Your Project Calculations

Project Name: MTSOLAR_FC210HAEEIFH

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=MTSOLAR_FC210HAEEIFH&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2024

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=cIOSfjdo4ObRG2Hmi60fw6SJaoY51qOvS5NmriC7DQ1N8Vtp5rDeEmAD8WgblcrA

Array Specification

Product:	Beam
Unique ID:	5P-19.75-8TOP-HD-24-L-4Hx16W-G8BB
Duty Classification:	HD
Module Width:	44.60 in
Module Length:	67.80in
Number of Rows:	4
Number of Columns:	16
Total Number of Modules:	64
Desired Tilt Angle:	60
Front Edge Clearance:	4
Total Array Height at Tilt:	16.95 ft
Total Frame Length:	90.50 ft
Frame Weight:	5164 lbs
Array Dimensions N/S:	15.03 ft
Array Dimensions E/W:	91.73 ft
Rail Length:	180.40 in
Rail Spacing:	2.82 ft
Rail Check:	Not Checked

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	10.51 ft
Number of Poles:	5
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.00 ft Pile 2: 7.50 ft Pile 3: 7.50 ft Pile 4: 7.50 ft Pile 5: 7.00 ft
Foundation Volume:	21.630 y^3
Foundation Result:	PASSED
Mount Twist:	2.870779 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	7708 N Sitze Rd, Wasilla, AK 99654, USA
Wind Speed:	114 mph
Snow Load:	148 psf
Design Uplift Pressure:	0.028654 ksf
Design Downforce Pressure:	-0.028654 ksf
Design Snow Pressure:	0.016275 ksf

Design Disclaimer

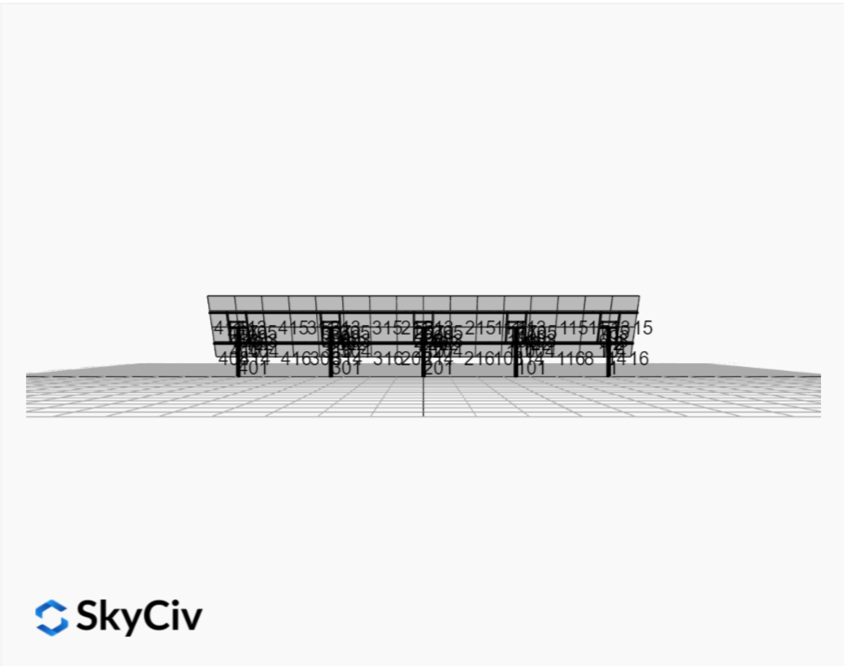
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

