text{ft}), (0.82154\ \text{ft})]$$

$$L_{e,req} = 5.972\ \text{ft}$$

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

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

$$Ratio = \frac{(5.972\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.91877$$

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

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

$$q = \frac{(10.946\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.68412\ \text{kip/ft}^2$$

$q = 0.68412\ \text{kip/ft}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.68412\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.34206$$

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:

$H_o = -0.34379\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.2025\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2025\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.34379\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (4.2025\ \text{kipft/ft})) + (4 \times (-0.34379\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4751\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.2025\ \text{kipft/ft})) + (3 \times (-0.34379\ \text{kip/ft}) \times (6.5\ \text{ft}))]^2}{(6.5\ \text{ft})^2 \times [(3 \times (4.2025\ \text{kipft/ft})) + (2 \times (-0.34379\ \text{kip/ft}) \times (6.5\ \text{ft}))]}$$

$$p = 0.22278\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.2025\ \text{kipft/ft})) + ((-0.34379\ \text{kip/ft}) \times (6.5\ \text{ft}))]}{(6.5\ \text{ft})^2}$$

$$s = 0.87628\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(4.4751\ \text{ft})}{2}$$

$$p_a = 0.33563\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.22278\ \text{kip/ft}^2)}{(0.33563\ \text{kip/ft}^2)}$$

$$Ratio = 0.66377$$

Status: **PASS**
Ratio: **0.660**

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

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

$$Ratio = \frac{(0.87628\ \mathrm{kip/ft^2})}{(0.975\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.89875$$

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

Considering z-direction:

$H_o = 0.0014331\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.006051\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.006051\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.006051\ \mathrm{kipft/ft})) + (4 \times (0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6077\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.006051\ \mathrm{kipft/ft})) + (3 \times (0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\,2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.006051\ \mathrm{kipft/ft})) + (2 \times (0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.0013125\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.006051\ \mathrm{kipft/ft})) + ((0.0014331\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.0030415\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6077\ \mathrm{ft})}{2}$$

$$p_a = 0.34558\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0013125\ \mathrm{kip/ft^2})}{(0.34558\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.0037979$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

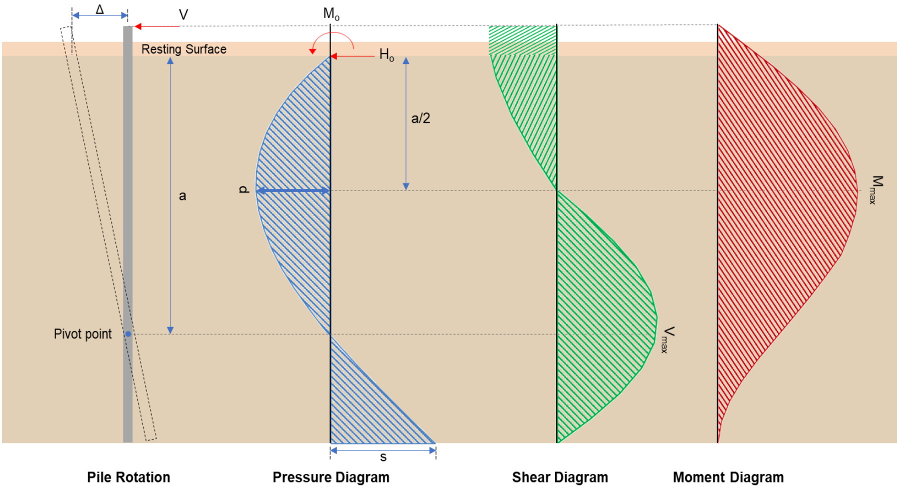
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0030415 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$Ratio = 0.0031195$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.599 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.57309 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(45.02 \text{ kipft}) + ((-3.599 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.1688 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.1688 \text{ kipft/ft})}{(-0.57309 \text{ kip/ft})}$$

$$E = 12.509 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.1688 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.57309 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (7.1688 \text{ kipft/ft})) + (4 \times (-0.57309 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.4727 \text{ ft}$$

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

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

$$V_{max} = ((-0.57309 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.509 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.4727 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.509 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.4727 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 9.3192 \text{ kip}$$

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

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

$$M_{max} = ((-0.57309\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.5\ \mathrm{ft})) \times \left[\left(\frac{(12.509\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + \frac{(4.4727\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (12.509\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.4727\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.509\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.4727\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 28.933\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.014\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.0022293\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.063\ \mathrm{kipft}) + ((0.014\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

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

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.010032\ \mathrm{kipft/ft})}{(0.0022293\ \mathrm{kip/ft})}$$

