

Your Project Calculations



Project Name: MTSOLAR_J83122LA0J9

S3D Model Link:

[https://platform.skyciv.com/structural?](https://platform.skyciv.com/structural?preload_name=MTSOLAR_J83122LA0J9&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/1_2024)

[preload_name=MTSOLAR_J83122LA0J9&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/1_2024](https://platform.skyciv.com/structural?preload_name=MTSOLAR_J83122LA0J9&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/1_2024)

Public Model Link:

https://platform.skyciv.com/structural-viewer?project_id=kydlgFDL2Sg3V72a5ULla4TSx64pcwVrxZyCzwMmKqm7sTYvb37r3IfLsMCPNUv5

Array Specification

Product:	Beam
Unique ID:	4P-22.5-8TOP-XD-57-L-5Hx14W-DI4B
Duty Classification:	XD
Module Width:	39.00 in
Module Length:	73.00in
Number of Rows:	5
Number of Columns:	14
Total Number of Modules:	70
Desired Tilt Angle:	18
Front Edge Clearance:	8
Total Array Height at Tilt:	13.05 ft
Total Frame Length:	84.50 ft
Frame Weight:	4324 lbs
Array Dimensions N/S:	16.46 ft
Array Dimensions E/W:	86.33 ft
Rail Length:	197.50 in
Rail Spacing:	3.04 ft
Rail Check:	Not Checked

Support Specifications

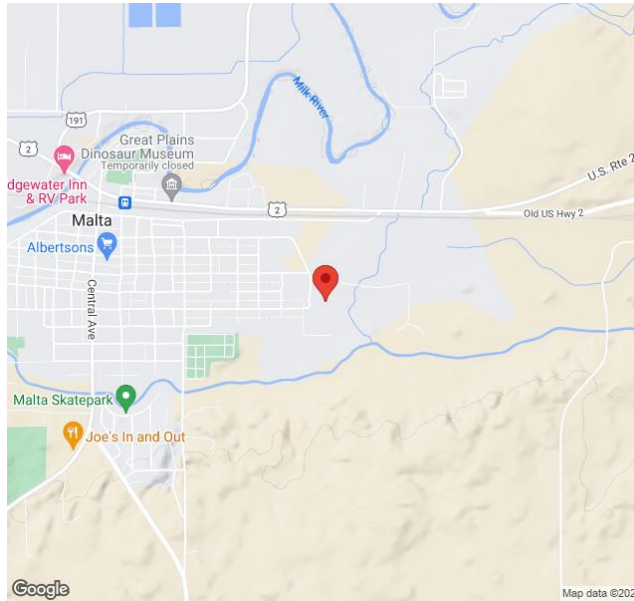
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	10.54 ft
Number of Poles:	4
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 8.75 ft Pile 2: 9.00 ft Pile 3: 9.00 ft Pile 4: 8.75 ft
Foundation Volume:	9.294 y ³
Foundation Result:	PASSED
Mount Twist:	0.211179 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	509 S 10th Ave E, Malta, MT 59538, USA
Wind Speed:	103 mph
Snow Load:	30 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.017154 ksf



Design Disclaimer

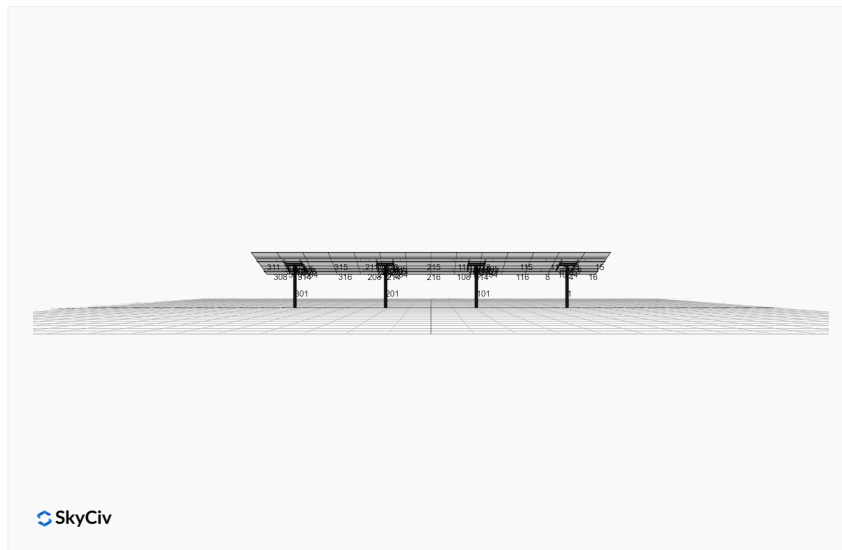
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

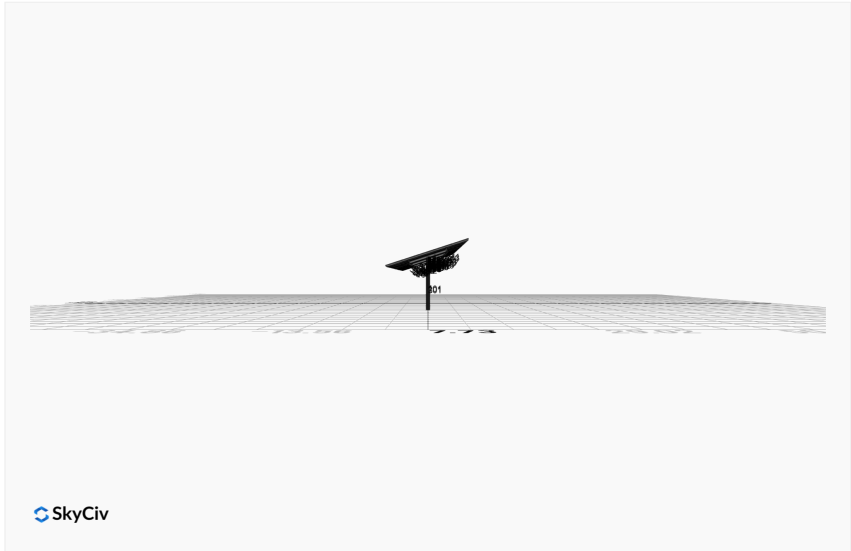
AutoDesigner Input

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  "site_address": "509 S 10th Ave E, Malta, MT 59538, USA",
  "module_width": 39,
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  "number_columns": 14,
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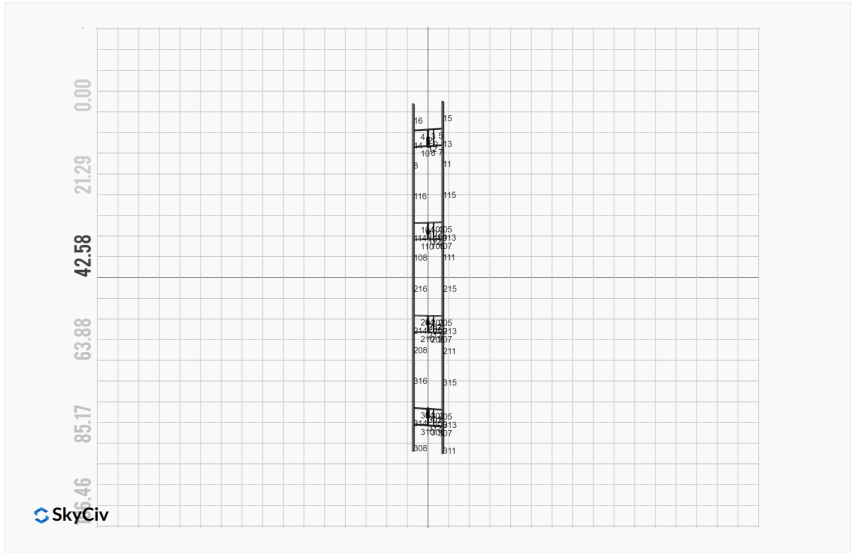
Design Notes:

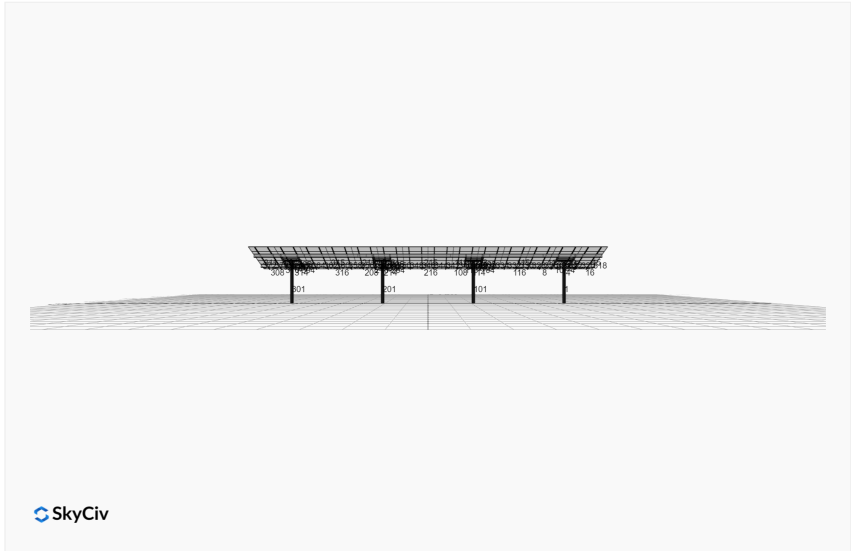
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