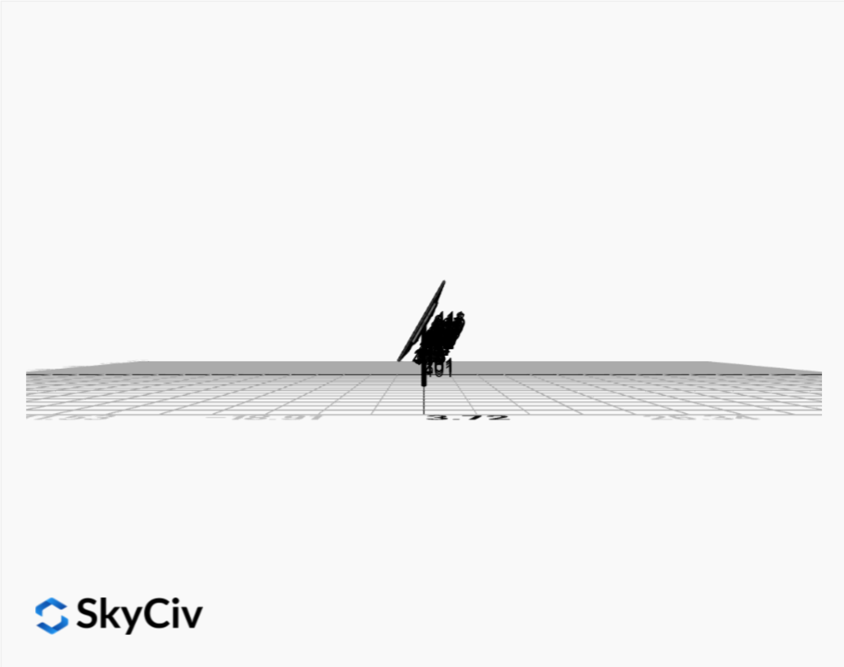
AutoDesigner Input

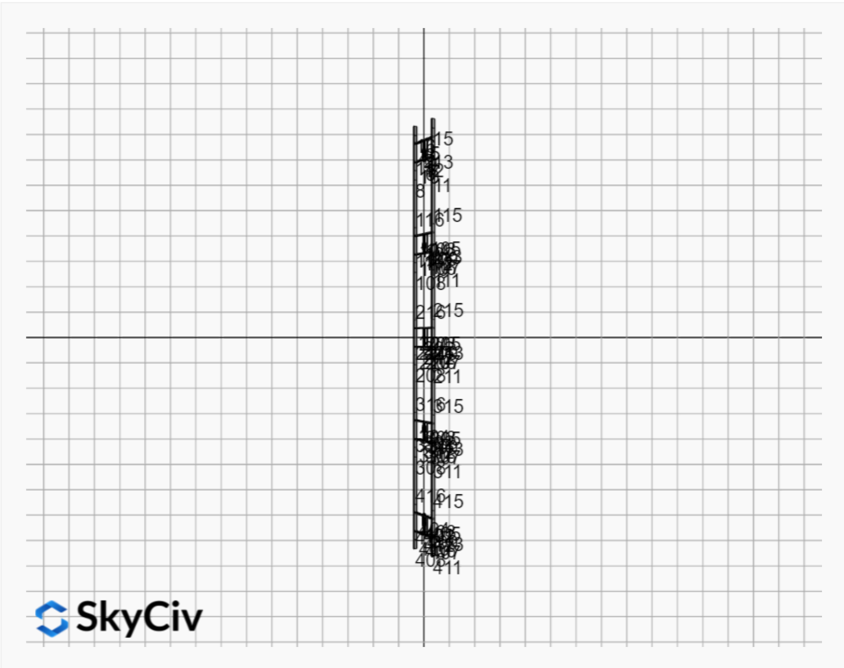
{"wind_speed_override":null,"snow_load_override":null,"direct_snow_load":false,"add_angle_brace":false,"product_type":"Beam","project_id":"MTSOLAR_FC210HAEEIFH","site_address":"7708 N Sitze Rd, Wasilla, AK 99654, USA","module_width":44.6,"module_length":67.8,"number_rows":"4","number_columns":16,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":60,"ground_clearance":4,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sand","customer_foundation_override":"48_Square","foundation_type":"Square","foundation_size":48,"check_rails":false}

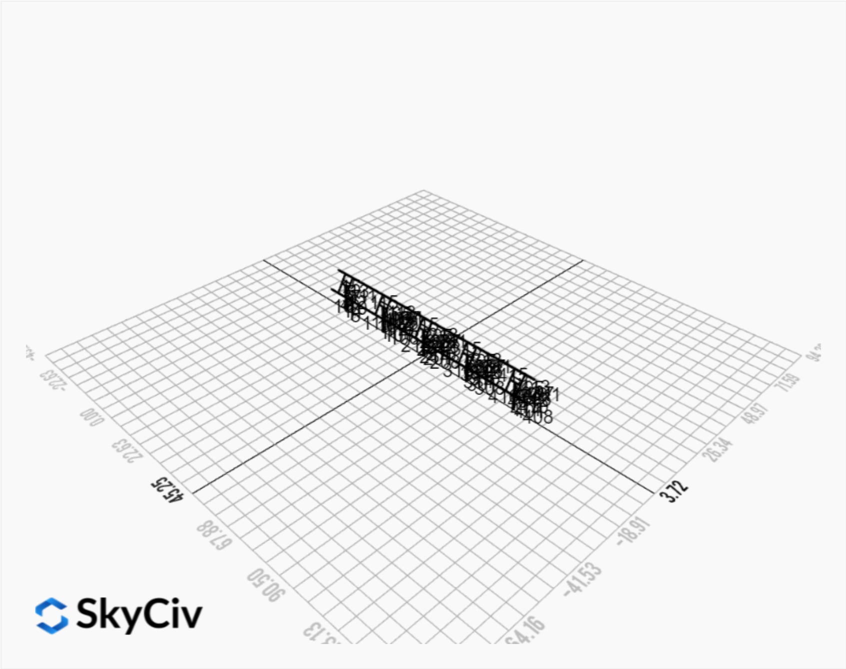
Design Notes:

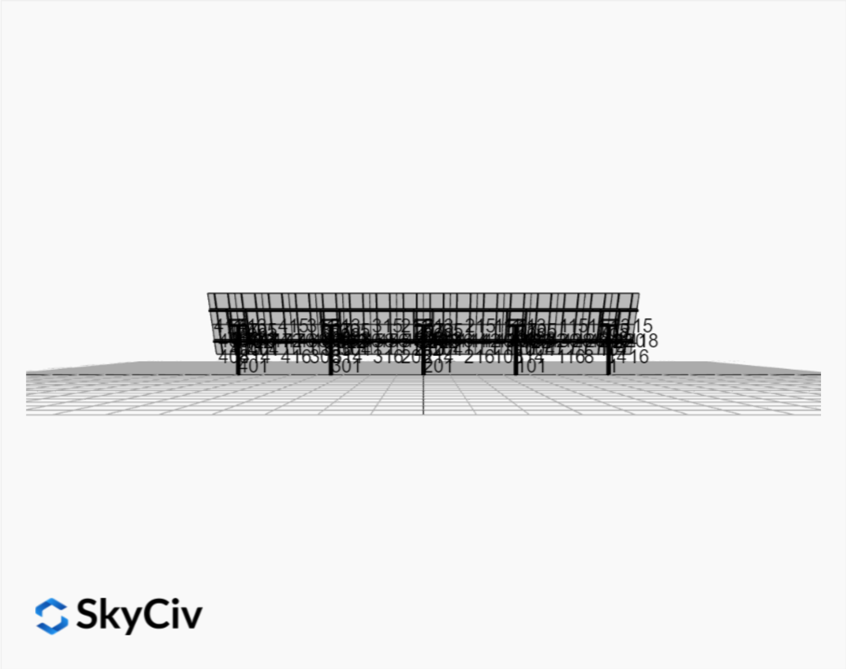
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



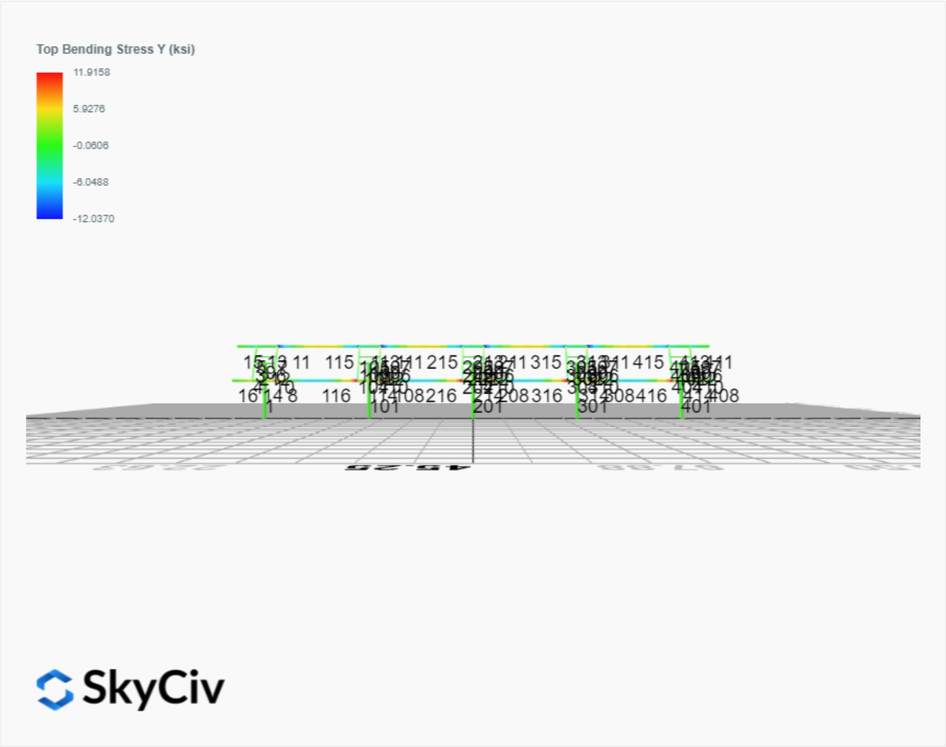


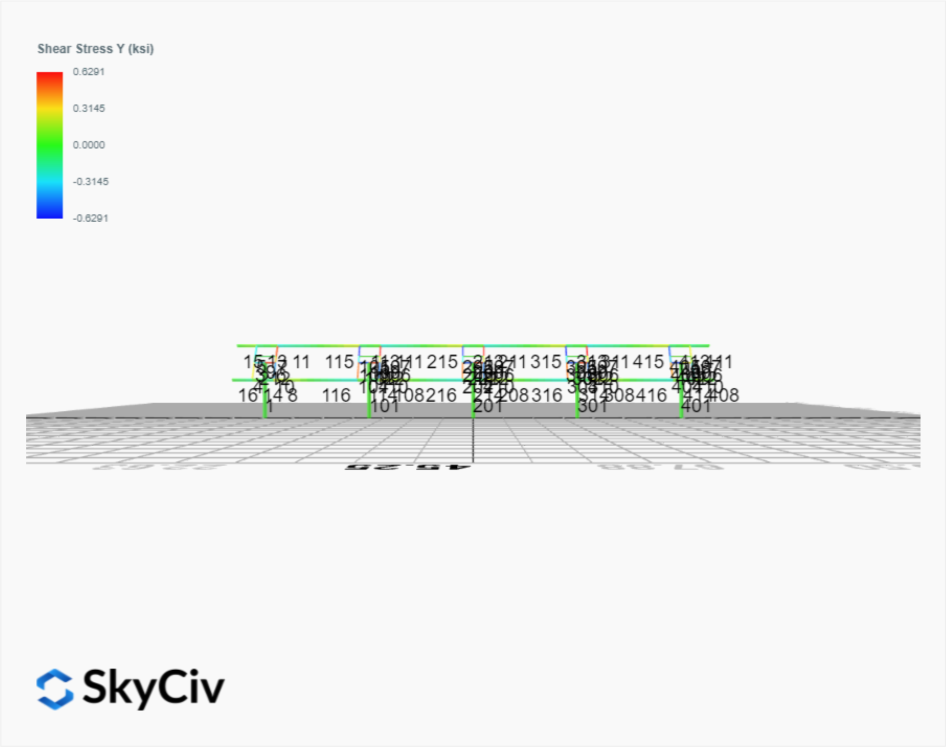






FEM Results (Envelope Worst Case for each member)