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

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.010032\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (0.0022293\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.010032\ \mathrm{kipft/ft})) + (4 \times (0.0022293\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.5991\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.0022293\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.5\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.5991\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.5\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.5991\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.016838\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.0022293\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (6.5\ \mathrm{ft})) \times \left[\left(\frac{(4.5\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + \frac{(4.5991\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (4.5\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.5991\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.5\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.5991\ \mathrm{ft})}{2 \times (6.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.049528 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(17.704 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -101.67 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-101.67 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(17.704\ \text{kip})}{(3183.4\ \text{kip})}$$

$$Ratio = 0.0055613$$

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 $f'_{ck} = 3\ \text{ksi} \to 3000\ \text{psi}$,

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \to 3000\ \text{psi}$, $P = 17.704\ \text{kip} \to 17704\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \text{psi})} + \frac{(17704\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 132.15\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \text{kip}), (132.15\ \text{kip}), (406.27\ \text{kip})\right]$$

$$V_c = 132.15\ \text{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 807.65\ \text{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(807.65\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((132.15\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 118.98\ \text{kip}$$ **Considering x-direction:** $V_{max} = 9.3192\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(9.3192\ \text{kip})}{(118.98\ \text{kip})}$$ $$Ratio = 0.078325$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $V_{max} = 0.016838\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.016838\ \text{kip})}{(118.98\ \text{kip})}$$ $$Ratio = 0.00014151$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$	

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 28.933 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(28.933 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.10582$$

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

Considering z-direction:

$M_{max} = 0.049528 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.049528 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.00018114$$

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

REFERENCES	CALCULATIONS	RESULTS

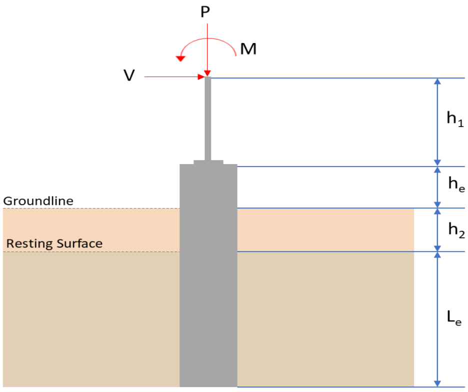
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	11.008	17.811
V_x (kip)	-2.161	-3.609
V_z (kip)	0.010	0.018
M_x (kipft)	0.032	0.059
M_z (kipft)	26.005	44.214

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.161\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.34411\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.005\ \text{kipft}) + ((-2.161\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 4.1409\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.9325\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.032\ \text{kipft}) + ((0.01\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0050955\ \text{kipft/ft}$$

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:
$L_{e,z} = 0.78452\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(5.9325\ \text{ft}), (0.78452\ \text{ft})]$$

$$L_{e,req} = 5.932\ \text{ft}$$

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

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

$$Ratio = \frac{(5.932\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.91262$$

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

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

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

$$q = \frac{(11.008\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.688\ \text{kip/ft}^2$$

$$q = 0.688\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.688\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.344$$

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:

$H_o = -0.34411\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 4.1409\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.1409\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.34411\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (4.1409\ \mathrm{kipft/ft})) + (4 \times (-0.34411\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.4767\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (4.1409\ \mathrm{kipft/ft})) + (3 \times (-0.34411\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\ 2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (4.1409\ \mathrm{kipft/ft})) + (2 \times (-0.34411\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.21682\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (4.1409\ \mathrm{kipft/ft})) + ((-0.34411\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.85848\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.4767\ \mathrm{ft})}{2}$$

$$p_a = 0.33576\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21682\ \mathrm{kip/ft^2}\right)}{\left(0.33576\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.64575$$

Status: **PASS**
Ratio: **0.650**

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

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

$$Ratio = \frac{\left(0.85848\ \mathrm{kip/ft^2}\right)}{\left(0.975\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.88049$$

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

Considering z-direction:

$H_o = 0.0015924\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0050955\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0050955\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (0.0015924\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.0050955\ \mathrm{kipft/ft})) + (4 \times (0.0015924\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6449\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0050955\ \mathrm{kipft/ft})) + (3 \times (0.0015924\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.0050955\ \mathrm{kipft/ft})) + (2 \times (0.0015924\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.0013049\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0050955\ \mathrm{kipft/ft})) + ((0.0015924\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.0029171\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.6449\ \mathrm{ft})}{2}$$

$$p_a = 0.34837\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0013049\ \mathrm{kip/ft^2}\right)}{\left(0.34837\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0037457$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