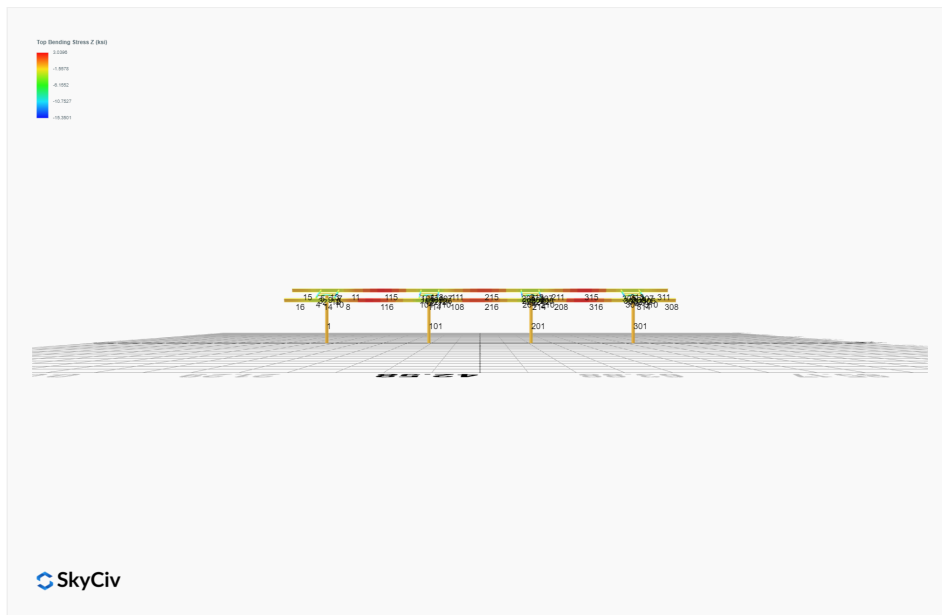
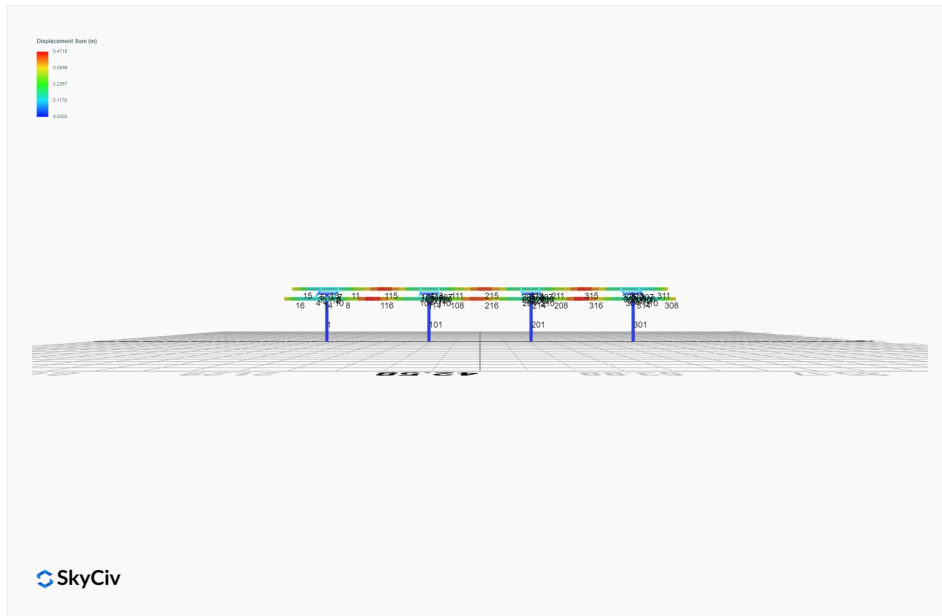


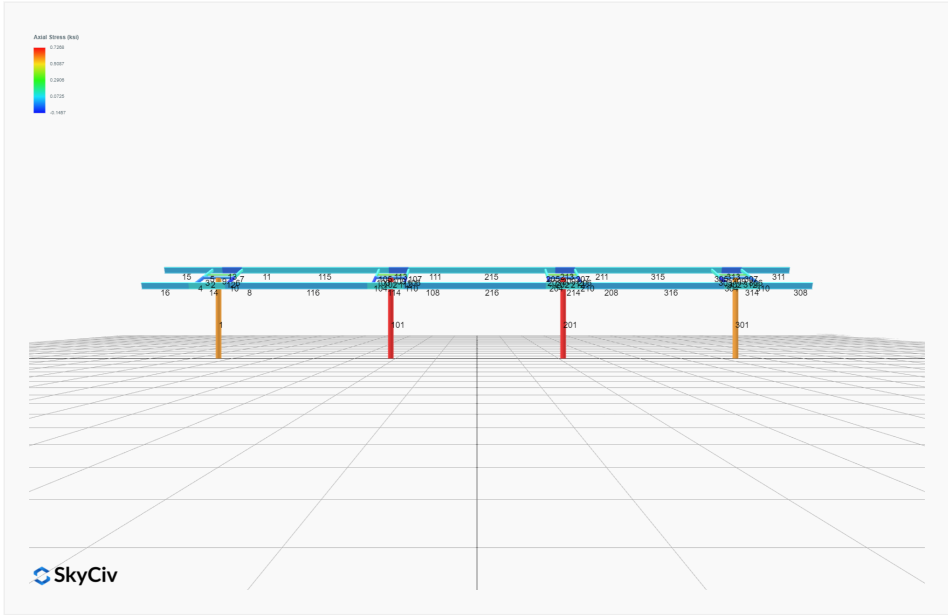
SkyCiv





FEM Results (Envelope Worst Case for each member)





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	0.0071	2.5490	0.0353	0.1081	-0.0028	-0.0387
ULS: 2. D + L	0.0071	2.5490	0.0353	0.1081	-0.0028	-0.0387
ULS: 3. D + (S or Lr or R)	0.0260	7.7893	0.1296	0.3973	-0.0106	-0.2121
ULS: 3. D + (S or Lr or R)	0.0071	2.5490	0.0353	0.1081	-0.0028	-0.0387
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0213	6.4792	0.1060	0.3250	-0.0086	-0.1687
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0071	2.5490	0.0353	0.1081	-0.0028	-0.0387
ULS: 5b. D + 0.7E	0.0071	2.5490	0.0353	0.1081	-0.0028	-0.0387
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0213	6.4792	0.1060	0.3250	-0.0086	-0.1687
ULS: 8. 0.6D + 0.7E	0.0043	1.5294	0.0212	0.0649	-0.0017	-0.0232
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.4689	7.0627	0.1282	0.3819	-0.1241	17.1939
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.4689	7.0627	0.1282	0.3819	-0.1241	17.1939
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2074	-1.1288	-0.0364	-0.1029	0.0895	-10.9793
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.0595	-0.6484	-0.0403	-0.1137	0.1013	-22.1561
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0857	9.8645	0.1757	0.5304	-0.0997	12.7558
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0857	9.8645	0.1757	0.5304	-0.0997	12.7558
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9215	3.7209	0.0523	0.1668	0.0605	-8.3742
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8106	4.0811	0.0494	0.1587	0.0694	-16.7568
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0999	5.9342	0.1050	0.3134	-0.0938	12.8858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0999	5.9342	0.1050	0.3134	-0.0938	12.8858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9073	-0.2093	-0.0185	-0.0502	0.0664	-8.2442
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.7964	0.1509	-0.0214	-0.0582	0.0753	-16.6267
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.4718	6.0431	0.1141	0.3387	-0.1230	17.2094
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.4718	6.0431	0.1141	0.3387	-0.1230	17.2094
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.2045	-2.1484	-0.0505	-0.1461	0.0906	-10.9639
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.0567	-1.6680	-0.0544	-0.1569	0.1024	-22.1406

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	15.2050
Shear X	-2.4600
Shear Z	0.2723
Moment X	0.8278
Moment Y (Twist)	0.2108
Moment Z	37.6899

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	9.8645
Shear X	-1.4718
Shear Z	0.1757
Moment X	0.5304
Moment Y (Twist)	0.1241
Moment Z	22.1561

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	-0.0071	2.8747	-0.0038	-0.0115	0.0042	0.1039
ULS: 2. D + L	-0.0071	2.8747	-0.0038	-0.0115	0.0042	0.1039
ULS: 3. D + (S or Lr or R)	-0.0260	8.9791	-0.0138	-0.0424	0.0155	0.3174
ULS: 3. D + (S or Lr or R)	-0.0071	2.8747	-0.0038	-0.0115	0.0042	0.1039
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0213	7.4530	-0.0113	-0.0347	0.0127	0.2640
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0071	2.8747	-0.0038	-0.0115	0.0042	0.1039
ULS: 5b. D + 0.7E	-0.0071	2.8747	-0.0038	-0.0115	0.0042	0.1039