Top Bending Stress Y (ksi)
11.9158
5.9276
-0.0606
-6.0488
-12.0370
SkyCiv


Shear Stress Y (ksi)
0.6291
0.3145
0.0000
-0.3145
-0.6291
SkyCiv


Axial Stress (ksi)
0.2406
0.1240
0.0073
-0.1093
-0.2260

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	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 2. D + L	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 3. D + (S or Lr or R)	0.0519	3.9797	0.1645	0.4662	-0.1806	-0.5047
ULS: 3. D + (S or Lr or R)	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0445	3.5066	0.1409	0.3994	-0.1547	-0.4307
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 5b. D + 0.7E	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0445	3.5066	0.1409	0.3994	-0.1547	-0.4307
ULS: 8. 0.6D + 0.7E	0.0133	1.2522	0.0422	0.1194	-0.0462	-0.1251
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.4432	4.0659	0.2598	0.6636	-1.7075	36.6243
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.4860	0.1090	-0.1170	-0.2602	1.5376	-36.5975
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5546	4.9907	0.2830	0.7478	-1.3775	27.1940
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0445	3.5066	0.1409	0.3994	-0.1547	-0.4307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6423	2.0230	0.0004	0.0549	1.0563	-27.7224
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0445	3.5066	0.1409	0.3994	-0.1547	-0.4307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5769	3.5712	0.2125	0.5474	-1.2999	27.4161
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6200	0.6035	-0.0702	-0.1454	1.1339	-27.5003
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0222	2.0871	0.0703	0.1991	-0.0771	-0.2086
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.4521	3.2311	0.2317	0.5839	-1.6766	36.7077
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0133	1.2522	0.0422	0.1194	-0.0462	-0.1251
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.4771	-0.7258	-0.1452	-0.3398	1.5684	-36.5141
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0133	1.2522	0.0422	0.1194	-0.0462	-0.1251

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.1819
Shear X	-5.8155
Shear Z	0.4488
Moment X	1.1506
Moment Y (Twist)	2.8704
Moment Z	61.4609

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	4.9907
Shear X	-3.4860
Shear Z	0.2830
Moment X	0.7478
Moment Y (Twist)	1.7075
Moment Z	36.7077

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	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307
ULS: 2. D + L	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307
ULS: 3. D + (S or Lr or R)	-0.0513	4.9284	-0.0054	-0.0204	0.0574	0.5236
ULS: 3. D + (S or Lr or R)	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0440	4.3197	-0.0047	-0.0175	0.0492	0.4504
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307
ULS: 5b. D + 0.7E	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0440	4.3197	-0.0047	-0.0175	0.0492	0.4504
ULS: 8. 0.6D + 0.7E	-0.0132	1.4961	-0.0014	-0.0053	0.0148	0.1384
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.5648	5.1378	0.0037	-0.0024	-0.0909	48.0761
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.5231	-0.1520	-0.0074	-0.0129	0.1309	-46.9243
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.4511	6.3029	-0.0001	-0.0127	-0.0374	36.3344
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0440	4.3197	-0.0047	-0.0175	0.0492	0.4504
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3649	2.3356	-0.0085	-0.0205	0.1289	-34.9159
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0440	4.3197	-0.0047	-0.0175	0.0492	0.4504
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.4291	4.4767	0.0022	-0.0040	-0.0621	36.1148
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3869	0.5094	-0.0061	-0.0118	0.1043	-35.1355
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0220	2.4935	-0.0023	-0.0088	0.0246	0.2307
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.5560	4.1404	0.0046	0.0011	-0.1008	47.9838
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0132	1.4961	-0.0014	-0.0053	0.0148	0.1384
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.5319	-1.1494	-0.0065	-0.0094	0.1210	-47.0165
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0132	1.4961	-0.0014	-0.0053	0.0148	0.1384

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	9.0911
Shear X	-7.6106
Shear Z	-0.0135
Moment X	-0.0341
Moment Y (Twist)	0.2303
Moment Z	80.8139

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	6.3029
Shear X	-4.5648
Shear Z	-0.0085
Moment X	-0.0205
Moment Y (Twist)	0.1309
Moment Z	48.0761

