

Your Project Calculations



Project Name: Plin04-JB-RevA

S3D Model Link:

https://platform.skyciv.com/structural?preload_name=Plin04-JB-RevA&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023

Public Model Link:

https://platform.skyciv.com/structural-viewer?project_id=ZVowE2iS88IBqOSNukcr8lqVWGLZz3XF4kFi3RCMIWjCOv5VhU5oOdNzDBlcObXi

Array Specification

Product:	Beam
Unique ID:	4P-22.5-8TOP-HD-12-L-4Hx13W-K15C
Duty Classification:	HD
Module Width:	38.00 in
Module Length:	71.00in
Number of Rows:	4
Number of Columns:	13
Total Number of Modules:	52
Desired Tilt Angle:	30
Front Edge Clearance:	9
Total Array Height at Tilt:	15.37 ft
Total Frame Length:	77.00 ft
Frame Weight:	3794 lbs
Array Dimensions N/S:	12.83 ft
Array Dimensions E/W:	78.00 ft
Rail Length:	154.00 in
Rail Spacing:	2.96 ft
Rail Check:	

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	12.21 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: 8.00 ft Pile 2: 9.00 ft Pile 3: 9.00 ft Pile 4: 8.00 ft
Foundation Volume:	8.901 y ³
Foundation Result:	PASSED
Mount Twist:	1.543099 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	Renovo, PA 17764, USA
Wind Speed:	103 mph
Snow Load:	30 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.013196 ksf



Design Disclaimer

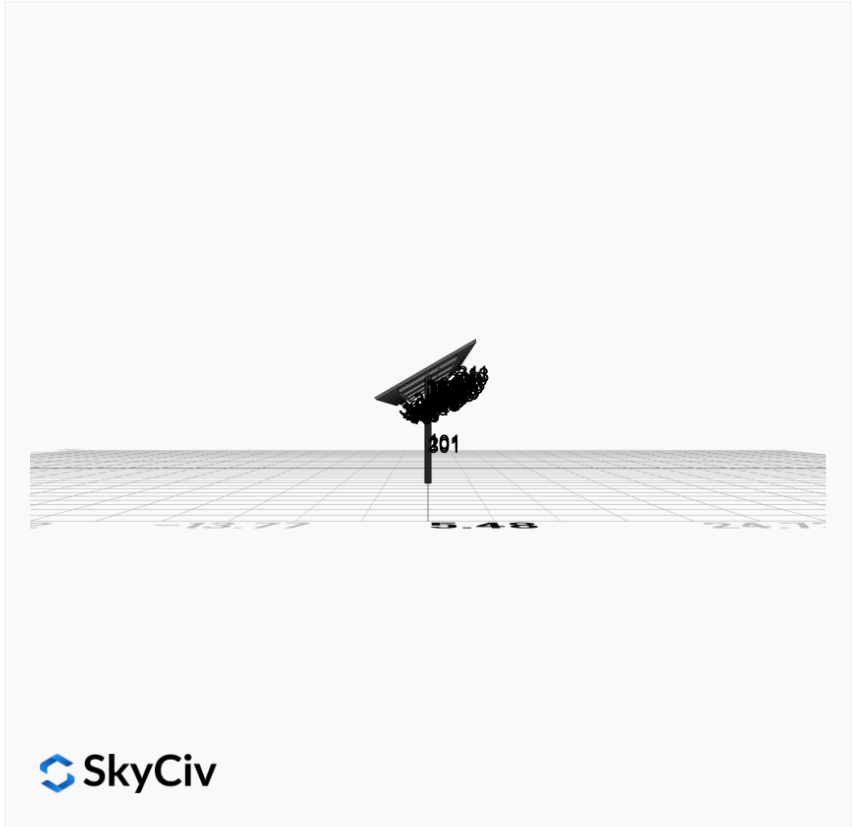
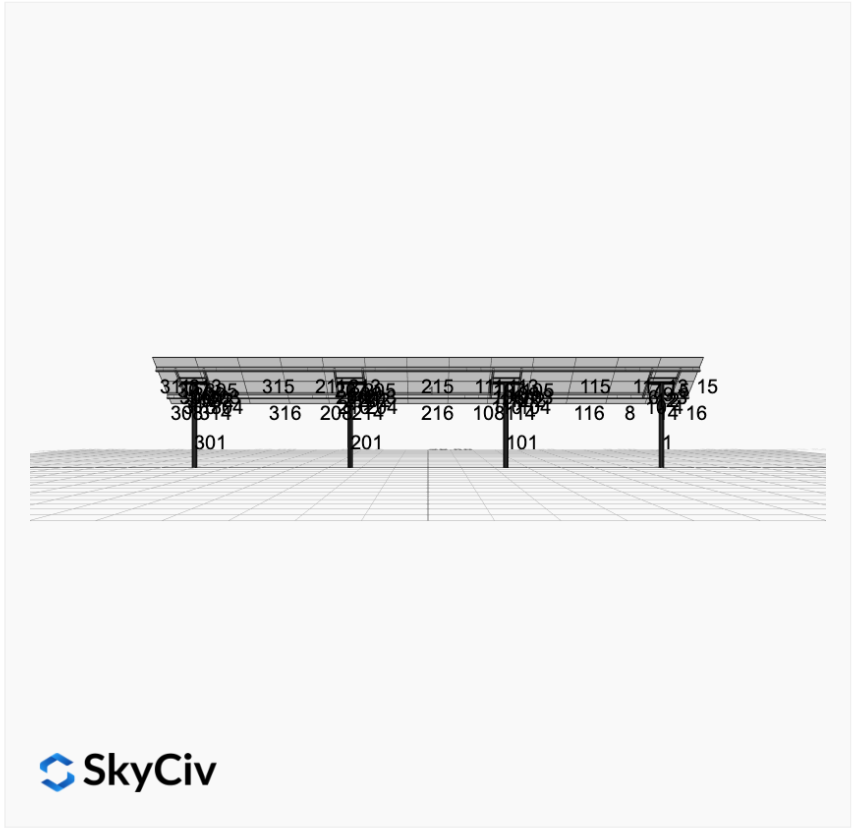
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