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0213	7.4530	-0.0113	-0.0347	0.0127	0.2640
ULS: 8. 0.6D + 0.7E	-0.0043	1.7248	-0.0023	-0.0069	0.0025	0.0623
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7058	8.1318	-0.0066	-0.0215	-0.0005	19.8410
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.7058	8.1318	-0.0066	-0.0215	-0.0005	19.8410
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.3809	-1.4136	0.0007	0.0027	0.0035	-12.4412
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.1850	-0.8360	-0.0076	-0.0213	0.0200	-24.8704
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2953	11.3958	-0.0134	-0.0422	0.0092	15.0668
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2953	11.3958	-0.0134	-0.0422	0.0092	15.0668
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0198	4.2367	-0.0080	-0.0240	0.0122	-9.1448
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8728	4.6700	-0.0142	-0.0420	0.0246	-18.4667
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2811	6.8175	-0.0059	-0.0190	0.0007	14.9067
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2811	6.8175	-0.0059	-0.0190	0.0007	14.9067
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0339	-0.3416	-0.0004	-0.0008	0.0037	-9.3049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8870	0.0917	-0.0066	-0.0189	0.0161	-18.6268
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7030	6.9820	-0.0051	-0.0169	-0.0021	19.7994
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.7030	6.9820	-0.0051	-0.0169	-0.0021	19.7994
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.3838	-2.5635	0.0022	0.0074	0.0018	-12.4827
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.1879	-1.9859	-0.0061	-0.0167	0.0183	-24.9120

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	17.5973
Shear X	-2.8485
Shear Z	-0.0247
Moment X	-0.0740
Moment Y (Twist)	0.0385
Moment Z	42.2582

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	11.3958
Shear X	-1.7058
Shear Z	-0.0142
Moment X	-0.0424
Moment Y (Twist)	0.0246
Moment Z	24.9120

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	-0.0071	2.8747	0.0038	0.0115	-0.0042	0.1039
ULS: 2. D + L	-0.0071	2.8747	0.0038	0.0115	-0.0042	0.1039
ULS: 3. D + (S or Lr or R)	-0.0260	8.9791	0.0138	0.0424	-0.0154	0.3174
ULS: 3. D + (S or Lr or R)	-0.0071	2.8747	0.0038	0.0115	-0.0042	0.1039
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0213	7.4530	0.0113	0.0347	-0.0126	0.2640
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0071	2.8747	0.0038	0.0115	-0.0042	0.1039
ULS: 5b. D + 0.7E	-0.0071	2.8747	0.0038	0.0115	-0.0042	0.1039
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0213	7.4530	0.0113	0.0347	-0.0126	0.2640
ULS: 8. 0.6D + 0.7E	-0.0043	1.7248	0.0023	0.0069	-0.0025	0.0623
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7058	8.1318	0.0066	0.0215	0.0005	19.8410
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.7058	8.1318	0.0066	0.0215	0.0005	19.8410
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.3809	-1.4136	-0.0007	-0.0027	-0.0035	-12.4412
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.1850	-0.8360	0.0076	0.0213	-0.0200	-24.8704
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2953	11.3958	0.0134	0.0422	-0.0091	15.0668
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2953	11.3958	0.0134	0.0422	-0.0091	15.0668
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0198	4.2367	0.0080	0.0240	-0.0121	-9.1448
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8728	4.6700	0.0142	0.0420	-0.0244	-18.4667

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	-1.2811	6.8175	0.0059	0.0190	-0.0007	14.9067
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.2811	6.8175	0.0059	0.0190	-0.0007	14.9067
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.0339	-0.3416	0.0004	0.0008	-0.0037	-9.3049
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8870	0.0917	0.0066	0.0189	-0.0161	-18.6268
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.7030	6.9820	0.0051	0.0169	0.0022	19.7994
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.7030	6.9820	0.0051	0.0169	0.0022	19.7994
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.3838	-2.5635	-0.0022	-0.0073	-0.0018	-12.4827
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.1879	-1.9859	0.0061	0.0167	-0.0183	-24.9120

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	17.5973
Shear X	-2.8485
Shear Z	0.0247
Moment X	0.0743
Moment Y (Twist)	0.0385
Moment Z	42.2582

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	11.3958
Shear X	-1.7058
Shear Z	0.0142
Moment X	0.0424
Moment Y (Twist)	0.0244
Moment Z	24.9120

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	0.0071	2.5490	-0.0353	-0.1081	0.0028	-0.0387
ULS: 2. D + L	0.0071	2.5490	-0.0353	-0.1081	0.0028	-0.0387
ULS: 3. D + (S or Lr or R)	0.0260	7.7893	-0.1296	-0.3974	0.0108	-0.2120
ULS: 3. D + (S or Lr or R)	0.0071	2.5490	-0.0353	-0.1081	0.0028	-0.0387
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0213	6.4792	-0.1060	-0.3251	0.0088	-0.1687
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0071	2.5490	-0.0353	-0.1081	0.0028	-0.0387
ULS: 5b. D + 0.7E	0.0071	2.5490	-0.0353	-0.1081	0.0028	-0.0387
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0213	6.4792	-0.1060	-0.3251	0.0088	-0.1687
ULS: 8. 0.6D + 0.7E	0.0043	1.5294	-0.0212	-0.0649	0.0017	-0.0232
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.4689	7.0627	-0.1282	-0.3819	0.1241	17.1939
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.4689	7.0627	-0.1282	-0.3819	0.1241	17.1939
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2074	-1.1288	0.0364	0.1029	-0.0894	-10.9793
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.0595	-0.6484	0.0403	0.1137	-0.1012	-22.1561
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0857	9.8645	-0.1757	-0.5304	0.0998	12.7558
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0857	9.8645	-0.1757	-0.5304	0.0998	12.7558
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9215	3.7209	-0.0523	-0.1668	-0.0604	-8.3741
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8106	4.0811	-0.0494	-0.1587	-0.0692	-16.7567
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0999	5.9342	-0.1050	-0.3134	0.0938	12.8858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0999	5.9342	-0.1050	-0.3134	0.0938	12.8858
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9073	-0.2093	0.0185	0.0502	-0.0664	-8.2442
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.7964	0.1509	0.0214	0.0582	-0.0752	-16.6267
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.4718	6.0431	-0.1141	-0.3387	0.1230	17.2094
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.4718	6.0431	-0.1141	-0.3387	0.1230	17.2094
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.2045	-2.1484	0.0505	0.1461	-0.0906	-10.9638
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.0567	-1.6680	0.0544	0.1569	-0.1024	-22.1406

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 Foundation Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	15.2050
Shear X	-2.4600
Shear Z	-0.2723
Moment X	-0.8281
Moment Y (Twist)	0.2112
Moment Z	37.6904

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	9.8645
Shear X	-1.4718
Shear Z	-0.1757
Moment X	-0.5304
Moment Y (Twist)	0.1241
Moment Z	22.1561

Project Details

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

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

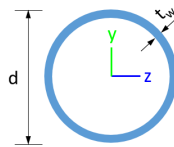


Design Input Information

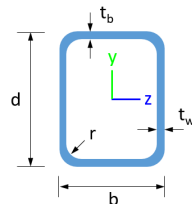
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

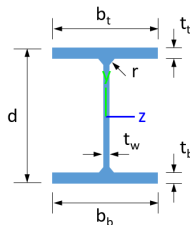
Section Dimensions



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

108	20	1.33	1.33	2.0 5	2.26,2.26,2.26,2.25,2.26,2.26,2.25,2.25,2.25,2.33,2.25,2.25,2.25,2.11,2.25,2.25,2.26,2.27,2.25,2.25,2.25,2.34,2.25,2.25,2.25,2.02	3 0 0	2 0 0	1
109	3	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
110	17	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.69	3 0 0	2 0 0	1
111	20	1.33	1.33	2.0 5	2.26,2.26,2.26,2.26,2.26,2.26,2.29,2.29,2.12,2.16,2.29,2.29,2.30,2.35,2.27,2.27,2.25,2.18,2.29,2.29,2.15,2.20,2.29,2.29,2.30,2.34	3 0 0	2 0 0	1
112	6	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
113	20	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.09,1.03,1.03,1.03,1.04,1.03,1.03,1.03,1.02,1.03,1.03,1.04,1.08,1.03,1.03,1.03,1.04	3 0 0	2 0 0	1
114	20	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.11,1.03,1.03,1.03,1.58,1.03,1.03,1.03,1.03,1.03,1.03,1.12,1.03,1.03,1.03,2.91	3 0 0	2 0 0	1
115	20	8.42	8.42	12. 95	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.16,1.13,1.14,1.16,1.16,1.16,1.15,1.16,1.16,1.17,1.19,1.16,1.16,1.14,1.14,1.16,1.16,1.16,1.15	3 0 0	2 0 0	1
116	20	8.42	8.42	12. 95	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.17,1.17,1.17,1.13,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.17,1.17,1.17,1.13	3 0 0	2 0 0	1
201	9	22.1 4	22.1 4	10. 54	-	3 0 0	2 0 0	1
202	6	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
203	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.17,1.18,1.18,1.17,1.18	3 0 0	2 0 0	1
204	17	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.69	3 0 0	2 0 0	1
205	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.66,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
206	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.14,1.17,1.18,1.18,1.17,1.18	3 0 0	2 0 0	1
207	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.64,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.62,1.66,1.67,1.67,1.66,1.66	3 0 0	2 0 0	1
208	20	1.33	1.33	2.0 5	2.30,2.30,2.30,2.30,2.30,2.30,2.29,2.29,2.29,2.14,2.29,2.29,2.29,1.99,2.29,2.29,2.30,2.32,2.29,2.29,2.29,2.13,2.29,2.29,2.30,1.62	3 0 0	2 0 0	1
209	3	2.60	2.60	4.0 0	-	3 0 0	2 0 0	1
210	17	2.44	2.44	3.7 5	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.69,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.64,1.69,1.67,1.67,1.66,1.70	3 0 0	2 0 0	1
211	20	1.33	1.33	2.0 5	2.31,2.31,2.31,2.31,2.31,2.31,2.35,2.35,2.09,2.11,2.35,2.35,2.35,2.13,2.32,2.32,2.29,2.23,2.34,2.34,2.11,2.11,2.36,2.36,2.36,2.14	3 0 0	2 0 0	1
212	6	1.30	1.30	2.0 0	-	3 0 0	2 0 0	1
213	20	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.04,1.09,1.03,1.03,1.03,1.04,1.03,1.03,1.03,1.02,1.03,1.03,1.04,1.08,1.03,1.03,1.03,1.04	3 0 0	2 0 0	1
214	20	4.88	4.00	7.5 0	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.11,1.03,1.03,1.03,1.58,1.03,1.03,1.03,1.03,1.03,1.03,1.12,1.03,1.03,1.03,2.91	3 0 0	2 0 0	1
215	20	8.42	8.42	12. 95	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.15,1.15,1.17,1.17,1.16,1.16,1.17,1.17,1.18,1.19,1.17,1.17,1.15,1.15,1.17,1.17,1.17,1.16	3 0 0	2 0 0	1
216	20	8.42	8.42	12. 95	1.17,1.17,1.17,1.17,1.17,1.17,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.14,1.18,1.18,1.17,1.17,1.18,1.18,1.16,1.18,1.18,1.18,1.13	3 0 0	2 0 0	1
301	9	22.1 4	22.1 4	10. 54	-	3 0 0	2 0 0	1