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	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 2. D + L	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 3. D + (S or Lr or R)	-0.0012	4.8950	0.0000	-0.0000	0.0000	0.0733
ULS: 3. D + (S or Lr or R)	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0010	4.2911	0.0000	-0.0000	0.0000	0.0645
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 5b. D + 0.7E	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0010	4.2911	0.0000	-0.0000	0.0000	0.0645
ULS: 8. 0.6D + 0.7E	-0.0003	1.4875	0.0000	-0.0000	0.0000	0.0228
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.5170	5.0878	0.0000	-0.0000	0.0000	47.9892
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.5149	-0.1285	0.0000	-0.0000	0.0000	-47.1829
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.3884	6.2475	0.0000	-0.0000	0.0000	36.0278
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0010	4.2911	0.0000	-0.0000	0.0000	0.0645
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3855	2.3353	0.0000	-0.0000	0.0000	-35.3512
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0010	4.2911	0.0000	-0.0000	0.0000	0.0645

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	-3.3879	4.4356	0.0000	-0.0000	0.0000	36.0014
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3860	0.5234	0.0000	-0.0000	0.0000	-35.3777
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0005	2.4792	0.0000	-0.0000	0.0000	0.0380
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.5168	4.0961	0.0000	-0.0000	0.0000	47.9740
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0003	1.4875	0.0000	-0.0000	0.0000	0.0228
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.5151	-1.1202	0.0000	-0.0000	0.0000	-47.1981
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0003	1.4875	0.0000	-0.0000	0.0000	0.0228

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	9.0149
Shear X	-7.5298
Shear Z	0.0000
Moment X	-0.0004
Moment Y (Twist)	0.0004
Moment Z	80.6671

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	6.2475
Shear X	-4.5170
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	47.9892

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	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 2. D + L	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 3. D + (S or Lr or R)	-0.0513	4.9284	0.0054	0.0203	-0.0574	0.5236
ULS: 3. D + (S or Lr or R)	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0440	4.3197	0.0047	0.0174	-0.0492	0.4503
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 5b. D + 0.7E	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0440	4.3197	0.0047	0.0174	-0.0492	0.4503
ULS: 8. 0.6D + 0.7E	-0.0132	1.4961	0.0014	0.0053	-0.0147	0.1384
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.5648	5.1378	-0.0037	0.0024	0.0910	48.0761
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.5231	-0.1520	0.0074	0.0129	-0.1309	-46.9243
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.4511	6.3029	0.0001	0.0126	0.0375	36.3344
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0440	4.3197	0.0047	0.0174	-0.0492	0.4503
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3649	2.3356	0.0085	0.0205	-0.1289	-34.9159
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0440	4.3197	0.0047	0.0174	-0.0492	0.4503
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.4291	4.4767	-0.0022	0.0040	0.0621	36.1148
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.3869	0.5094	0.0061	0.0118	-0.1043	-35.1355
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0220	2.4935	0.0023	0.0088	-0.0246	0.2307
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.5560	4.1404	-0.0046	-0.0011	0.1008	47.9838
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0132	1.4961	0.0014	0.0053	-0.0147	0.1384
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.5319	-1.1494	0.0065	0.0094	-0.1210	-47.0165
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0132	1.4961	0.0014	0.0053	-0.0147	0.1384

Worst Case Reactions LRFD

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	9.0912
Shear X	-7.6106
Shear Z	0.0135
Moment X	0.0342
Moment Y (Twist)	0.2304
Moment Z	80.8139

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	6.3029
Shear X	-4.5648
Shear Z	0.0085
Moment X	0.0205
Moment Y (Twist)	0.1309
Moment Z	48.0761

Reaction Forces for Foundation 5 (Node ID#401), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 2. D + L	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 3. D + (S or Lr or R)	0.0519	3.9797	-0.1645	-0.4664	0.1807	-0.5046
ULS: 3. D + (S or Lr or R)	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0445	3.5065	-0.1409	-0.3996	0.1548	-0.4306
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 5b. D + 0.7E	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0445	3.5065	-0.1409	-0.3996	0.1548	-0.4306
ULS: 8. 0.6D + 0.7E	0.0133	1.2522	-0.0422	-0.1195	0.0463	-0.1251
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.4432	4.0659	-0.2598	-0.6636	1.7075	36.6243
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.4860	0.1090	0.1170	0.2602	-1.5376	-36.5975
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5546	4.9907	-0.2830	-0.7479	1.3775	27.1940
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0445	3.5065	-0.1409	-0.3996	0.1548	-0.4306
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6423	2.0230	-0.0004	-0.0551	-1.0562	-27.7223
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0445	3.5065	-0.1409	-0.3996	0.1548	-0.4306
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.5769	3.5712	-0.2125	-0.5475	1.2999	27.4161
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.6200	0.6035	0.0702	0.1453	-1.1339	-27.5002
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0222	2.0871	-0.0703	-0.1991	0.0771	-0.2085
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.4521	3.2311	-0.2317	-0.5840	1.6766	36.7077
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0133	1.2522	-0.0422	-0.1195	0.0463	-0.1251
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.4771	-0.7258	0.1452	0.3398	-1.5684	-36.5141
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0133	1.2522	-0.0422	-0.1195	0.0463	-0.1251

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.1818
Shear X	-5.8155
Shear Z	-0.4488
Moment X	-1.1511
Moment Y (Twist)	2.8708
Moment Z	61.4615