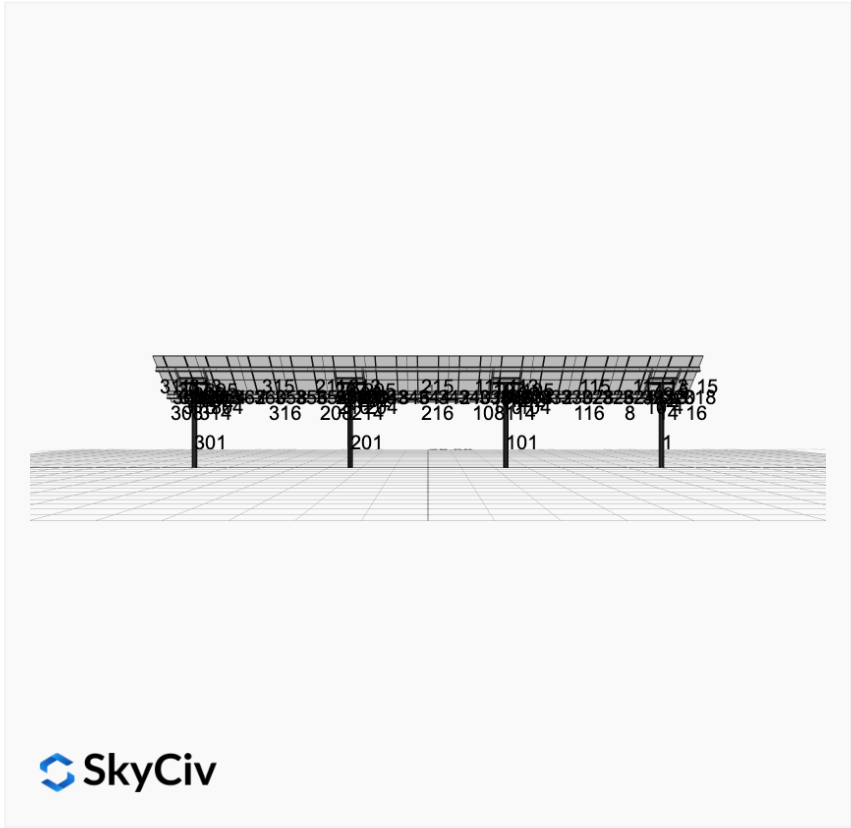
AutoDesigner Input

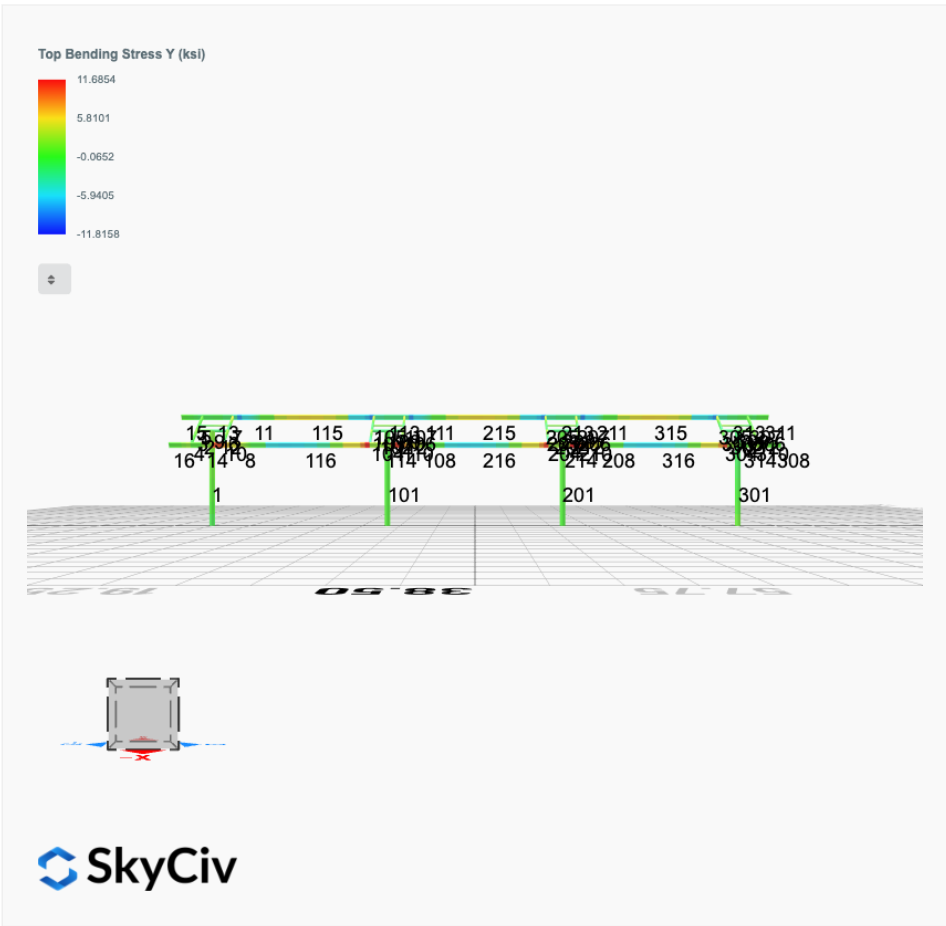
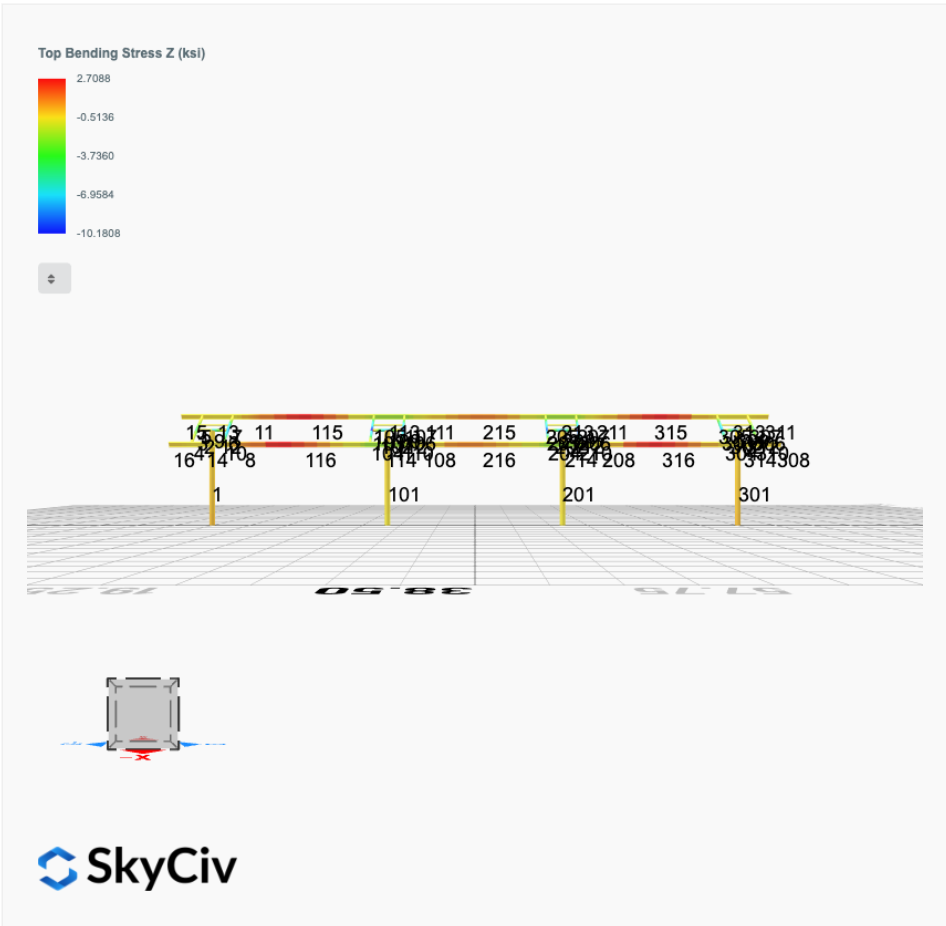
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Design Notes:

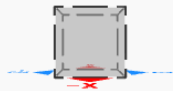
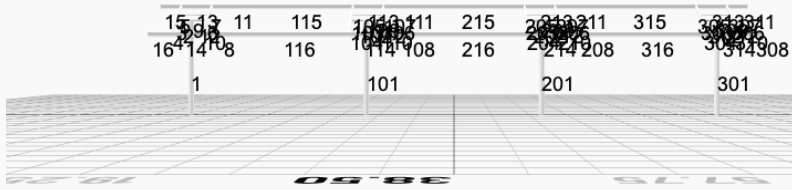
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only

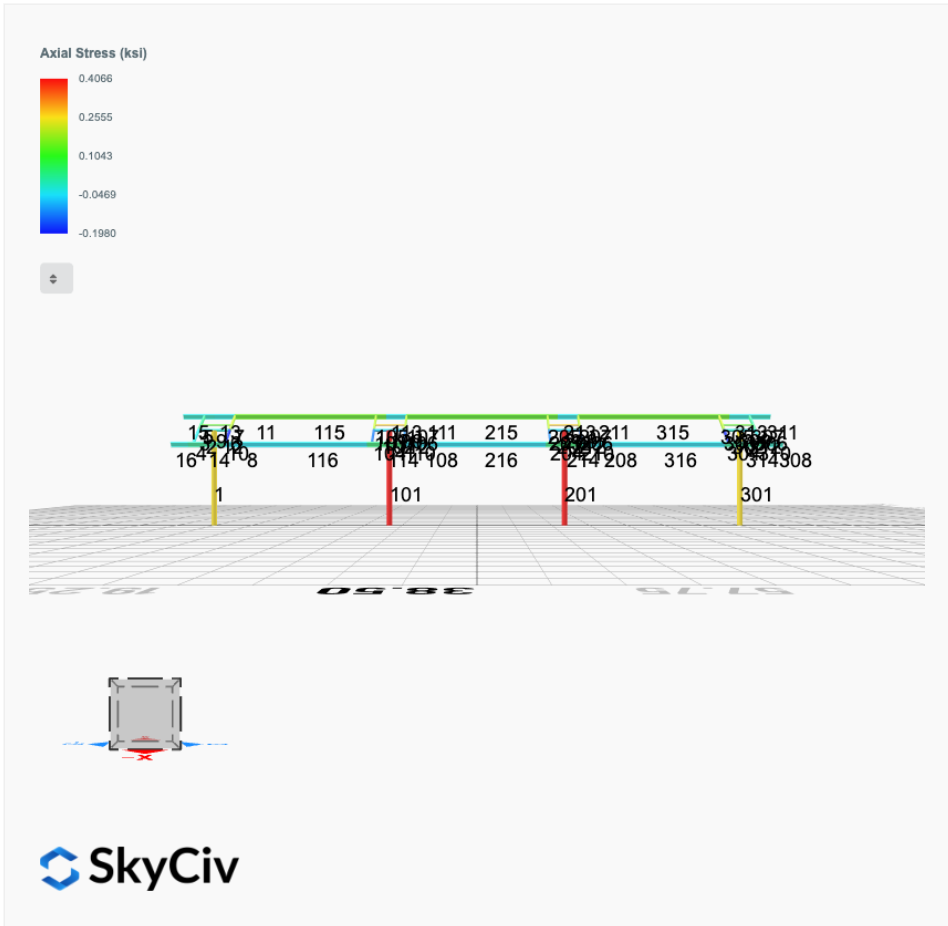






Shear Stress Y (ksi)