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	116.35	31.32	6.46	56.26	44.91
114	159.30	116.35	31.45	6.46	56.26	44.91
115	159.30	48.27	15.06	6.46	56.26	44.91
116	159.30	48.27	14.99	6.46	56.26	44.91
201	377.97	207.84	83.29	83.29	113.39	113.39
202	251.01	248.88	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	142.47	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	142.47	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	116.35	31.32	6.46	56.26	44.91
214	159.30	116.35	31.45	6.46	56.26	44.91
215	159.30	48.27	15.22	6.46	56.26	44.91
216	159.30	48.27	15.00	6.46	56.26	44.91
301	377.97	207.84	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	34.37	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	34.37	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	116.35	32.35	6.46	56.26	44.91
314	159.30	116.35	33.13	6.46	56.26	44.91
315	159.30	48.27	15.06	6.46	56.26	44.91
316	159.30	48.27	15.05	6.46	56.26	44.91

Design Ratio

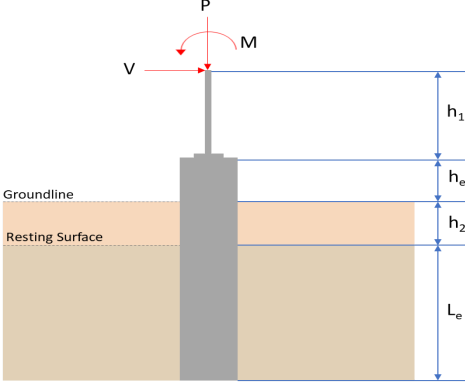
Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	φ	Status
1	0.073	0.453	0.024	0.022	0.002	0.455	#16	0.452	Not Required	Pass
2	0.003	0.431	0.092	0.093	0.016	0.504	#21	0.036	Not Required	Pass
3	0.005	0.645	0.028	0.064	0.005	0.658	#21	0.046	Not Required	Pass
4	0.005	0.617	0.106	0.063	0.022	0.601	#21	0.032	Not Required	Pass

4	0.005	0.400	0.102	0.064	0.027	0.425	#21	0.076	Not Required	Pass
5	0.005	0.400	0.102	0.064	0.027	0.425	#21	0.076	Not Required	Pass
6	0.006	0.717	0.047	0.072	0.006	0.767	#21	0.046	Not Required	Pass
7	0.007	0.444	0.142	0.071	0.037	0.484	#21	0.076	Not Required	Pass
8	0.001	0.063	0.175	0.046	0.014	0.202	#24	0.102	Not Required	Pass
9	0.014	0.075	0.048	0.002	0.002	0.130	#21	0.206	Not Required	Pass
10	0.007	0.681	0.132	0.068	0.028	0.755	#21	0.082	Not Required	Pass
11	0.002	0.063	0.179	0.048	0.014	0.208	#21	0.102	Not Required	Pass
12	0.003	0.506	0.099	0.105	0.017	0.583	#21	0.054	Not Required	Pass
13	0.005	0.261	0.374	0.060	0.018	0.576	#21	0.306	Not Required	Pass
14	0.006	0.252	0.369	0.057	0.018	0.554	#21	0.204	Not Required	Pass
15	0.000	0.089	0.149	0.031	0.009	0.238	#21	Not Required	Not Required	Pass
16	0.000	0.086	0.149	0.030	0.009	0.234	#21	Not Required	Not Required	Pass
101	0.085	0.507	0.002	0.025	0.000	0.509	#16	0.452	Not Required	Pass
102	0.003	0.548	0.112	0.115	0.019	0.637	#21	0.036	Not Required	Pass
103	0.007	0.792	0.033	0.079	0.001	0.829	#21	0.046	Not Required	Pass
104	0.007	0.763	0.134	0.076	0.028	0.848	#21	0.082	Not Required	Pass
105	0.007	0.492	0.141	0.078	0.037	0.530	#21	0.076	Not Required	Pass
106	0.007	0.789	0.032	0.079	0.001	0.822	#21	0.046	Not Required	Pass
107	0.007	0.490	0.138	0.078	0.036	0.527	#21	0.076	Not Required	Pass
108	0.001	0.070	0.170	0.048	0.014	0.241	#21	0.102	Not Required	Pass
109	0.016	0.078	0.034	0.001	0.000	0.120	#21	0.206	Not Required	Pass
110	0.006	0.755	0.133	0.076	0.028	0.841	#21	0.082	Not Required	Pass
111	0.002	0.069	0.174	0.049	0.014	0.244	#21	0.102	Not Required	Pass
112	0.003	0.541	0.112	0.114	0.019	0.630	#21	0.036	Not Required	Pass
113	0.005	0.299	0.375	0.062	0.018	0.647	#21	0.306	Not Required	Pass
114	0.007	0.300	0.372	0.060	0.018	0.641	#21	0.306	Not Required	Pass
115	0.007	0.518	0.198	0.051	0.014	0.720	#21	0.644	Not Required	Pass
116	0.002	0.496	0.199	0.049	0.014	0.694	#21	0.644	Not Required	Pass
201	0.085	0.507	0.002	0.025	0.000	0.509	#16	0.452	Not Required	Pass
202	0.003	0.541	0.112	0.114	0.019	0.630	#21	0.036	Not Required	Pass
203	0.007	0.789	0.032	0.079	0.001	0.822	#21	0.046	Not Required	Pass
204	0.006	0.755	0.133	0.076	0.028	0.841	#21	0.082	Not Required	Pass
205	0.007	0.490	0.138	0.078	0.036	0.527	#21	0.076	Not Required	Pass
206	0.007	0.792	0.033	0.079	0.001	0.829	#21	0.046	Not Required	Pass
207	0.007	0.492	0.141	0.078	0.037	0.530	#21	0.076	Not Required	Pass
208	0.001	0.065	0.177	0.049	0.014	0.243	#21	0.102	Not Required	Pass
209	0.016	0.078	0.034	0.001	0.000	0.120	#21	0.206	Not Required	Pass
210	0.007	0.763	0.134	0.076	0.028	0.848	#21	0.082	Not Required	Pass
211	0.002	0.063	0.180	0.051	0.014	0.244	#21	0.102	Not Required	Pass
212	0.003	0.548	0.112	0.115	0.019	0.637	#21	0.036	Not Required	Pass
213	0.005	0.299	0.375	0.062	0.018	0.647	#21	0.306	Not Required	Pass
214	0.007	0.300	0.372	0.060	0.018	0.641	#21	0.306	Not Required	Pass
215	0.006	0.457	0.198	0.049	0.014	0.658	#21	0.644	Not Required	Pass
216	0.002	0.428	0.198	0.048	0.014	0.625	#21	0.644	Not Required	Pass
301	0.073	0.453	0.024	0.022	0.002	0.455	#16	0.452	Not Required	Pass
302	0.003	0.506	0.099	0.105	0.017	0.583	#21	0.054	Not Required	Pass
303	0.006	0.717	0.047	0.072	0.006	0.767	#21	0.046	Not Required	Pass
304	0.007	0.681	0.132	0.068	0.028	0.755	#21	0.082	Not Required	Pass
305	0.007	0.444	0.142	0.071	0.037	0.484	#21	0.076	Not Required	Pass
306	0.005	0.645	0.028	0.064	0.005	0.658	#21	0.046	Not Required	Pass
307	0.005	0.400	0.102	0.064	0.027	0.425	#21	0.076	Not Required	Pass
308	0.000	0.086	0.149	0.030	0.009	0.234	#21	Not Required	Not Required	Pass
309	0.014	0.075	0.048	0.002	0.002	0.130	#21	0.206	Not Required	Pass