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	4.9907
Shear X	-3.4860
Shear Z	-0.2830
Moment X	-0.7479
Moment Y (Twist)	1.7075
Moment Z	36.7077

Project Details

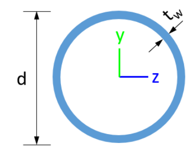
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

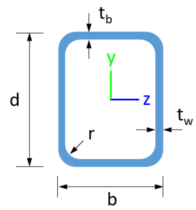
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

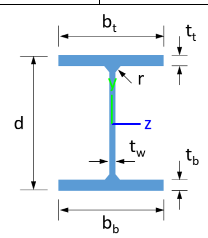
Section Dimensions



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					
10	8in Pipe Sch 80	8.63	0.50					



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
10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05

16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties

Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	22.07	22.07	10.51	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.15,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.64,1.68,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69	300	200	1
5	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
8	19	1.33	1.33	2.05	1.33,1.33,1.33,1.33,1.33,1.33,1.32,1.33,1.31,1.33,1.32,1.33,1.31,1.33,1.32,1.33,1.29,1.33,1.32,1.33,1.31,1.33,1.32,1.33,1.31,1.33	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.69,1.67,1.69	300	200	1
11	19	1.33	1.33	2.05	1.35,1.35,1.35,1.35,1.35,1.35,1.40,1.35,1.41,1.35,1.40,1.35,1.41,1.35,1.38,1.35,1.55,1.35,1.39,1.35,1.42,1.35,1.40,1.35,1.41,1.35	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.16,1.16,1.16,1.16,1.16,1.16,1.13,1.16,1.13,1.16,1.13,1.16,1.13,1.16,1.14,1.16,1.18,1.16,1.14,1.16,1.12,1.16,1.13,1.16,1.13,1.16	300	200	1
14	19	4.88	4.00	7.50	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16	300	200	1
15	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	10	22.07	22.07	10.51	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
106	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1

108	19	1.33	1.33	2.05	2.10,2.10,2.10,2.11,2.10,2.10,2.09,2.10,2.08,2.10,2.09,2.10,2.08,2.10,2.09,2.11,2.03,2.11,2.09,2.10,2.08,2.10,2.09,2.10,2.08,2.10	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
111	19	1.33	1.33	2.05	2.08,2.08,2.08,2.08,2.08,2.08,1.98,2.08,1.84,2.08,1.96,2.08,1.88,2.08,2.06,2.08,1.44,2.08,2.01,2.08,1.81,2.08,1.95,2.08,1.89,2.08	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1
113	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.08,1.05,1.09,1.05,1.08,1.05,1.09,1.05,1.07,1.05,1.22,1.05,1.08,1.05,1.09,1.05,1.08,1.05,1.08,1.05	300	200	1
114	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.07,1.05,1.06,1.05,1.07,1.05,1.06,1.05,1.11,1.05,1.06,1.05,1.07,1.05,1.06,1.05,1.07,1.05	300	200	1
115	19	6.63	6.63	10.20	1.15,1.15,1.15,1.15,1.15,1.15,1.12,1.15,1.11,1.15,1.12,1.15,1.12,1.15,1.13,1.15,1.07,1.15,1.12,1.15,1.11,1.15,1.12,1.15,1.12,1.15	300	200	1
116	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.15,1.16,1.15,1.16,1.15,1.16,1.15,1.16,1.13,1.16,1.15,1.16,1.15,1.16,1.15,1.16,1.15,1.16	300	200	1
201	10	22.07	22.07	10.51	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
204	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
205	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
206	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
207	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
208	19	1.33	1.33	2.05	2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.10,2.09,2.09,2.09,2.09,2.09,2.09,2.09,2.09	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
211	19	1.33	1.33	2.05	2.10,2.10,2.10,2.10,2.10,2.10,2.09,2.10,2.08,2.10,2.08,2.10,2.08,2.10,2.09,2.10,1.90,2.10,2.09,2.10,2.08,2.10,2.08,2.10,2.08,2.10	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04	300	200	1
214	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04,1.04	300	200	1
215	19	6.63	6.63	10.20	1.16,1.17,1.16,1.17,1.16,1.16,1.16,1.17,1.16,1.17,1.16,1.16,1.16,1.16,1.16,1.17,1.14,1.17,1.16,1.16,1.16,1.16,1.16,1.16,1.16	300	200	1
216	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16	300	200	1
301	10	22.07	22.07	10.51	-	300	200	1