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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0338	1.8122	0.1198	0.4385	-0.1169	-0.3678
ULS: 2. D + L	0.0338	1.8122	0.1198	0.4385	-0.1169	-0.3678
ULS: 3. D + (S or Lr or R)	0.0940	4.0430	0.3340	1.2230	-0.3261	-1.0665
ULS: 3. D + (S or Lr or R)	0.0338	1.8122	0.1198	0.4385	-0.1169	-0.3678
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0789	3.4853	0.2804	1.0269	-0.2738	-0.8918
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0338	1.8122	0.1198	0.4385	-0.1169	-0.3678
ULS: 5b. D + 0.7E	0.0338	1.8122	0.1198	0.4385	-0.1169	-0.3678
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0789	3.4853	0.2804	1.0269	-0.2738	-0.8918
ULS: 8. 0.6D + 0.7E	0.0203	1.0873	0.0719	0.2631	-0.0701	-0.2207
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.3614	4.1655	0.4260	1.5263	-0.8897	17.0940
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.3614	4.1655	0.4260	1.5263	-0.8897	17.0940
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2275	-0.2029	-0.1382	-0.4765	0.5343	-14.9285
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.0502	0.1209	-0.1188	-0.4067	0.4965	-17.7067
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.9675	5.2502	0.5101	1.8427	-0.8534	12.2045
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.9675	5.2502	0.5101	1.8427	-0.8534	12.2045
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9743	1.9740	0.0869	0.3406	0.2146	-11.8124
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8412	2.2168	0.1015	0.3930	0.1863	-13.8960
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0126	3.5772	0.3495	1.2543	-0.6965	12.7286
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0126	3.5772	0.3495	1.2543	-0.6965	12.7286
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9291	0.3009	-0.0737	-0.2478	0.3715	-11.2883
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.7961	0.5438	-0.0591	-0.1954	0.3431	-13.3720
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.3749	3.4406	0.3781	1.3509	-0.8429	17.2411
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.3749	3.4406	0.3781	1.3509	-0.8429	17.2411
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.2140	-0.9278	-0.1861	-0.6519	0.5810	-14.7814
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.0367	-0.6039	-0.1667	-0.5821	0.5433	-17.5596

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	7.7054
Shear X	-2.3253
Shear Z	0.7655
Moment X	2.7490
Moment Y (Twist)	1.5420
Moment Z	30.0929

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	5.2502
Shear X	-1.3749
Shear Z	0.5101
Moment X	1.8427
Moment Y (Twist)	0.8897
Moment Z	17.7067

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	-0.0338	2.4768	-0.0150	-0.0552	0.0345	0.4219
ULS: 2. D + L	-0.0338	2.4768	-0.0150	-0.0552	0.0345	0.4219
ULS: 3. D + (S or Lr or R)	-0.0940	5.8923	-0.0416	-0.1536	0.0961	1.1431
ULS: 3. D + (S or Lr or R)	-0.0338	2.4768	-0.0150	-0.0552	0.0345	0.4219
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0789	5.0384	-0.0350	-0.1290	0.0807	0.9628
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0338	2.4768	-0.0150	-0.0552	0.0345	0.4219
ULS: 5b. D + 0.7E	-0.0338	2.4768	-0.0150	-0.0552	0.0345	0.4219

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0789	5.0384	-0.0350	-0.1290	0.0807	0.9628
ULS: 8. 0.6D + 0.7E	-0.0203	1.4861	-0.0090	-0.0331	0.0207	0.2531
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1106	6.1371	-0.0271	-0.1039	0.0267	26.1159
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1106	6.1371	-0.0271	-0.1039	0.0267	26.1159
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7484	-0.6627	-0.0025	-0.0063	0.0347	-20.8066
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4298	-0.1274	-0.0185	-0.0630	0.0809	-24.3080
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6365	7.7837	-0.0440	-0.1656	0.0748	20.2334
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6365	7.7837	-0.0440	-0.1656	0.0748	20.2334
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2577	2.6838	-0.0256	-0.0923	0.0808	-14.9585
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0188	3.0853	-0.0376	-0.1349	0.1155	-17.5846
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.5914	5.2220	-0.0240	-0.0917	0.0287	19.6924
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5914	5.2220	-0.0240	-0.0917	0.0287	19.6924
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3029	0.1222	-0.0056	-0.0185	0.0346	-15.4995
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0639	0.5236	-0.0176	-0.0610	0.0693	-18.1255
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.0971	5.1464	-0.0211	-0.0819	0.0129	25.9472
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.0971	5.1464	-0.0211	-0.0819	0.0129	25.9472
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7619	-1.6534	0.0035	0.0158	0.0208	-20.9753
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4433	-1.1181	-0.0125	-0.0409	0.0671	-24.4767

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	11.4867
Shear X	-3.5302
Shear Z	-0.0694
Moment X	-0.2609
Moment Y (Twist)	0.1854
Moment Z	44.4461

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	7.7837
Shear X	-2.1106
Shear Z	-0.0440
Moment X	-0.1656
Moment Y (Twist)	0.1155
Moment Z	26.1159

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	-0.0338	2.4768	0.0150	0.0551	-0.0345	0.4219
ULS: 2. D + L	-0.0338	2.4768	0.0150	0.0551	-0.0345	0.4219
ULS: 3. D + (S or Lr or R)	-0.0940	5.8923	0.0416	0.1535	-0.0958	1.1431
ULS: 3. D + (S or Lr or R)	-0.0338	2.4768	0.0150	0.0551	-0.0345	0.4219
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0789	5.0384	0.0350	0.1289	-0.0805	0.9628
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0338	2.4768	0.0150	0.0551	-0.0345	0.4219
ULS: 5b. D + 0.7E	-0.0338	2.4768	0.0150	0.0551	-0.0345	0.4219
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0789	5.0384	0.0350	0.1289	-0.0805	0.9628
ULS: 8. 0.6D + 0.7E	-0.0203	1.4861	0.0090	0.0331	-0.0207	0.2531
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.1106	6.1371	0.0271	0.1039	-0.0266	26.1159
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.1106	6.1371	0.0271	0.1039	-0.0266	26.1159
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7484	-0.6627	0.0025	0.0063	-0.0346	-20.8066
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.4298	-0.1274	0.0185	0.0630	-0.0808	-24.3080
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.6365	7.7837	0.0440	0.1654	-0.0746	20.2333
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.6365	7.7837	0.0440	0.1654	-0.0746	20.2333
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2577	2.6838	0.0256	0.0922	-0.0805	-14.9585
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0188	3.0853	0.0376	0.1348	-0.1152	-17.5846

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	-1.5914	5.2220	0.0240	0.0917	-0.0286	19.6924
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.5914	5.2220	0.0240	0.0917	-0.0286	19.6924
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3029	0.1222	0.0056	0.0185	-0.0346	-15.4995
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.0639	0.5236	0.0176	0.0610	-0.0692	-18.1255
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.0971	5.1464	0.0211	0.0818	-0.0129	25.9472
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.0971	5.1464	0.0211	0.0818	-0.0129	25.9472
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7619	-1.6534	-0.0035	-0.0158	-0.0208	-20.9753
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.4433	-1.1181	0.0125	0.0409	-0.0670	-24.4767

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	11.4868
Shear X	-3.5302
Shear Z	0.0695
Moment X	0.2597
Moment Y (Twist)	0.1844
Moment Z	44.4462

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	7.7837
Shear X	-2.1106
Shear Z	0.0440
Moment X	0.1654
Moment Y (Twist)	0.1152
Moment Z	26.1159

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	0.0338	1.8122	-0.1198	-0.4385	0.1170	-0.3677
ULS: 2. D + L	0.0338	1.8122	-0.1198	-0.4385	0.1170	-0.3677
ULS: 3. D + (S or Lr or R)	0.0940	4.0429	-0.3340	-1.2233	0.3264	-1.0663
ULS: 3. D + (S or Lr or R)	0.0338	1.8122	-0.1198	-0.4385	0.1170	-0.3677
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0789	3.4853	-0.2804	-1.0271	0.2740	-0.8916
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0338	1.8122	-0.1198	-0.4385	0.1170	-0.3677
ULS: 5b. D + 0.7E	0.0338	1.8122	-0.1198	-0.4385	0.1170	-0.3677
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0789	3.4853	-0.2804	-1.0271	0.2740	-0.8916
ULS: 8. 0.6D + 0.7E	0.0203	1.0873	-0.0719	-0.2631	0.0702	-0.2206
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.3614	4.1655	-0.4261	-1.5263	0.8898	17.0940
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.3614	4.1655	-0.4261	-1.5263	0.8898	17.0940
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.2275	-0.2029	0.1382	0.4765	-0.5342	-14.9285
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.0502	0.1209	0.1188	0.4067	-0.4965	-17.7067
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.9675	5.2502	-0.5101	-1.8430	0.8536	12.2047
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.9675	5.2502	-0.5101	-1.8430	0.8536	12.2047
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9742	1.9739	-0.0869	-0.3409	-0.2144	-11.8122
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.8412	2.2168	-0.1015	-0.3932	-0.1860	-13.8958
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.0126	3.5772	-0.3495	-1.2544	0.6966	12.7286
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.0126	3.5772	-0.3495	-1.2544	0.6966	12.7286
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.9291	0.3009	0.0737	0.2477	-0.3714	-11.2883
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.7961	0.5438	0.0591	0.1954	-0.3431	-13.3719
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.3749	3.4406	-0.3781	-1.3509	0.8430	17.2411
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.3749	3.4406	-0.3781	-1.3509	0.8430	17.2411
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.2140	-0.9278	0.1861	0.6519	-0.5810	-14.7814
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.0367	-0.6039	0.1667	0.5821	-0.5432	-17.5596