310	0.005	0.617	0.106	0.062	0.023	0.691	#21	0.082	Not Required	Pass
311	0.000	0.089	0.149	0.031	0.009	0.238	#21	Not Required	Not Required	Pass
312	0.003	0.431	0.092	0.093	0.016	0.504	#21	0.036	Not Required	Pass
313	0.005	0.261	0.374	0.060	0.018	0.576	#21	0.204	Not Required	Pass
314	0.006	0.252	0.369	0.057	0.018	0.554	#21	0.306	Not Required	Pass
315	0.007	0.527	0.198	0.048	0.014	0.728	#21	0.644	Not Required	Pass
316	0.002	0.507	0.198	0.046	0.014	0.702	#21	0.644	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry Pile shape: round $D = 36$ in - Pile diameter $L = 8.75$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resisting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1" data-bbox="416 1079 1193 1171"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1" data-bbox="676 1265 935 1435"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>9.864</td> <td>15.205</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.472</td> <td>-2.460</td> </tr> <tr> <td>V_z (kip)</td> <td>0.176</td> <td>0.272</td> </tr> <tr> <td>M_x (kipft)</td> <td>0.530</td> <td>0.828</td> </tr> <tr> <td>M_z (kipft)</td> <td>22.156</td> <td>37.690</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 2.5$ ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	9.864	15.205	V_x (kip)	-1.472	-2.460	V_z (kip)	0.176	0.272	M_x (kipft)	0.530	0.828	M_z (kipft)	22.156	37.690	
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	<p>Required depth to resist lateral loads (ASD) H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction: H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-1.472 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.49067 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(22.156 \text{ kipft}) + ((-1.472 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.3853 \text{ kipft/ft}$$

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:

$L_{e,x} = 8.1897 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.176 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.058667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.53 \text{ kipft}) + ((0.176 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.17667 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:

$L_{e,z} = 3.4572 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(8.1897 \text{ ft}), (3.4572 \text{ ft})]$$

$$L_{e,req} = 8.19 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (8.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.75 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(8.19 \text{ ft})}{(8.75 \text{ ft})}$$

$$\text{Ratio} = 0.936$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(9.864 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.3955 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.3955 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.69774$$

Status: **PASS**
Ratio: **0.700**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.9167$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.49067 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 7.3853 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.3853 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (7.3853 \text{ kipft/ft})) + (4 \times (-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.037 \text{ ft}$$

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

$$p = \frac{1.178 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.3853 \text{ kipft/ft})) + (3 \times (-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft}))]^2}{(8.75 \text{ ft})^2 \times [(3 \times (7.3853 \text{ kipft/ft})) + (2 \times (-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = 0.31477 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

$$s = \frac{9.425 [(2 M_o) + (H_o L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.3853 \text{ kipft/ft})) + ((-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = 1.2898 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.037 \text{ ft})}{2}$$

$$p_a = 0.45277 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.31477 \text{ kip/ft}^2)}{(0.45277 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.6952$$

Status: **PASS**
Ratio: **0.700**

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.75 \text{ ft})$$

$$p_s = 1.3125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.2898 \text{ kip/ft}^2)}{(1.3125 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.98269$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = 0.058667 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.17667 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17667 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (0.058667 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (0.17667 \text{ kipft/ft})) + (4 \times (0.058667 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.3142 \text{ ft}$$

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

$$p = \frac{1.178 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.17667 \text{ kipft/ft})) + (3 \times (0.058667 \text{ kip/ft}) \times (8.75 \text{ ft}))]^2}{(8.75 \text{ ft})^2 \times [(3 \times (0.17667 \text{ kipft/ft})) + (2 \times (0.058667 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = 0.04989 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

$$s = \frac{9.425 [(2 M_o) + (H_o L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.17667 \text{ kipft/ft})) + ((0.058667 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = 0.10669 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.3142 \text{ ft})}{2}$$

$$p_a = 0.47357 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.04989 \text{ kip/ft}^2)}{(0.47357 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.10535$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.75 \text{ ft})$$

$$p_s = 1.3125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

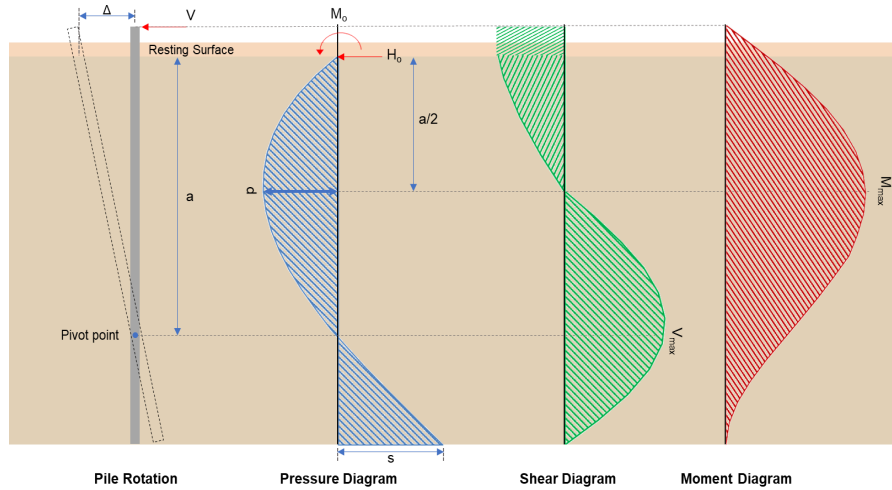
Status: **PASS**
Ratio: **0.110**

$$ratio = \frac{M_o}{p_s}$$

$$Ratio = \frac{(0.10669 \text{ kip/ft}^2)}{(1.3125 \text{ kip/ft}^2)}$$

$$Ratio = 0.081286$$

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



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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-2.46 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.82 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.69 \text{ kipft}) + ((-2.46 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 12.563 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.563 \text{ kipft/ft})}{(-0.82 \text{ kip/ft})}$$

$$E = 15.321 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.563 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (-0.82 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (12.563 \text{ kipft/ft})) + (4 \times (-0.82 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.0344 \text{ ft}$$

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

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

$$V_{max} = ((-0.82 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.321 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.0344 \text{ ft})}{(8.75 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (15.321 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.0344 \text{ ft})}{(8.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.2447 \text{ kip}$$

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

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

$$M_{max} = ((-0.82 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(15.321 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.0344 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (15.321 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.0344 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (15.321 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.0344 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 38.491 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.272 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.090667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.828 \text{ kipft}) + ((0.272 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.276 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.276 \text{ kipft/ft})}{(0.090667 \text{ kip/ft})}$$

$$E = 3.0441 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.276 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (0.090667 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (0.276 \text{ kipft/ft})) + (4 \times (0.090667 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.3125 \text{ ft}$$

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

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

$$V_{max} = ((0.090667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.0441 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.3125 \text{ ft})}{(8.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.0441 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.3125 \text{ ft})}{(8.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.34969 \text{ kip}$$

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

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

$$M_{max} = ((0.090667 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(3.0441 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.3125 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.0441 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.3125 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.0441 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.3125 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.3186 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

- $f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
 $f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
 $\phi = 0.65$ - Reduction factor for axial strength,
 $\alpha = 0.85$ - Alpha factor for axial strength,
 $A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(15.205 \text{ kip})}{(0.65)(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.898 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-36.898 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

$$\text{Ratio} = 0.99533$$

25.2.3

s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

25.7.2.2

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

25.7.2.1

s_{ties} - Maximum center-to-center spacing of ties,

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

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]$$

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

Summary:

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

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]$$

$$\phi P_N = 1253.9 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(15,205 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.012126$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2

$b_w = 36 \text{ in}$ - Effective width,
 d - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3

λ_s - size effect modification factor

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

$$\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.71796$$

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

22.5.5.1.1

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,max} = 186.09 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15,205 \text{ kip} \rightarrow 15205 \text{ lbf}$.

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(15205 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.019 \text{ kip}$$

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

22.5.5.1.2

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

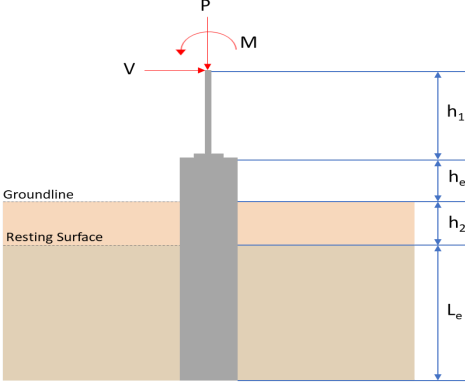
V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (77.019 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;">$V_c = 77.019 \text{ kip}$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$.</p> <p>$V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$ $V_{s,a} = 414.72 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>$V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 38.17 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$ $V_s = 38.17 \text{ kip}$ <p>ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((77.019 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 74.873 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 9.2447 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(9.2447 \text{ kip})}{(74.873 \text{ kip})}$ $Ratio = 0.12347$ <p>Considering z-direction:</p> <p>$V_{max} = 0.34969 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.34969 \text{ kip})}{(74.873 \text{ kip})}$ $Ratio = 0.0046704$	<p>Status: PASS Ratio: 0.120</p> <p>Status: PASS Ratio: 0.000</p>
	<p>Flexural Strength (ACI 318-19, LFRD)</p> <p>S_m - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (36 \text{ in})^3}{32}$	