302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
305	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
306	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
307	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
308	19	1.33	1.33	2.05	2.07,2.07,2.07,2.07,2.07,2.07,1.93,2.07,1.87,2.07,1.92,2.07,1.89,2.07,1.98,2.07,1.63,2.07,1.94,2.07,1.86,2.07,1.92,2.07,1.89,2.07	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
311	19	1.33	1.33	2.05	1.91,1.91,1.91,1.91,1.91,1.92,1.58,1.91,1.50,1.91,1.57,1.91,1.52,1.91,1.66,1.91,1.25,1.91,1.60,1.91,1.48,1.91,1.57,1.92,1.53,1.92	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.08,1.05,1.09,1.05,1.08,1.05,1.09,1.05,1.07,1.05,1.22,1.05,1.08,1.05,1.09,1.05,1.08,1.05,1.08,1.05	300	200	1
314	19	4.88	4.00	7.50	1.05,1.05,1.05,1.05,1.05,1.05,1.06,1.05,1.07,1.05,1.06,1.05,1.07,1.05,1.06,1.05,1.11,1.05,1.06,1.05,1.07,1.05,1.06,1.05,1.07,1.05	300	200	1
315	19	6.63	6.63	10.20	1.16,1.16,1.16,1.16,1.16,1.16,1.14,1.16,1.13,1.16,1.14,1.16,1.13,1.16,1.14,1.16,1.10,1.16,1.14,1.16,1.13,1.16,1.13,1.16,1.13,1.16	300	200	1
316	19	6.63	6.63	10.20	1.16,1.17,1.16,1.17,1.17,1.16,1.16,1.17,1.15,1.17,1.16,1.16,1.16,1.16,1.16,1.17,1.14,1.17,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.16	300	200	1
401	10	22.07	22.07	10.51	-	300	200	1
402	5	1.30	1.30	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
404	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.69,1.67,1.69	300	200	1
405	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
406	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.15,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
407	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.65,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
408	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.64,1.68,1.67,1.69,1.66,1.69,1.67,1.69,1.66,1.69	300	200	1
411	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1

412	5	1.30	1.30	2.00	-	300	200	1
413	19	4.88	4.00	7.50	1.16,1.16,1.16,1.16,1.16,1.16,1.13,1.16,1.13,1.16,1.13,1.16,1.13,1.16,1.14,1.16,1.18,1.16,1.14,1.16,1.12,1.16,1.13,1.16,1.13,1.16	300	200	1
414	19	4.88	4.00	7.50	1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.15,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16,1.16	300	200	1
415	19	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.13,1.09,1.09,1.09,1.10,1.09,1.09,1.09,1.10,1.09	300	200	1
416	19	6.63	6.63	10.20	1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.09,1.08,1.09,1.09,1.09,1.08,1.09,1.09,1.09,1.08,1.09,1.09,1.09,1.08,1.09,1.09,1.09,1.08,1.09	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	574.32	309.22	123.94	123.94	172.30	172.30
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	123.95	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	123.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	25.74	6.12	40.24	43.62
14	133.20	85.85	26.43	6.12	40.24	43.62
15	133.20	102.39	32.87	6.12	40.24	43.62
16	133.20	102.39	32.87	6.12	40.24	43.62
101	574.32	309.22	123.94	123.94	172.30	172.30
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	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	123.95	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	123.95	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	85.85	24.15	6.12	40.24	43.62
114	133.20	85.85	24.04	6.12	40.24	43.62
115	133.20	69.16	16.61	6.12	40.24	43.62
116	133.20	69.16	17.50	6.12	40.24	43.62
201	574.32	309.22	123.94	123.94	172.30	172.30
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	123.95	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	123.95	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	23.73	6.12	40.24	43.62
214	133.20	85.85	23.73	6.12	40.24	43.62
215	133.20	69.16	17.69	6.12	40.24	43.62
216	133.20	69.16	17.90	6.12	40.24	43.62
301	574.32	309.22	123.94	123.94	172.30	172.30
302	198.33	196.72	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	123.95	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	123.95	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	85.85	24.15	6.12	40.24	43.62
314	133.20	85.85	24.04	6.12	40.24	43.62
315	133.20	69.16	16.95	6.12	40.24	43.62
316	133.20	69.16	17.60	6.12	40.24	43.62
401	574.32	309.22	123.94	123.94	172.30	172.30
402	198.33	196.72	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28
407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	102.39	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	102.39	32.87	6.12	40.24	43.62
412	198.33	196.72	21.95	21.95	59.50	59.50
413	133.20	85.85	25.73	6.12	40.24	43.62
414	133.20	85.85	26.46	6.12	40.24	43.62
415	133.20	69.16	16.84	6.12	40.24	43.62
416	133.20	69.16	16.69	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	δ	Status
1	0.023	0.496	0.029	0.034	0.003	0.516	#13	0.460	Not Required	Pass
2	0.002	0.148	0.178	0.040	0.040	0.318	#13	0.053	Not Required	Pass
3	0.007	0.383	0.028	0.037	0.001	0.396	#13	0.045	Not Required	Pass
4	0.006	0.383	0.079	0.039	0.020	0.447	#13	0.080	Not Required	Pass
5	0.006	0.238	0.063	0.038	0.016	0.243	#13	0.074	Not Required	Pass
6	0.012	0.583	0.108	0.060	0.029	0.653	#13	0.045	Not Required	Pass
7	0.013	0.362	0.185	0.058	0.045	0.387	#13	0.074	Not Required	Pass
8	0.004	0.110	0.169	0.036	0.019	0.178	#21	0.095	Not Required	Pass