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	7.7053
Shear X	-2.3253
Shear Z	-0.7655
Moment X	-2.7497
Moment Y (Twist)	1.5431
Moment Z	30.0932

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

Result	Value (kip, kip-ft)
Axial	5.2502
Shear X	-1.3749
Shear Z	-0.5101
Moment X	-1.8430
Moment Y (Twist)	0.8898
Moment Z	17.7067

Project Details

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

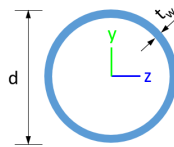


Design Input Information

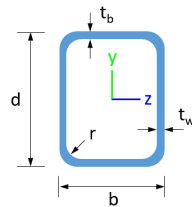
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

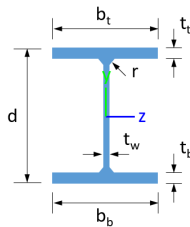
Section Dimensions



ID	Name	d (in)	t_w (in)				
2	2in Pipe Sch 80	2.38	0.22				
5	4in Pipe Sch 80	4.50	0.34				
9	8in Pipe Sch 40	8.63	0.32				



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)	
16	HSS5x3x3/16	5.00	3.00	0.17	0.17	0.17	



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	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)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21

103	110.10	115.41	15.79	11.10	42.08	23.28
104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	126.01	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	126.01	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	104.94	23.60	6.12	40.24	43.62
114	133.20	104.94	23.60	6.12	40.24	43.62
115	133.20	46.28	11.81	6.12	40.24	43.62
116	133.20	46.28	12.46	6.12	40.24	43.62
201	377.97	169.51	83.29	83.29	113.39	113.39
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	126.01	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	126.01	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	104.94	23.60	6.12	40.24	43.62
214	133.20	104.94	23.60	6.12	40.24	43.62
215	133.20	46.28	12.13	6.12	40.24	43.62
216	133.20	46.28	11.92	6.12	40.24	43.62
301	377.97	169.51	83.29	83.29	113.39	113.39
302	198.33	182.14	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	121.82	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	121.82	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	104.94	26.35	6.12	40.24	43.62
314	133.20	104.94	27.27	6.12	40.24	43.62
315	133.20	46.28	11.92	6.12	40.24	43.62
316	133.20	46.28	11.92	6.12	40.24	43.62

Design Ratio

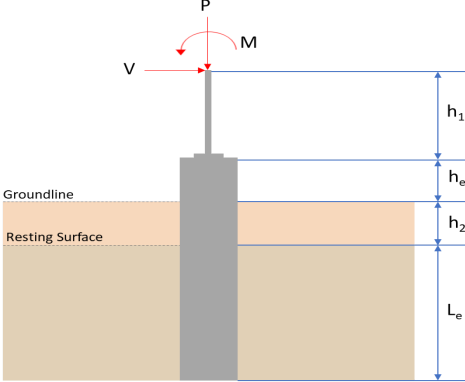
Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	φ	Status
1	0.045	0.361	0.079	0.020	0.007	0.399	#13	0.524	Not Required	Pass
2	0.003	0.125	0.068	0.037	0.015	0.179	#13	0.053	Not Required	Pass
3	0.004	0.266	0.023	0.025	0.012	0.284	#21	0.045	Not Required	Pass
4	0.003	0.370	0.067	0.037	0.015	0.235	#13	0.120	Not Required	Pass

4	U.U0Z	U.Z7U	U.U07	U.UZ7	U.U10	U.33D	#13	U.1ZU	Not Required	Pass
5	0.003	0.165	0.021	0.027	0.006	0.173	#13	0.074	Not Required	Pass
6	0.009	0.565	0.096	0.059	0.025	0.642	#21	0.045	Not Required	Pass
7	0.009	0.349	0.169	0.056	0.041	0.376	#21	0.074	Not Required	Pass
8	0.004	0.127	0.183	0.036	0.015	0.209	#24	0.095	Not Required	Pass
9	0.007	0.072	0.085	0.004	0.006	0.142	#21	0.204	Not Required	Pass
10	0.011	0.534	0.150	0.054	0.031	0.572	#21	0.080	Not Required	Pass
11	0.007	0.114	0.190	0.038	0.015	0.213	#24	0.095	Not Required	Pass
12	0.002	0.416	0.139	0.086	0.025	0.549	#13	0.171	Not Required	Pass
13	0.008	0.073	0.394	0.048	0.018	0.423	#21	0.286	Not Required	Pass
14	0.004	0.063	0.384	0.045	0.018	0.414	#24	0.190	Not Required	Pass
15	0.000	0.003	0.007	0.006	0.002	0.010	#21	Not Required	Not Required	Pass
16	0.000	0.003	0.007	0.006	0.002	0.010	#21	Not Required	Not Required	Pass
101	0.068	0.534	0.007	0.031	0.001	0.568	#13	0.524	Not Required	Pass
102	0.004	0.437	0.171	0.095	0.029	0.588	#13	0.035	Not Required	Pass
103	0.009	0.630	0.045	0.063	0.001	0.675	#21	0.045	Not Required	Pass
104	0.009	0.651	0.169	0.065	0.034	0.743	#21	0.080	Not Required	Pass
105	0.009	0.390	0.182	0.063	0.046	0.437	#21	0.074	Not Required	Pass
106	0.008	0.623	0.041	0.063	0.004	0.647	#21	0.045	Not Required	Pass
107	0.008	0.387	0.169	0.062	0.043	0.424	#21	0.074	Not Required	Pass
108	0.005	0.075	0.174	0.042	0.014	0.248	#21	0.095	Not Required	Pass
109	0.018	0.059	0.047	0.001	0.000	0.113	#21	0.204	Not Required	Pass
110	0.008	0.621	0.164	0.062	0.034	0.712	#21	0.080	Not Required	Pass
111	0.007	0.062	0.179	0.042	0.014	0.244	#21	0.095	Not Required	Pass
112	0.004	0.410	0.168	0.091	0.030	0.567	#13	0.035	Not Required	Pass
113	0.008	0.235	0.411	0.055	0.018	0.624	#21	0.286	Not Required	Pass
114	0.007	0.269	0.407	0.058	0.018	0.644	#21	0.286	Not Required	Pass
115	0.018	0.499	0.209	0.046	0.015	0.706	#21	0.601	Not Required	Pass
116	0.009	0.491	0.209	0.048	0.015	0.686	#21	0.601	Not Required	Pass
201	0.068	0.534	0.007	0.031	0.001	0.568	#13	0.524	Not Required	Pass
202	0.004	0.410	0.168	0.091	0.030	0.567	#13	0.035	Not Required	Pass
203	0.008	0.623	0.041	0.063	0.004	0.647	#21	0.045	Not Required	Pass
204	0.008	0.621	0.164	0.062	0.034	0.712	#21	0.080	Not Required	Pass
205	0.008	0.387	0.169	0.062	0.043	0.424	#21	0.074	Not Required	Pass
206	0.009	0.630	0.045	0.063	0.001	0.675	#21	0.045	Not Required	Pass
207	0.009	0.390	0.182	0.063	0.046	0.437	#21	0.074	Not Required	Pass
208	0.004	0.062	0.201	0.048	0.015	0.262	#21	0.095	Not Required	Pass
209	0.018	0.059	0.047	0.001	0.000	0.113	#21	0.204	Not Required	Pass
210	0.009	0.651	0.169	0.065	0.034	0.743	#21	0.080	Not Required	Pass
211	0.007	0.064	0.205	0.046	0.015	0.253	#21	0.095	Not Required	Pass
212	0.004	0.437	0.171	0.095	0.029	0.588	#13	0.035	Not Required	Pass
213	0.008	0.235	0.411	0.055	0.018	0.624	#21	0.286	Not Required	Pass
214	0.007	0.269	0.406	0.058	0.018	0.644	#21	0.286	Not Required	Pass
215	0.018	0.342	0.210	0.042	0.014	0.538	#21	0.601	Not Required	Pass
216	0.010	0.294	0.206	0.042	0.014	0.492	#21	0.601	Not Required	Pass
301	0.045	0.361	0.079	0.020	0.007	0.399	#13	0.524	Not Required	Pass
302	0.002	0.416	0.139	0.086	0.025	0.549	#13	0.171	Not Required	Pass
303	0.009	0.565	0.096	0.059	0.025	0.642	#21	0.045	Not Required	Pass
304	0.011	0.534	0.150	0.054	0.031	0.572	#21	0.080	Not Required	Pass
305	0.009	0.349	0.169	0.056	0.041	0.376	#21	0.074	Not Required	Pass
306	0.004	0.266	0.023	0.025	0.012	0.284	#21	0.045	Not Required	Pass
307	0.003	0.165	0.021	0.027	0.006	0.173	#13	0.074	Not Required	Pass
308	0.000	0.003	0.007	0.006	0.002	0.010	#21	Not Required	Not Required	Pass
309	0.007	0.072	0.086	0.004	0.006	0.142	#21	0.204	Not Required	Pass