	<p style="text-align: center;">$S_m = 4580.4 \text{ in}^3$</p> <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 4580.442 \text{ in}^3$ $\phi M_{n,1} = 62.027 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$ $\phi M_n = 62.027 \text{ kipft}$ <p>Considering x-direction: $M_{max} = 38.491 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(38.491 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.62055$	<p>Status: PASS Ratio: 0.620</p>
	<p>Considering z-direction: $M_{max} = 1.3186 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(1.3186 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.021258$	<p>Status: PASS Ratio: 0.020</p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry Pile shape: round $D = 36$ in - Pile diameter $L = 8.75$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resisting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1" data-bbox="416 1079 1193 1171"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1" data-bbox="676 1265 935 1435"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>9.864</td> <td>15.205</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.472</td> <td>-2.460</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.176</td> <td>-0.272</td> </tr> <tr> <td>M_x (kipft)</td> <td>-0.530</td> <td>-0.828</td> </tr> <tr> <td>M_z (kipft)</td> <td>22.156</td> <td>37.690</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 2.5$ ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	9.864	15.205	V_x (kip)	-1.472	-2.460	V_z (kip)	-0.176	-0.272	M_x (kipft)	-0.530	-0.828	M_z (kipft)	22.156	37.690	
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	<p>Required depth to resist lateral loads (ASD) H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction: H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-1.472 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.49067 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(22.156 \text{ kipft}) + ((-1.472 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.3853 \text{ kipft/ft}$$

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:

$L_{e,x} = 8.1897 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.176 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.058667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.53 \text{ kipft}) + ((-0.176 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.17667 \text{ kipft/ft}$$

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:

$L_{e,z} = 2.1691 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(8.1897 \text{ ft}), (2.1691 \text{ ft})]$$

$$L_{e,req} = 8.19 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (8.75 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.75 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(8.19 \text{ ft})}{(8.75 \text{ ft})}$$

$$\text{Ratio} = 0.936$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(9.864 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.3955 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.3955 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.69774$$

Status: **PASS**
Ratio: **0.700**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.75 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.9167$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.49067 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 7.3853 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.3853 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (7.3853 \text{ kipft/ft})) + (4 \times (-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.037 \text{ ft}$$

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

$$p = \frac{1.178 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.3853 \text{ kipft/ft})) + (3 \times (-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft}))]^2}{(8.75 \text{ ft})^2 \times [(3 \times (7.3853 \text{ kipft/ft})) + (2 \times (-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = 0.31477 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

$$s = \frac{9.425 [(2 M_o) + (H_o L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.3853 \text{ kipft/ft})) + ((-0.49067 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = 1.2898 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.037 \text{ ft})}{2}$$

$$p_a = 0.45277 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.31477 \text{ kip/ft}^2)}{(0.45277 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.6952$$

Status: **PASS**
Ratio: **0.700**

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.75 \text{ ft})$$

$$p_s = 1.3125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.2898 \text{ kip/ft}^2)}{(1.3125 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.98269$$

Status: **PASS**
Ratio: **0.980**

Considering z-direction:

$H_o = -0.058667 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.17667 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17667 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (-0.058667 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (0.17667 \text{ kipft/ft})) + (4 \times (-0.058667 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.3142 \text{ ft}$$

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

$$p = \frac{1.178 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.17667 \text{ kipft/ft})) + (3 \times (-0.058667 \text{ kip/ft}) \times (8.75 \text{ ft}))]^2}{(8.75 \text{ ft})^2 \times [(3 \times (0.17667 \text{ kipft/ft})) + (2 \times (-0.058667 \text{ kip/ft}) \times (8.75 \text{ ft}))]}$$

$$p = -0.021513 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

$$s = \frac{9.425 [(2 M_o) + (H_o L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.17667 \text{ kipft/ft})) + ((-0.058667 \text{ kip/ft}) \times (8.75 \text{ ft}))]}{(8.75 \text{ ft})^2}$$

$$s = -0.019696 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.3142 \text{ ft})}{2}$$

$$p_a = 0.47357 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.021513 \text{ kip/ft}^2)}{(0.47357 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.045428$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8.75 \text{ ft})$$

$$p_s = 1.3125 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

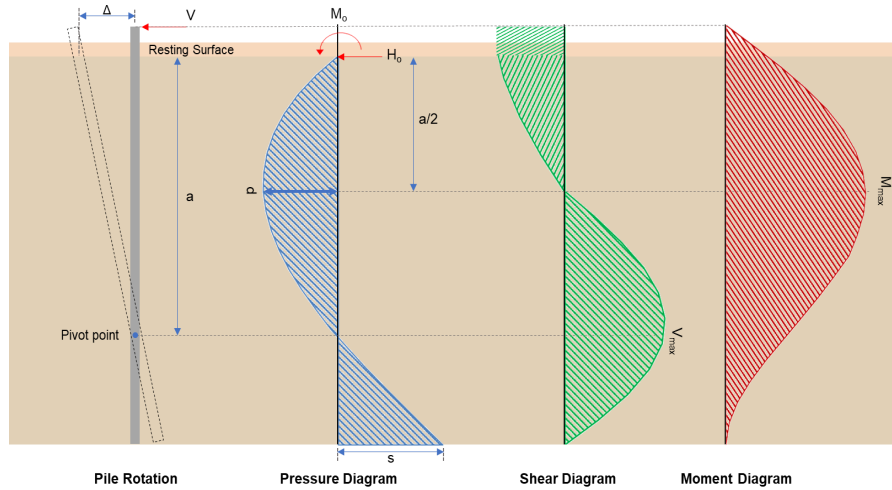
Status: **PASS**
Ratio: **-0.050**

$$ratio = \frac{M_o}{p_s}$$

$$Ratio = \frac{(-0.019696 \text{ kip/ft}^2)}{(1.3125 \text{ kip/ft}^2)}$$

$$Ratio = -0.015007$$

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



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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-2.46 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.82 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(37.69 \text{ kipft}) + ((-2.46 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 12.563 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.563 \text{ kipft/ft})}{(-0.82 \text{ kip/ft})}$$

$$E = 15.321 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.563 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (-0.82 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (12.563 \text{ kipft/ft})) + (4 \times (-0.82 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.0344 \text{ ft}$$

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

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

$$V_{max} = ((-0.82 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (15.321 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.0344 \text{ ft})}{(8.75 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (15.321 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.0344 \text{ ft})}{(8.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.2447 \text{ kip}$$

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

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

$$M_{max} = ((-0.82 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(15.321 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.0344 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (15.321 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.0344 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (15.321 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.0344 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 38.491 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.272 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.090667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.828 \text{ kipft}) + ((-0.272 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.276 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.276 \text{ kipft/ft})}{(-0.090667 \text{ kip/ft})}$$

$$E = 3.0441 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.276 \text{ kipft/ft}) \times (8.75 \text{ ft})) + (3 \times (-0.090667 \text{ kip/ft}) \times (8.75 \text{ ft})^2)}{(6 \times (0.276 \text{ kipft/ft})) + (4 \times (-0.090667 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.3125 \text{ ft}$$

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

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

$$V_{max} = ((-0.090667 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.0441 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.3125 \text{ ft})}{(8.75 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (3.0441 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.3125 \text{ ft})}{(8.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.34969 \text{ kip}$$

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

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

$$M_{max} = ((-0.090667 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(3.0441 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.3125 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.0441 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.3125 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (3.0441 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.3125 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 1.3186 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

- $f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
 $f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
 $\phi = 0.65$ - Reduction factor for axial strength,
 $\alpha = 0.85$ - Alpha factor for axial strength,
 $A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(15.205 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.898 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-36.898 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

$$\text{Ratio} = 0.99533$$

25.2.3

s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

25.7.2.2

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

25.7.2.1

s_{ties} - Maximum center-to-center spacing of ties,

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

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]$$

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

Summary:

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

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]$$

$$\phi P_N = 1253.9 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(15,205 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.012126$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2

$b_w = 36 \text{ in}$ - Effective width,
 d - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3

λ_s - size effect modification factor

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

$$\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.71796$$

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

22.5.5.1.1

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,max} = 186.09 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 15,205 \text{ kip} \rightarrow 15205 \text{ lbf}$.

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(15205 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.019 \text{ kip}$$

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

22.5.5.1.2

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

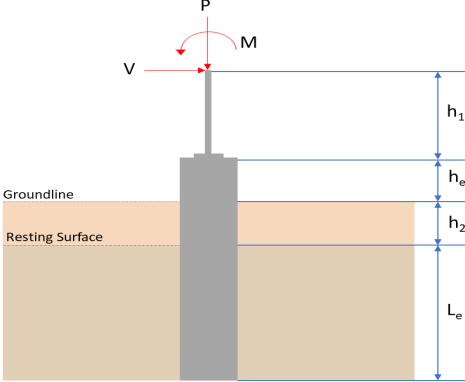
V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (77.019 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;">$V_c = 77.019 \text{ kip}$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$.</p> <p>$V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$ $V_{s,a} = 414.72 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>$V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 38.17 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$ $V_s = 38.17 \text{ kip}$ <p>ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((77.019 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 74.873 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 9.2447 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(9.2447 \text{ kip})}{(74.873 \text{ kip})}$ $Ratio = 0.12347$ <p>Considering z-direction:</p> <p>$V_{max} = 0.34969 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.34969 \text{ kip})}{(74.873 \text{ kip})}$ $Ratio = 0.0046704$	<p>Status: PASS Ratio: 0.120</p> <p>Status: PASS Ratio: 0.000</p>
	<p>Flexural Strength (ACI 318-19, LRFD)</p> <p>S_m - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (36 \text{ in})^3}{32}$	