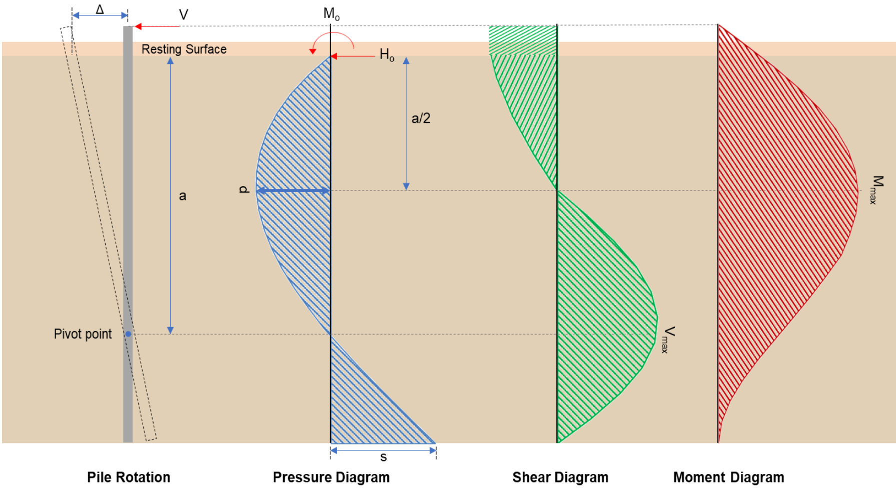
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0029171\ \text{kip/ft}^2)}{(0.975\ \text{kip/ft}^2)}$$

$$Ratio = 0.002992$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.609\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.57468\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.214\ \text{kipft}) + ((-3.609\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 7.0404\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(7.0404\ \text{kipft/ft})}{(-0.57468\ \text{kip/ft})}$$

$$E = 12.251\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.0404\ \text{kipft/ft}) \times (6.5\ \text{ft})) + \left(3 \times (-0.57468\ \text{kip/ft}) \times (6.5\ \text{ft})^2\right)}{(6 \times (7.0404\ \text{kipft/ft})) + (4 \times (-0.57468\ \text{kip/ft}) \times (6.5\ \text{ft}))}$$

$$a = 4.4749\ \text{ft}$$

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

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

$$V_{max} = ((-0.57468\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.251\ \text{ft})}{(6.5\ \text{ft})} + 3\right) \times \left(\frac{(4.4749\ \text{ft})}{(6.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.251\ \text{ft})}{(6.5\ \text{ft})} + 2\right) \times \left(\frac{(4.4749\ \text{ft})}{(6.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 9.1834\ \text{kip}$$

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

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

$$M_{max} = ((-0.57468 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(12.251 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.4749 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.251 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.4749 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.251 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.4749 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 28.488 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.018 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0028662 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.059 \text{ kipft}) + ((0.018 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.009395 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.009395 \text{ kipft/ft})}{(0.0028662 \text{ kip/ft})}$$

$$E = 3.2778 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.009395 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (0.0028662 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.009395 \text{ kipft/ft})) + (4 \times (0.0028662 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6417 \text{ ft}$$

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

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

$$V_{max} = ((0.0028662 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.2778 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.6417 \text{ ft})}{(6.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.2778 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.6417 \text{ ft})}{(6.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.017868 \text{ kip}$$

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

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

$$M_{max} = ((0.0028662 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(3.2778 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6417 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.2778 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.6417 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.2778 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.6417 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^4 \right] \right]$$

	$$M_{max} = 0.051424 \text{ kipft}$$	

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(17.811 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -101.67 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-101.67 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(17.811\ \mathrm{kip})}{(3183.4\ \mathrm{kip})}$$

$$Ratio = 0.0055949$$

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 $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$,

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 17.811\ \mathrm{kip} \rightarrow 17811\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(17811\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 132.17\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(324.49\ \mathrm{kip}), (132.17\ \mathrm{kip}), (406.27\ \mathrm{kip})\right]$$

$$V_c = 132.17\ \mathrm{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 807.65\ \text{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(807.65\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((132.17\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 118.99\ \text{kip}$$ **Considering x-direction:** $V_{max} = 9.1834\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(9.1834\ \text{kip})}{(118.99\ \text{kip})}$$ $$Ratio = 0.077178$$	Status: **PASS** Ratio: **0.080**
	Considering z-direction: $V_{max} = 0.017868\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.017868\ \text{kip})}{(118.99\ \text{kip})}$$ $$Ratio = 0.00015016$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$	

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2545.9\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(273.42\text{ kipft}), (2545.9\text{ kipft})]$$ $$\phi M_n = 273.42\text{ kipft}$$ **Considering x-direction:** $M_{max} = 28.488\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(28.488\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.10419$$	Status: **PASS** Ratio: **0.100**
	Considering z-direction: $M_{max} = 0.051424\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.051424\text{ kipft})}{(273.42\text{ kipft})}$$ $$Ratio = 0.00018807$$	Status: **PASS** Ratio: **0.000**