310	0.002	0.270	0.067	0.027	0.016	0.335	#13	0.120	Not Required	Pass
311	0.000	0.003	0.007	0.006	0.002	0.010	#21	Not Required	Not Required	Pass
312	0.003	0.125	0.068	0.037	0.015	0.179	#13	0.053	Not Required	Pass
313	0.008	0.073	0.393	0.048	0.018	0.422	#21	0.190	Not Required	Pass
314	0.004	0.063	0.384	0.045	0.018	0.414	#24	0.286	Not Required	Pass
315	0.018	0.529	0.209	0.038	0.015	0.729	#21	0.601	Not Required	Pass
316	0.009	0.529	0.205	0.037	0.015	0.720	#21	0.601	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 $L = 8$ 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>5.250</td> <td>7.705</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.375</td> <td>-2.325</td> </tr> <tr> <td>V_z (kip)</td> <td>0.510</td> <td>0.766</td> </tr> <tr> <td>M_x (kipft)</td> <td>1.843</td> <td>2.749</td> </tr> <tr> <td>M_z (kipft)</td> <td>17.707</td> <td>30.093</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)	5.250	7.705	V_x (kip)	-1.375	-2.325	V_z (kip)	0.510	0.766	M_x (kipft)	1.843	2.749	M_z (kipft)	17.707	30.093	
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																									
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M_z (kipft)	17.707	30.093																										
	<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> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-1.375 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.45833 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(17.707 \text{ kipft}) + ((-1.375 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.9023 \text{ kipft/ft}$$

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:

$L_{e,x} = 7.4802 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.51 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.17 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.843 \text{ kipft}) + ((0.51 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.61433 \text{ kipft/ft}$$

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:

$L_{e,z} = 5.4861 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(7.4802 \text{ ft}), (5.4861 \text{ ft})]$$

$$L_{e,req} = 7.48 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (8 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.48 \text{ ft})}{(8 \text{ ft})}$$

$$\text{Ratio} = 0.935$$

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

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

$$q = \frac{(5.25 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.74272 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.74272 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.37136$$

Status: **PASS**
Ratio: **0.370**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.6667$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.45833 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 5.9023 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.9023 \text{ kipft/ft}) \times (8 \text{ ft})) + (3 \times (-0.45833 \text{ kip/ft}) \times (8 \text{ ft})^2)}{(6 \times (5.9023 \text{ kipft/ft})) + (4 \times (-0.45833 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5286 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.9023 \text{ kipft/ft})) + (3 \times (-0.45833 \text{ kip/ft}) \times (8 \text{ ft}))]^2}{(8 \text{ ft})^2 \times [(3 \times (5.9023 \text{ kipft/ft})) + (2 \times (-0.45833 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = 0.28211 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{9.425 \times [(2 \times (5.9023 \text{ kipft/ft})) + ((-0.45833 \text{ kip/ft}) \times (8 \text{ ft}))]}{(8 \text{ ft})^2}$$

$$s = 1.1984 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5286 \text{ ft})}{2}$$

$$p_a = 0.41464 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.28211 \text{ kip/ft}^2)}{(0.41464 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.68037$$

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

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8 \text{ ft})$$

$$p_s = 1.2 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1984 \text{ kip/ft}^2)}{(1.2 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.99871$$

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

Considering z-direction:

$H_o = 0.17 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.61433 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.61433 \text{ kipft/ft}) \times (8 \text{ ft})) + (3 \times (0.17 \text{ kip/ft}) \times (8 \text{ ft})^2)}{(6 \times (0.61433 \text{ kipft/ft})) + (4 \times (0.17 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.7307 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.61433 \text{ kipft/ft})) + (3 \times (0.17 \text{ kip/ft}) \times (8 \text{ ft}))]^2}{(8 \text{ ft})^2 \times [(3 \times (0.61433 \text{ kipft/ft})) + (2 \times (0.17 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = 0.17239 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{9.425 \times [(2 \times (0.61433 \text{ kipft/ft})) + ((0.17 \text{ kip/ft}) \times (8 \text{ ft}))]}{(8 \text{ ft})^2}$$

$$s = 0.38122 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.7307 \text{ ft})}{2}$$

$$p_a = 0.4298 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.17239 \text{ kip/ft}^2)}{(0.4298 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.40109$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8 \text{ ft})$$

$$p_s = 1.2 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

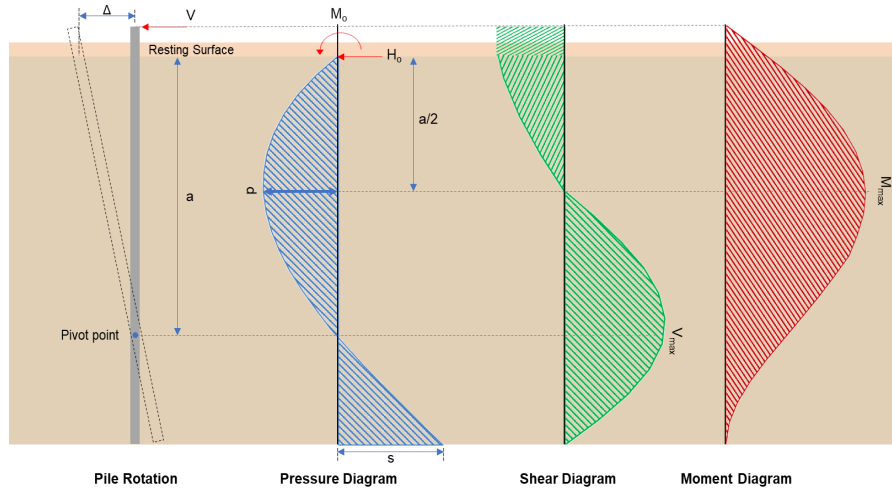
Status: **PASS**
Ratio: **0.400**

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

$$Ratio = \frac{(0.38122 \text{ kip/ft}^2)}{(1.2 \text{ kip/ft}^2)}$$

$$Ratio = 0.31768$$

Status: **PASS**
Ratio: **0.320**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.325 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.775 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(30.093 \text{ kipft}) + ((-2.325 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 10.031 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.031 \text{ kipft/ft})}{(-0.775 \text{ kip/ft})}$$

$$E = 12.943 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.031 \text{ kipft/ft}) \times (8 \text{ ft})) + (3 \times (-0.775 \text{ kip/ft}) \times (8 \text{ ft})^2)}{(6 \times (10.031 \text{ kipft/ft})) + (4 \times (-0.775 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5279 \text{ ft}$$

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

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

$$V_{max} = ((-0.775 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.943 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.5279 \text{ ft})}{(8 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (12.943 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.5279 \text{ ft})}{(8 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 8.1894 \text{ kip}$$

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

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

$$M_{max} = ((-0.775 \text{ kip/ft}) \times (36 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(12.943 \text{ ft})}{(8 \text{ ft})} + \frac{(5.5279 \text{ ft})}{2 \times (8 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.943 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.5279 \text{ ft})}{2 \times (8 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.943 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.5279 \text{ ft})}{2 \times (8 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 31.07 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.766 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.25533 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.749 \text{ kipft}) + ((0.766 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.91633 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.91633 \text{ kipft/ft})}{(0.25533 \text{ kip/ft})}$$

$$E = 3.5888 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.91633 \text{ kipft/ft}) \times (8 \text{ ft})) + (3 \times (0.25533 \text{ kip/ft}) \times (8 \text{ ft})^2)}{(6 \times (0.91633 \text{ kipft/ft})) + (4 \times (0.25533 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.7318 \text{ ft}$$

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

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

$$V_{max} = ((0.25533 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5888 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.7318 \text{ ft})}{(8 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.5888 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.7318 \text{ ft})}{(8 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 1.1193 \text{ kip}$$

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

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

$$M_{max} = ((0.25533 \text{ kip/ft}) \times (36 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(3.5888 \text{ ft})}{(8 \text{ ft})} + \frac{(5.7318 \text{ ft})}{2 \times (8 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.5888 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.7318 \text{ ft})}{2 \times (8 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.5888 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.7318 \text{ ft})}{2 \times (8 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 3.9312 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.705 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37.132 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-37.132 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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

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

$$\text{Ratio} = \frac{(7.705 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.0061448$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.705 \text{ kip} \rightarrow 7705 \text{ lbf}$.