<p>14.5.2.1b</p>	<p style="text-align: center;">$S_m = 4580.4 \text{ in}^3$</p> <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 4580.442 \text{ in}^3$ $\phi M_{n,1} = 62.027 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$ $\phi M_n = 62.027 \text{ kipft}$ <p>Considering x-direction: $M_{max} = 38.491 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(38.491 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.62055$	<p>Status: PASS Ratio: 0.620</p>
	<p>Considering z-direction: $M_{max} = 1.3186 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(1.3186 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.021258$	<p>Status: PASS Ratio: 0.020</p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry Pile shape: round $D = 36$ in - Pile diameter $L = 9$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resisting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1" data-bbox="416 1079 1193 1171"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1" data-bbox="676 1265 935 1435"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>11.396</td> <td>17.597</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.706</td> <td>-2.848</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.014</td> <td>-0.025</td> </tr> <tr> <td>M_x (kipft)</td> <td>-0.042</td> <td>-0.074</td> </tr> <tr> <td>M_z (kipft)</td> <td>24.912</td> <td>42.258</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 2.5$ ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	11.396	17.597	V_x (kip)	-1.706	-2.848	V_z (kip)	-0.014	-0.025	M_x (kipft)	-0.042	-0.074	M_z (kipft)	24.912	42.258	
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M_z (kipft)	24.912	42.258																										
	<p>Required depth to resist lateral loads (ASD) H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction: H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-1.706 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.56867 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(24.912 \text{ kipft}) + ((-1.706 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 8.304 \text{ kipft/ft}$$

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:

$L_{e,x} = 8.402 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.014 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0046667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.042 \text{ kipft}) + ((-0.014 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.014 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.0861 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(8.402 \text{ ft}), (1.0861 \text{ ft})]$$

$$L_{e,req} = 8.402 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (9 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 9 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(8.402 \text{ ft})}{(9 \text{ ft})}$$

$$\text{Ratio} = 0.93356$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(11.396 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.6122 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.6122 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.8061$$

Status: **PASS**
Ratio: **0.810**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(9 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 3$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.56867 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 8.304 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.304 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.56867 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (8.304 \text{ kipft/ft})) + (4 \times (-0.56867 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.2184 \text{ ft}$$

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

$$p = \frac{1.178 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (8.304 \text{ kipft/ft})) + (3 \times (-0.56867 \text{ kip/ft}) \times (9 \text{ ft}))]^2}{(9 \text{ ft})^2 \times [(3 \times (8.304 \text{ kipft/ft})) + (2 \times (-0.56867 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = 0.31616 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

$$s = \frac{9.425 [(2 M_o) + (H_o L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (8.304 \text{ kipft/ft})) + ((-0.56867 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = 1.337 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.2184 \text{ ft})}{2}$$

$$p_a = 0.46638 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.31616 \text{ kip/ft}^2)}{(0.46638 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.67791$$

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

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9 \text{ ft})$$

$$p_s = 1.35 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.337 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.99034$$

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

Considering z-direction:

$H_o = -0.0046667 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.014 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.014 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.0046667 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (0.014 \text{ kipft/ft})) + (4 \times (-0.0046667 \text{ kip/ft}) \times (9 \text{ ft}))}$$

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

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

$$p = \frac{1.178 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.014 \text{ kipft/ft})) + (3 \times (-0.0046667 \text{ kip/ft}) \times (9 \text{ ft}))]^2}{(9 \text{ ft})^2 \times [(3 \times (0.014 \text{ kipft/ft})) + (2 \times (-0.0046667 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = -0.0016967 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

$$s = \frac{9.425 [(2 M_o) + (H_o L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.014 \text{ kipft/ft})) + ((-0.0046667 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = -0.001629 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.5 \text{ ft})}{2}$$

$$p_a = 0.4875 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0016967 \text{ kip/ft}^2)}{(0.4875 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.0034804$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9 \text{ ft})$$

$$p_s = 1.35 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

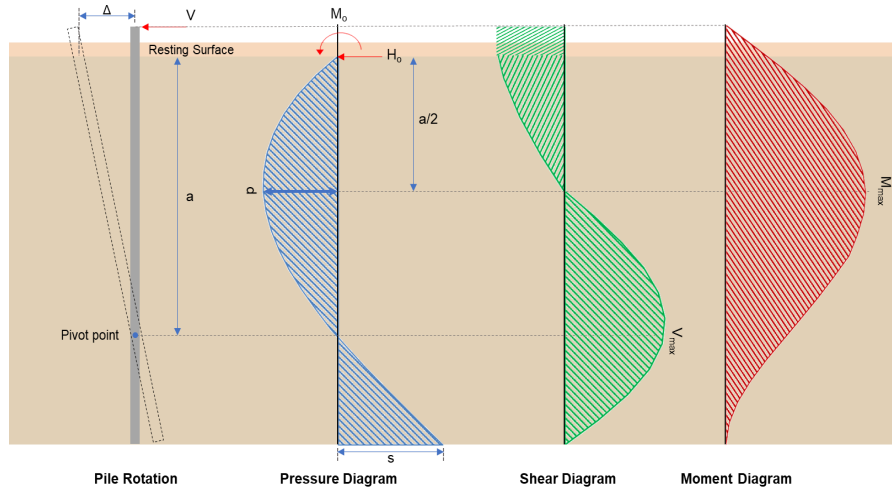
Status: **PASS**
Ratio: **0.000**

$$ratio = \frac{M_o}{p_s}$$

$$Ratio = \frac{(-0.001629 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$Ratio = -0.0012067$$

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



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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-2.848 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.94933 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(42.258 \text{ kipft}) + ((-2.848 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.086 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.086 \text{ kipft/ft})}{(-0.94933 \text{ kip/ft})}$$

$$E = 14.838 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.086 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.94933 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (14.086 \text{ kipft/ft})) + (4 \times (-0.94933 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.216 \text{ ft}$$

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

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

$$V_{max} = ((-0.94933 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.838 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.216 \text{ ft})}{(9 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (14.838 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.216 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.187 \text{ kip}$$

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

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

$$M_{max} = ((-0.94933 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(14.838 \text{ ft})}{(9 \text{ ft})} + \frac{(6.216 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.838 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.216 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (14.838 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.216 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 43.514 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.025 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.0083333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.074 \text{ kipft}) + ((-0.025 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.024667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.024667 \text{ kipft/ft})}{(-0.0083333 \text{ kip/ft})}$$

$$E = 2.96 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.024667 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.0083333 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (0.024667 \text{ kipft/ft})) + (4 \times (-0.0083333 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.5022 \text{ ft}$$

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

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

$$V_{max} = ((-0.0083333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.96 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.5022 \text{ ft})}{(9 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.96 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.5022 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.031314 \text{ kip}$$

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

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

$$M_{max} = ((-0.0083333 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(2.96 \text{ ft})}{(9 \text{ ft})} + \frac{(6.5022 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.96 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.5022 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.96 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.5022 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.12095 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

- $f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
- $f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
- $\phi = 0.65$ - Reduction factor for axial strength,
- $\alpha = 0.85$ - Alpha factor for axial strength,
- $A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(17.597 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.823 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-36.823 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

$$\text{Ratio} = 0.99533$$

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

25.2.3

s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

25.7.2.2

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

25.7.2.1

s_{ties} - Maximum center-to-center spacing of ties,

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

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]$$

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LFRD)

22.4.2.2

ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]$$

$$\phi P_N = 1253.9 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(17.597 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.014034$$

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

Shear Strength (ACI 318-19, LFRD)

Parameters:

22.5.2.2

$b_w = 36 \text{ in}$ - Effective width,
 d - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3

λ_s - size effect modification factor

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

$$\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.71796$$

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

22.5.5.1.1

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,max} = 186.09 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.597 \text{ kip} \rightarrow 17597 \text{ lbf}$.

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(17597 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.425 \text{ kip}$$

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

22.5.5.1.2

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

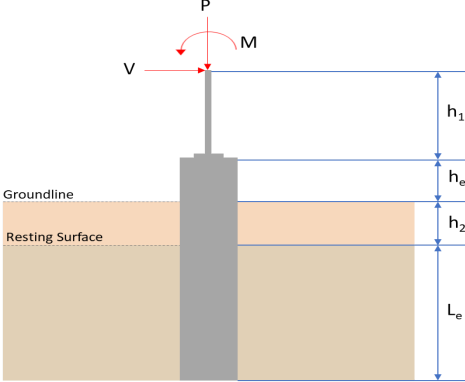
V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (77.425 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;">$V_c = 77.425 \text{ kip}$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$.</p> <p>$V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$ $V_{s,a} = 414.72 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>$V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 38.17 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$ $V_s = 38.17 \text{ kip}$ <p>ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((77.425 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 75.137 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 10.187 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(10.187 \text{ kip})}{(75.137 \text{ kip})}$ $Ratio = 0.13557$ <p>Considering z-direction:</p> <p>$V_{max} = 0.031314 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.031314 \text{ kip})}{(75.137 \text{ kip})}$ $Ratio = 0.00041676$	<p>Status: PASS Ratio: 0.140</p> <p>Status: PASS Ratio: 0.000</p>
	<p>Flexural Strength (ACI 318-19, LRFD)</p> <p>S_m - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (36 \text{ in})^3}{32}$	

<p>14.5.2.1b</p>	<p style="text-align: center;">$S_m = 4580.4 \text{ in}^3$</p> <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 4580.442 \text{ in}^3$ $\phi M_{n,1} = 62.027 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$ $\phi M_n = 62.027 \text{ kipft}$ <p>Considering x-direction: $M_{max} = 43.514 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(43.514 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.70153$	<p>Status: PASS Ratio: 0.700</p>
	<p>Considering z-direction: $M_{max} = 0.12095 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.12095 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.00195$	<p>Status: PASS Ratio: 0.000</p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry Pile shape: round $D = 36$ in - Pile diameter $L = 9$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resisting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1" data-bbox="416 1079 1193 1171"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1" data-bbox="676 1265 935 1435"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>11.396</td> <td>17.597</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.706</td> <td>-2.848</td> </tr> <tr> <td>V_z (kip)</td> <td>0.014</td> <td>0.025</td> </tr> <tr> <td>M_x (kipft)</td> <td>0.042</td> <td>0.074</td> </tr> <tr> <td>M_z (kipft)</td> <td>24.912</td> <td>42.258</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 2.5$ ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	11.396	17.597	V_x (kip)	-1.706	-2.848	V_z (kip)	0.014	0.025	M_x (kipft)	0.042	0.074	M_z (kipft)	24.912	42.258	
Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)																									
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$$M_o = \frac{(24.912 \text{ kipft}) + ((-1.706 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 8.304 \text{ kipft/ft}$$

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:

$L_{e,x} = 8.402 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.014 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0046667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.042 \text{ kipft}) + ((0.014 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.014 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.3284 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(8.402 \text{ ft}), (1.3284 \text{ ft})]$$

$$L_{e,req} = 8.402 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (9 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 9 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(8.402 \text{ ft})}{(9 \text{ ft})}$$

$$\text{Ratio} = 0.93356$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(11.396 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.6122 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.6122 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.8061$$

Status: **PASS**
Ratio: **0.810**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(9 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 3$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.56867 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 8.304 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.304 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.56867 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (8.304 \text{ kipft/ft})) + (4 \times (-0.56867 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.2184 \text{ ft}$$

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

$$p = \frac{1.178 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (8.304 \text{ kipft/ft})) + (3 \times (-0.56867 \text{ kip/ft}) \times (9 \text{ ft}))]^2}{(9 \text{ ft})^2 \times [(3 \times (8.304 \text{ kipft/ft})) + (2 \times (-0.56867 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = 0.31616 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

$$s = \frac{9.425 [(2 M_o) + (H_o L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (8.304 \text{ kipft/ft})) + ((-0.56867 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = 1.337 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.2184 \text{ ft})}{2}$$

$$p_a = 0.46638 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.31616 \text{ kip/ft}^2)}{(0.46638 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.67791$$

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

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9 \text{ ft})$$

$$p_s = 1.35 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.337 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.99034$$

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

Considering z-direction:

$H_o = 0.0046667 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.014 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.014 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (0.0046667 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (0.014 \text{ kipft/ft})) + (4 \times (0.0046667 \text{ kip/ft}) \times (9 \text{ ft}))}$$

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

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

$$p = \frac{1.178 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.014 \text{ kipft/ft})) + (3 \times (0.0046667 \text{ kip/ft}) \times (9 \text{ ft}))]^2}{(9 \text{ ft})^2 \times [(3 \times (0.014 \text{ kipft/ft})) + (2 \times (0.0046667 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = 0.0038232 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

$$s = \frac{9.425 [(2 M_o) + (H_o L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.014 \text{ kipft/ft})) + ((0.0046667 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = 0.0081451 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.5 \text{ ft})}{2}$$

$$p_a = 0.4875 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.0038232 \text{ kip/ft}^2)}{(0.4875 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.0078426$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (9 \text{ ft})$$

$$p_s = 1.35 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

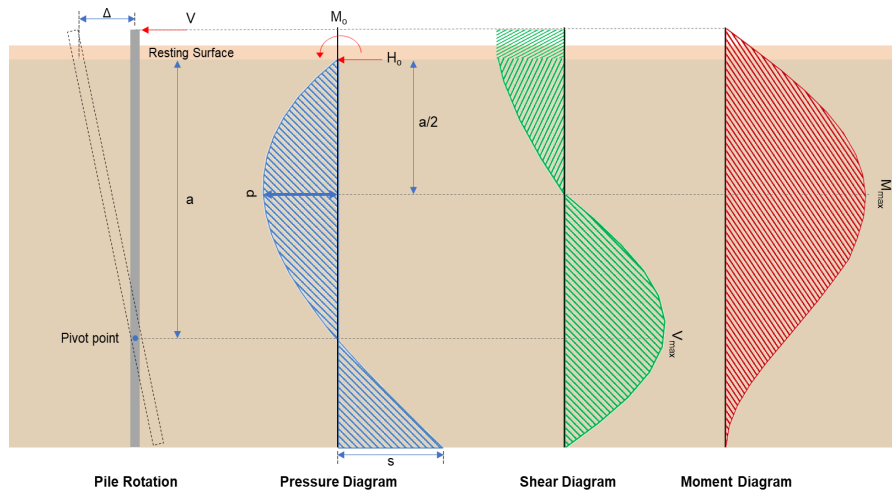
Status: **PASS**
Ratio: **0.010**

$$ratio = \frac{M_o}{p_s}$$

$$Ratio = \frac{(0.0081451 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$Ratio = 0.0060334$$

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



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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-2.848 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.94933 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(42.258 \text{ kipft}) + ((-2.848 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.086 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.086 \text{ kipft/ft})}{(-0.94933 \text{ kip/ft})}$$

$$E = 14.838 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.086 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.94933 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (14.086 \text{ kipft/ft})) + (4 \times (-0.94933 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.216 \text{ ft}$$

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

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

$$V_{max} = ((-0.94933 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.838 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.216 \text{ ft})}{(9 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (14.838 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.216 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 10.187 \text{ kip}$$

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

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

$$M_{max} = ((-0.94933 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(14.838 \text{ ft})}{(9 \text{ ft})} + \frac{(6.216 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (14.838 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.216 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (14.838 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.216 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 43.514 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.025 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.0083333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.074 \text{ kipft}) + ((0.025 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.024667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.024667 \text{ kipft/ft})}{(0.0083333 \text{ kip/ft})}$$

$$E = 2.96 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.024667 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (0.0083333 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (0.024667 \text{ kipft/ft})) + (4 \times (0.0083333 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.5022 \text{ ft}$$

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

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

$$V_{max} = ((0.0083333 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.96 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.5022 \text{ ft})}{(9 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (2.96 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.5022 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.031314 \text{ kip}$$

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

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

$$M_{max} = ((0.0083333 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(2.96 \text{ ft})}{(9 \text{ ft})} + \frac{(6.5022 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (2.96 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.5022 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.96 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.5022 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.12095 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

- $f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
- $f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
- $\phi = 0.65$ - Reduction factor for axial strength,
- $\alpha = 0.85$ - Alpha factor for axial strength,
- $A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(17.597 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -36.823 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-36.823 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(1.8322 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.8322 \text{ in}^2)}{(1.8408 \text{ in}^2)}$$

$$\text{Ratio} = 0.99533$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum center-to-center spacing of ties,

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

$$s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), (36 \text{ in})]$$

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

Summary:

Main reinforcement: **6 - #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

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

$$\phi P_N = (0.65) \times 0.85 \times [(0.85 \times (2.5 \text{ ksi}) \times [(1017.9 \text{ in}^2) - (1.8408 \text{ in}^2)]) + ((60 \text{ ksi}) \times (1.8408 \text{ in}^2))]$$

$$\phi P_N = 1253.9 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(17.597 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.014034$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2

$b_w = 36 \text{ in}$ - Effective width,
 d - Effective depth

$$d = 0.80 D$$

$$d = 0.80 \times (36 \text{ in})$$

$$d = 28.8 \text{ in}$$

22.5.5.1.3

λ_s - size effect modification factor

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

$$\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(28.8 \text{ in})}{10}}}, 1 \right]$$

$$\lambda_s = 0.71796$$

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

22.5.5.1.1

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,max} = 186.09 \text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 17.597 \text{ kip} \rightarrow 17597 \text{ lbf}$.

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(17597 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 77.425 \text{ kip}$$

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

22.5.5.1.2

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,b} = 204.04 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (77.425 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;">$V_c = 77.425 \text{ kip}$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$.</p> <p>$V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$ $V_{s,a} = 414.72 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>$V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 38.17 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(414.72 \text{ kip}), (38.17 \text{ kip})]$ $V_s = 38.17 \text{ kip}$ <p>ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((77.425 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 75.137 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 10.187 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(10.187 \text{ kip})}{(75.137 \text{ kip})}$ $Ratio = 0.13557$ <p>Considering z-direction:</p> <p>$V_{max} = 0.031314 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.031314 \text{ kip})}{(75.137 \text{ kip})}$ $Ratio = 0.00041676$	<p>Status: PASS Ratio: 0.140</p> <p>Status: PASS Ratio: 0.000</p>
	<p>Flexural Strength (ACI 318-19, LFRD)</p> <p>S_m - Section modulus</p> $S_m = \frac{\pi D^3}{32}$ $S_m = \frac{\pi \times (36 \text{ in})^3}{32}$	

<p>14.5.2.1b</p>	<p style="text-align: center;">$S_m = 4580.4 \text{ in}^3$</p> <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{2.5 \text{ ksi}} \times 4580.442 \text{ in}^3$ $\phi M_{n,1} = 62.027 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(62.027 \text{ kipft}), (527.23 \text{ kipft})]$ $\phi M_n = 62.027 \text{ kipft}$ <p>Considering x-direction: $M_{max} = 43.514 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(43.514 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.70153$	<p>Status: PASS Ratio: 0.700</p>
	<p>Considering z-direction: $M_{max} = 0.12095 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.12095 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.00195$	<p>Status: PASS Ratio: 0.000</p>