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(7705 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 75.746 \text{ kip}$$

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)

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

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

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

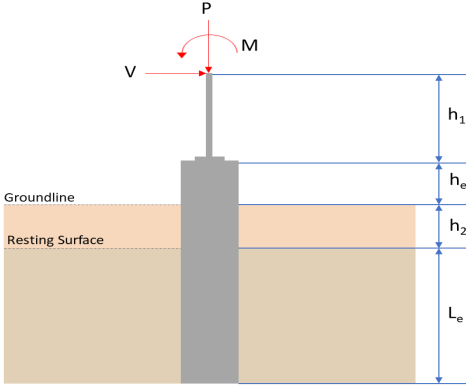
V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (75.746 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;">$V_c = 75.746 \text{ kip}$</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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((75.746 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 74.046 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 8.1894 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(8.1894 \text{ kip})}{(74.046 \text{ kip})}$ $Ratio = 0.1106$ <p>Considering z-direction:</p> <p>$V_{max} = 1.1193 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(1.1193 \text{ kip})}{(74.046 \text{ kip})}$ $Ratio = 0.015116$	<p>Status: PASS Ratio: 0.110</p> <p>Status: PASS Ratio: 0.020</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: $M_{max} = 31.07 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(31.07 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.50092$	<p>Status: PASS Ratio: 0.500</p>
	<p>Considering z-direction: $M_{max} = 3.9312 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(3.9312 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.06338$	<p>Status: PASS Ratio: 0.060</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 $L = 8$ 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 1077 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 1263 935 1435"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>5.250</td> <td>7.705</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.375</td> <td>-2.325</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.510</td> <td>-0.766</td> </tr> <tr> <td>M_x (kipft)</td> <td>-1.843</td> <td>-2.750</td> </tr> <tr> <td>M_z (kipft)</td> <td>17.707</td> <td>30.093</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)	5.250	7.705	V_x (kip)	-1.375	-2.325	V_z (kip)	-0.510	-0.766	M_x (kipft)	-1.843	-2.750	M_z (kipft)	17.707	30.093	
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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> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-1.375 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.45833 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(17.707 \text{ kipft}) + ((-1.375 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 5.9023 \text{ kipft/ft}$$

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:

$L_{e,x} = 7.4802 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.51 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.17 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.843 \text{ kipft}) + ((-0.51 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.61433 \text{ kipft/ft}$$

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:

$L_{e,z} = 3.0489 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(7.4802 \text{ ft}), (3.0489 \text{ ft})]$$

$$L_{e,req} = 7.48 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (8 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(7.48 \text{ ft})}{(8 \text{ ft})}$$

$$\text{Ratio} = 0.935$$

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

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

$$q = \frac{(5.25 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.74272 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.74272 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.37136$$

Status: **PASS**
Ratio: **0.370**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.6667$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.45833 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 5.9023 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.9023 \text{ kipft/ft}) \times (8 \text{ ft})) + (3 \times (-0.45833 \text{ kip/ft}) \times (8 \text{ ft})^2)}{(6 \times (5.9023 \text{ kipft/ft})) + (4 \times (-0.45833 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5286 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (5.9023 \text{ kipft/ft})) + (3 \times (-0.45833 \text{ kip/ft}) \times (8 \text{ ft}))]^2}{(8 \text{ ft})^2 \times [(3 \times (5.9023 \text{ kipft/ft})) + (2 \times (-0.45833 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = 0.28211 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{9.425 \times [(2 \times (5.9023 \text{ kipft/ft})) + ((-0.45833 \text{ kip/ft}) \times (8 \text{ ft}))]}{(8 \text{ ft})^2}$$

$$s = 1.1984 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.5286 \text{ ft})}{2}$$

$$p_a = 0.41464 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.28211 \text{ kip/ft}^2)}{(0.41464 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.68037$$

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

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8 \text{ ft})$$

$$p_s = 1.2 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(1.1984 \text{ kip/ft}^2)}{(1.2 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.99871$$

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

Considering z-direction:

$H_o = -0.17 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.61433 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.61433 \text{ kipft/ft}) \times (8 \text{ ft})) + (3 \times (-0.17 \text{ kip/ft}) \times (8 \text{ ft})^2)}{(6 \times (0.61433 \text{ kipft/ft})) + (4 \times (-0.17 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.7307 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.61433 \text{ kipft/ft})) + (3 \times (-0.17 \text{ kip/ft}) \times (8 \text{ ft}))]^2}{(8 \text{ ft})^2 \times [(3 \times (0.61433 \text{ kipft/ft})) + (2 \times (-0.17 \text{ kip/ft}) \times (8 \text{ ft}))]}$$

$$p = -0.055262 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{9.425 \times [(2 \times (0.61433 \text{ kipft/ft})) + ((-0.17 \text{ kip/ft}) \times (8 \text{ ft}))]}{(8 \text{ ft})^2}$$

$$s = -0.019341 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.7307 \text{ ft})}{2}$$

$$p_a = 0.4298 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.055262 \text{ kip/ft}^2)}{(0.4298 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.12857$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (8 \text{ ft})$$

$$p_s = 1.2 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

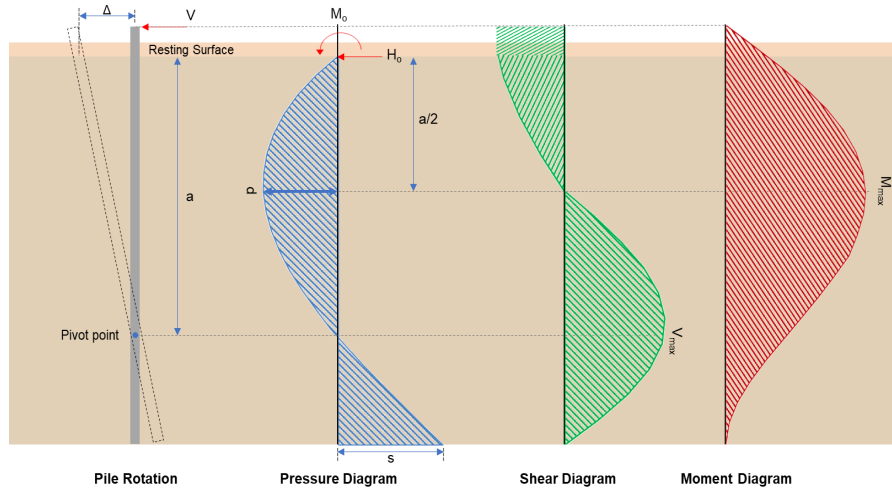
Status: **PASS**
Ratio: **-0.130**

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

$$Ratio = \frac{(-0.019341 \text{ kip/ft}^2)}{(1.2 \text{ kip/ft}^2)}$$

$$Ratio = -0.016117$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.325 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.775 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(30.093 \text{ kipft}) + ((-2.325 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 10.031 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.031 \text{ kipft/ft})}{(-0.775 \text{ kip/ft})}$$

$$E = 12.943 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.031 \text{ kipft/ft}) \times (8 \text{ ft})) + (3 \times (-0.775 \text{ kip/ft}) \times (8 \text{ ft})^2)}{(6 \times (10.031 \text{ kipft/ft})) + (4 \times (-0.775 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.5279 \text{ ft}$$

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

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

$$V_{max} = ((-0.775 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.943 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.5279 \text{ ft})}{(8 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (12.943 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.5279 \text{ ft})}{(8 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 8.1894 \text{ kip}$$

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

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

$$M_{max} = ((-0.775 \text{ kip/ft}) \times (36 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(12.943 \text{ ft})}{(8 \text{ ft})} + \frac{(5.5279 \text{ ft})}{2 \times (8 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.943 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.5279 \text{ ft})}{2 \times (8 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.943 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.5279 \text{ ft})}{2 \times (8 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 31.07 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.766 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.25533 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.75 \text{ kipft}) + ((-0.766 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.91667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.91667 \text{ kipft/ft})}{(-0.25533 \text{ kip/ft})}$$

$$E = 3.5901 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.91667 \text{ kipft/ft}) \times (8 \text{ ft})) + (3 \times (-0.25533 \text{ kip/ft}) \times (8 \text{ ft})^2)}{(6 \times (0.91667 \text{ kipft/ft})) + (4 \times (-0.25533 \text{ kip/ft}) \times (8 \text{ ft}))}$$

$$a = 5.7318 \text{ ft}$$

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

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

$$V_{max} = ((-0.25533 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.5901 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.7318 \text{ ft})}{(8 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.5901 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.7318 \text{ ft})}{(8 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 1.1195 \text{ kip}$$

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

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

$$M_{max} = ((-0.25533 \text{ kip/ft}) \times (36 \text{ in}) \times (8 \text{ ft})) \times \left[\left(\frac{(3.5901 \text{ ft})}{(8 \text{ ft})} + \frac{(5.7318 \text{ ft})}{2 \times (8 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.5901 \text{ ft})}{(8 \text{ ft})} + 3 \right) \times \left(\frac{(5.7318 \text{ ft})}{2 \times (8 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.5901 \text{ ft})}{(8 \text{ ft})} + 2 \right) \times \left(\frac{(5.7318 \text{ ft})}{2 \times (8 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 3.9321 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.705 \text{ kip})}{(0.65)(0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37.132 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-37.132 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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, 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

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

$$\text{Ratio} = \frac{(7.705 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.0061448$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.705 \text{ kip} \rightarrow 7705 \text{ lbf}$.

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(7705 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 75.746 \text{ kip}$$

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)

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

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

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

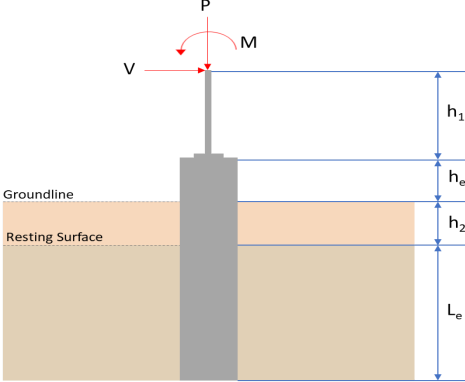
V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (75.746 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;">$V_c = 75.746 \text{ kip}$</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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((75.746 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 74.046 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 8.1894 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(8.1894 \text{ kip})}{(74.046 \text{ kip})}$ $Ratio = 0.1106$ <p>Considering z-direction:</p> <p>$V_{max} = 1.1195 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(1.1195 \text{ kip})}{(74.046 \text{ kip})}$ $Ratio = 0.015119$	<p>Status: PASS Ratio: 0.110</p> <p>Status: PASS Ratio: 0.020</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> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <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: $M_{max} = 31.07 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(31.07 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.50092$	<p>Status: PASS Ratio: 0.500</p>
	<p>Considering z-direction: $M_{max} = 3.9321 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(3.9321 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.063394$	<p>Status: PASS Ratio: 0.060</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>7.784</td> <td>11.487</td> </tr> <tr> <td>V_x (kip)</td> <td>-2.111</td> <td>-3.530</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.044</td> <td>-0.069</td> </tr> <tr> <td>M_x (kipft)</td> <td>-0.166</td> <td>-0.261</td> </tr> <tr> <td>M_z (kipft)</td> <td>26.116</td> <td>44.446</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)	7.784	11.487	V_x (kip)	-2.111	-3.530	V_z (kip)	-0.044	-0.069	M_x (kipft)	-0.166	-0.261	M_z (kipft)	26.116	44.446	
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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> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-2.111 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.70367 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(26.116 \text{ kipft}) + ((-2.111 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 8.7053 \text{ kipft/ft}$$

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:

$L_{e,x} = 8.1951 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.044 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.014667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.166 \text{ kipft}) + ((-0.044 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.055333 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.6686 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(8.1951 \text{ ft}), (1.6686 \text{ ft})]$$

$$L_{e,req} = 8.195 \text{ ft}$$

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

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

$$\text{Ratio} = \frac{(8.195 \text{ ft})}{(9 \text{ ft})}$$

$$\text{Ratio} = 0.91056$$

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

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

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

$$q = \frac{(7.784 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.1012 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.1012 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.55061$$

Status: **PASS**
Ratio: **0.550**

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:

$H_o = -0.70367 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 8.7053 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.7053 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.70367 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (8.7053 \text{ kipft/ft})) + (4 \times (-0.70367 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.2449 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (8.7053 \text{ kipft/ft})) + (3 \times (-0.70367 \text{ kip/ft}) \times (9 \text{ ft}))]^2}{(9 \text{ ft})^2 \times [(3 \times (8.7053 \text{ kipft/ft})) + (2 \times (-0.70367 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = 0.27069 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{9.425 \times [(2 \times (8.7053 \text{ kipft/ft})) + ((-0.70367 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = 1.289 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.2449 \text{ ft})}{2}$$

$$p_a = 0.46837 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.27069 \text{ kip/ft}^2)}{(0.46837 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.57795$$

Status: **PASS**
Ratio: **0.580**

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

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

$$\text{Ratio} = \frac{(1.289 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.9548$$

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

Considering z-direction:

$H_o = -0.014667 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.055333 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.055333 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.014667 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (0.055333 \text{ kipft/ft})) + (4 \times (-0.014667 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.4605 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.055333 \text{ kipft/ft})) + (3 \times (-0.014667 \text{ kip/ft}) \times (9 \text{ ft}))]^2}{(9 \text{ ft})^2 \times [(3 \times (0.055333 \text{ kipft/ft})) + (2 \times (-0.014667 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = -0.0045275 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{9.425 \times [(2 \times (0.055333 \text{ kipft/ft})) + ((-0.014667 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = -0.0024823 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.4605 \text{ ft})}{2}$$

$$p_a = 0.48453 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(-0.0045275 \text{ kip/ft}^2)}{(0.48453 \text{ kip/ft}^2)}$$

$$\text{Ratio} = -0.0093439$$

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

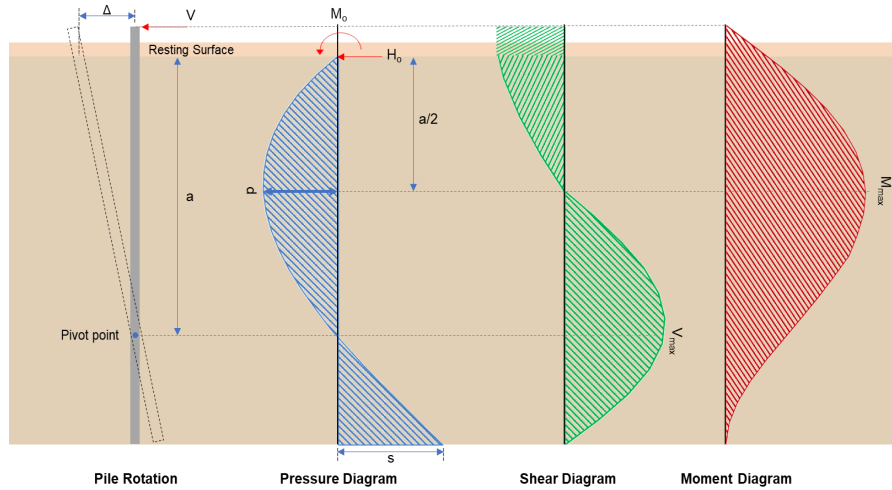
Status: **PASS**
Ratio: **-0.010**

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

$$Ratio = \frac{(-0.0024823 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$Ratio = -0.0018387$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.53 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.1767 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.446 \text{ kipft}) + ((-3.53 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.815 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.815 \text{ kipft/ft})}{(-1.1767 \text{ kip/ft})}$$

$$E = 12.591 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.815 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-1.1767 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (14.815 \text{ kipft/ft})) + (4 \times (-1.1767 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.2421 \text{ ft}$$

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

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

$$V_{max} = ((-1.1767 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.591 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.2421 \text{ ft})}{(9 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (12.591 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.2421 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 11.066 \text{ kip}$$

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

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

$$M_{max} = ((-1.1767 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(12.591 \text{ ft})}{(9 \text{ ft})} + \frac{(6.2421 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.591 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.2421 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (12.591 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.2421 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 46.922 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.069 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.023 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.261 \text{ kipft}) + ((-0.069 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.087 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.087 \text{ kipft/ft})}{(-0.023 \text{ kip/ft})}$$

$$E = 3.7826 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.087 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.023 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (0.087 \text{ kipft/ft})) + (4 \times (-0.023 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.46 \text{ ft}$$

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

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

$$V_{max} = ((-0.023 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.7826 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.46 \text{ ft})}{(9 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (3.7826 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.46 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.097411 \text{ kip}$$

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

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

$$M_{max} = ((-0.023 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(3.7826 \text{ ft})}{(9 \text{ ft})} + \frac{(6.46 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.7826 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.46 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (3.7826 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.46 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 0.38309 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(11.487 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37.014 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-37.014 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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, 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

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

$$\text{Ratio} = \frac{(11.487 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.0091609$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.487 \text{ kip} \rightarrow 11487 \text{ lbf}$.

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(11487 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.388 \text{ kip}$$

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)

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

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

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

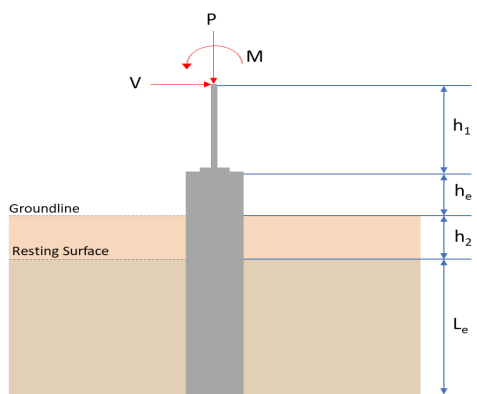
V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.388 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;">$V_c = 76.388 \text{ kip}$</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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((76.388 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 74.463 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 11.066 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(11.066 \text{ kip})}{(74.463 \text{ kip})}$ $Ratio = 0.14861$ <p>Considering z-direction:</p> <p>$V_{max} = 0.097411 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.097411 \text{ kip})}{(74.463 \text{ kip})}$ $Ratio = 0.0013082$	<p>Status: PASS Ratio: 0.150</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> $\phi M_{n,2} = \phi \times 0.85 f'_c S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (4580.4 \text{ in}^3)$ $\phi M_{n,2} = 527.23 \text{ kipft}$ <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: $M_{max} = 46.922 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(46.922 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.75647$	<p>Status: PASS Ratio: 0.760</p>
	<p>Considering z-direction: $M_{max} = 0.38309 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.38309 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.0061762$	<p>Status: PASS Ratio: 0.010</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="414 1075 1189 1176"> <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="670 1265 933 1433"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>7.784</td> <td>11.487</td> </tr> <tr> <td>V_x (kip)</td> <td>-2.111</td> <td>-3.530</td> </tr> <tr> <td>V_z (kip)</td> <td>0.044</td> <td>0.069</td> </tr> <tr> <td>M_x (kipft)</td> <td>0.165</td> <td>0.260</td> </tr> <tr> <td>M_z (kipft)</td> <td>26.116</td> <td>44.446</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)	7.784	11.487	V_x (kip)	-2.111	-3.530	V_z (kip)	0.044	0.069	M_x (kipft)	0.165	0.260	M_z (kipft)	26.116	44.446	
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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> $H_o = \frac{V_x}{D}$ $H_o = \frac{(-2.111 \text{ kip})}{(36 \text{ in})}$ $H_o = -0.70367 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{D}$																											

$$M_o = \frac{(26.116 \text{ kipft}) + ((-2.111 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 8.7053 \text{ kipft/ft}$$

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:

$L_{e,x} = 8.1951 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.044 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.014667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.165 \text{ kipft}) + ((0.044 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.055 \text{ kipft/ft}$$

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:

$L_{e,z} = 2.1457 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(8.1951 \text{ ft}), (2.1457 \text{ ft})]$$

$$L_{e,req} = 8.195 \text{ ft}$$

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

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

$$\text{Ratio} = \frac{(8.195 \text{ ft})}{(9 \text{ ft})}$$

$$\text{Ratio} = 0.91056$$

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

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

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

$$q = \frac{(7.784 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.1012 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(1.1012 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.55061$$

Status: **PASS**
Ratio: **0.550**

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:

$H_o = -0.70367 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 8.7053 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.7053 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-0.70367 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (8.7053 \text{ kipft/ft})) + (4 \times (-0.70367 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.2449 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (8.7053 \text{ kipft/ft})) + (3 \times (-0.70367 \text{ kip/ft}) \times (9 \text{ ft}))]^2}{(9 \text{ ft})^2 \times [(3 \times (8.7053 \text{ kipft/ft})) + (2 \times (-0.70367 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = 0.27069 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{9.425 \times [(2 \times (8.7053 \text{ kipft/ft})) + ((-0.70367 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = 1.289 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.2449 \text{ ft})}{2}$$

$$p_a = 0.46837 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.27069 \text{ kip/ft}^2)}{(0.46837 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.57795$$

Status: **PASS**
Ratio: **0.580**

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

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

$$\text{Ratio} = \frac{(1.289 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.9548$$

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

Considering z-direction:

$H_o = 0.014667 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.055 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.055 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (0.014667 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (0.055 \text{ kipft/ft})) + (4 \times (0.014667 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.4615 \text{ ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.055 \text{ kipft/ft})) + (3 \times (0.014667 \text{ kip/ft}) \times (9 \text{ ft}))]^2}{(9 \text{ ft})^2 \times [(3 \times (0.055 \text{ kipft/ft})) + (2 \times (0.014667 \text{ kip/ft}) \times (9 \text{ ft}))]}$$

$$p = 0.012864 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{9.425 \times [(2 \times (0.055 \text{ kipft/ft})) + ((0.014667 \text{ kip/ft}) \times (9 \text{ ft}))]}{(9 \text{ ft})^2}$$

$$s = 0.028159 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.4615 \text{ ft})}{2}$$

$$p_a = 0.48462 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.012864 \text{ kip/ft}^2)}{(0.48462 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.026544$$

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

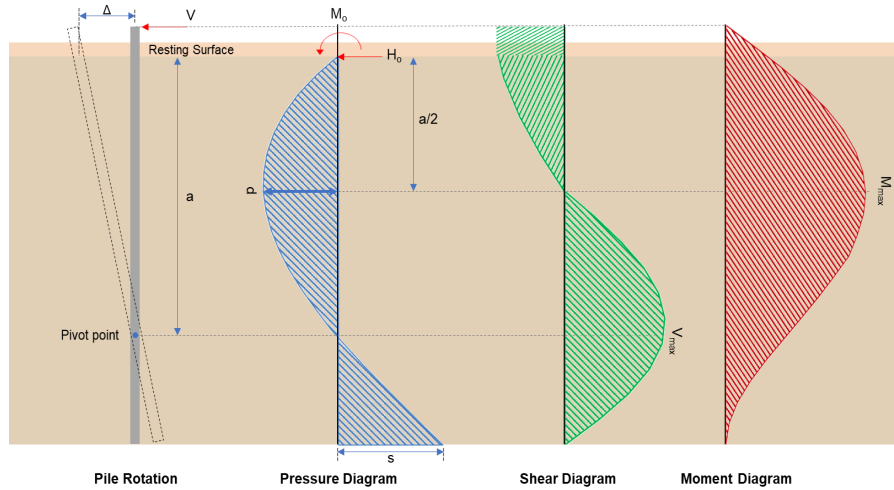
Status: **PASS**
Ratio: **0.030**

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

$$Ratio = \frac{(0.028159 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$Ratio = 0.020858$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.53 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.1767 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(44.446 \text{ kipft}) + ((-3.53 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 14.815 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(14.815 \text{ kipft/ft})}{(-1.1767 \text{ kip/ft})}$$

$$E = 12.591 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (14.815 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (-1.1767 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (14.815 \text{ kipft/ft})) + (4 \times (-1.1767 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.2421 \text{ ft}$$

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

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

$$V_{max} = ((-1.1767 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.591 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.2421 \text{ ft})}{(9 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (12.591 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.2421 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 11.066 \text{ kip}$$

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

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

$$M_{max} = ((-1.1767 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(12.591 \text{ ft})}{(9 \text{ ft})} + \frac{(6.2421 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.591 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.2421 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.591 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.2421 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 46.922 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.069 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.023 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.26 \text{ kipft}) + ((0.069 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.086667 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.086667 \text{ kipft/ft})}{(0.023 \text{ kip/ft})}$$

$$E = 3.7681 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.086667 \text{ kipft/ft}) \times (9 \text{ ft})) + (3 \times (0.023 \text{ kip/ft}) \times (9 \text{ ft})^2)}{(6 \times (0.086667 \text{ kipft/ft})) + (4 \times (0.023 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.4607 \text{ ft}$$

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

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

$$V_{max} = ((0.023 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.7681 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.4607 \text{ ft})}{(9 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.7681 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.4607 \text{ ft})}{(9 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.097217 \text{ kip}$$

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

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

$$M_{max} = ((0.023 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(3.7681 \text{ ft})}{(9 \text{ ft})} + \frac{(6.4607 \text{ ft})}{2 \times (9 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.7681 \text{ ft})}{(9 \text{ ft})} + 3 \right) \times \left(\frac{(6.4607 \text{ ft})}{2 \times (9 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.7681 \text{ ft})}{(9 \text{ ft})} + 2 \right) \times \left(\frac{(6.4607 \text{ ft})}{2 \times (9 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.38222 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(11.487 \text{ kip})}{(0.65) \times (0.85)} - (0.85 \times (2.5 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2)) \right]$$

$$A_{st,required} = -37.014 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-37.014 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))]$$

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

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

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

$$\text{Ratio} = \frac{(11.487 \text{ kip})}{(1253.9 \text{ kip})}$$

$$\text{Ratio} = 0.0091609$$

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 $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.487 \text{ kip} \rightarrow 11487 \text{ lbf}$.

22.5.5.1.1(a)

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500 \text{ psi})} + \frac{(11487 \text{ lbf})}{6 \times (1017.9 \text{ in}^2)} \right] \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{c,a} = 76.388 \text{ kip}$$

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

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

$$V_c = \text{Min}[(186.09 \text{ kip}), (76.388 \text{ kip}), (204.04 \text{ kip})]$$

<p>22.5.1.2</p> <p>22.5.8.5.3</p> <p>22.5.1.1</p>	<p style="text-align: center;">$V_c = 76.388 \text{ kip}$</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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((76.388 \text{ kip}) + (38.17 \text{ kip}))$ $\phi V_n = 74.463 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 11.066 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(11.066 \text{ kip})}{(74.463 \text{ kip})}$ $Ratio = 0.14861$ <p>Considering z-direction:</p> <p>$V_{max} = 0.097217 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.097217 \text{ kip})}{(74.463 \text{ kip})}$ $Ratio = 0.0013056$	<p>Status: PASS Ratio: 0.150</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: $M_{max} = 46.922 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(46.922 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.75647$	<p>Status: PASS Ratio: 0.760</p>
	<p>Considering z-direction: $M_{max} = 0.38222 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.38222 \text{ kipft})}{(62.027 \text{ kipft})}$ $\text{Ratio} = 0.0061621$	<p>Status: PASS Ratio: 0.010</p>