9	0.007	0.051	0.081	0.004	0.004	0.107	#13	0.204	Not Required	Pass
10	0.013	0.556	0.180	0.056	0.039	0.591	#13	0.080	Not Required	Pass
11	0.005	0.102	0.173	0.038	0.019	0.180	#21	0.095	Not Required	Pass
12	0.001	0.302	0.308	0.072	0.060	0.610	#13	0.053	Not Required	Pass
13	0.008	0.100	0.441	0.050	0.024	0.488	#21	0.286	Not Required	Pass
14	0.005	0.092	0.435	0.047	0.024	0.461	#21	0.190	Not Required	Pass
15	0.000	0.016	0.043	0.013	0.006	0.055	#21	Not Required	Not Required	Pass
16	0.000	0.016	0.043	0.013	0.006	0.055	#21	Not Required	Not Required	Pass
101	0.029	0.652	0.001	0.044	0.000	0.666	#13	0.460	Not Required	Pass
102	0.003	0.287	0.324	0.072	0.063	0.612	#13	0.035	Not Required	Pass
103	0.012	0.616	0.072	0.061	0.011	0.662	#13	0.045	Not Required	Pass
104	0.012	0.637	0.185	0.064	0.039	0.715	#13	0.080	Not Required	Pass
105	0.012	0.382	0.193	0.061	0.049	0.411	#13	0.074	Not Required	Pass
106	0.012	0.631	0.072	0.063	0.011	0.673	#13	0.045	Not Required	Pass
107	0.012	0.392	0.188	0.063	0.047	0.421	#13	0.074	Not Required	Pass
108	0.005	0.048	0.163	0.040	0.019	0.189	#21	0.095	Not Required	Pass
109	0.015	0.031	0.059	0.001	0.000	0.094	#13	0.204	Not Required	Pass
110	0.012	0.634	0.180	0.063	0.038	0.706	#13	0.080	Not Required	Pass
111	0.005	0.060	0.168	0.039	0.019	0.188	#21	0.095	Not Required	Pass
112	0.003	0.291	0.331	0.072	0.065	0.622	#13	0.035	Not Required	Pass
113	0.008	0.174	0.446	0.053	0.024	0.553	#21	0.286	Not Required	Pass
114	0.007	0.205	0.441	0.055	0.024	0.567	#21	0.286	Not Required	Pass
115	0.010	0.297	0.243	0.041	0.019	0.459	#21	0.473	Not Required	Pass
116	0.004	0.290	0.241	0.044	0.019	0.447	#21	0.473	Not Required	Pass
201	0.029	0.651	0.000	0.044	0.000	0.665	#13	0.460	Not Required	Pass
202	0.003	0.287	0.325	0.071	0.063	0.613	#13	0.035	Not Required	Pass
203	0.012	0.628	0.071	0.063	0.011	0.673	#13	0.045	Not Required	Pass
204	0.012	0.618	0.179	0.062	0.038	0.690	#13	0.080	Not Required	Pass
205	0.012	0.390	0.188	0.062	0.047	0.417	#13	0.074	Not Required	Pass
206	0.012	0.628	0.071	0.063	0.011	0.673	#13	0.045	Not Required	Pass
207	0.012	0.390	0.188	0.062	0.047	0.417	#13	0.074	Not Required	Pass
208	0.005	0.048	0.163	0.040	0.019	0.189	#21	0.095	Not Required	Pass
209	0.014	0.029	0.060	0.001	0.000	0.092	#13	0.204	Not Required	Pass
210	0.012	0.618	0.179	0.062	0.038	0.690	#13	0.080	Not Required	Pass
211	0.005	0.051	0.168	0.041	0.019	0.195	#21	0.095	Not Required	Pass
212	0.003	0.287	0.325	0.071	0.063	0.613	#13	0.035	Not Required	Pass
213	0.008	0.202	0.434	0.052	0.024	0.570	#21	0.286	Not Required	Pass
214	0.007	0.205	0.427	0.051	0.024	0.559	#21	0.286	Not Required	Pass
215	0.010	0.221	0.243	0.041	0.019	0.402	#21	0.473	Not Required	Pass
216	0.005	0.209	0.240	0.040	0.019	0.389	#21	0.473	Not Required	Pass
301	0.029	0.652	0.001	0.044	0.000	0.666	#13	0.460	Not Required	Pass
302	0.003	0.291	0.331	0.072	0.065	0.622	#13	0.035	Not Required	Pass
303	0.012	0.631	0.072	0.063	0.011	0.673	#13	0.045	Not Required	Pass
304	0.012	0.634	0.180	0.063	0.038	0.706	#13	0.080	Not Required	Pass
305	0.012	0.392	0.188	0.063	0.047	0.421	#13	0.074	Not Required	Pass
306	0.012	0.616	0.072	0.061	0.011	0.662	#13	0.045	Not Required	Pass
307	0.012	0.382	0.193	0.061	0.049	0.411	#13	0.074	Not Required	Pass
308	0.004	0.071	0.174	0.044	0.019	0.191	#21	0.095	Not Required	Pass
309	0.015	0.031	0.059	0.001	0.000	0.094	#13	0.204	Not Required	Pass
310	0.012	0.637	0.185	0.064	0.039	0.715	#13	0.080	Not Required	Pass
311	0.005	0.087	0.178	0.041	0.019	0.185	#21	0.095	Not Required	Pass
312	0.003	0.287	0.324	0.072	0.063	0.612	#13	0.035	Not Required	Pass
313	0.008	0.174	0.447	0.053	0.024	0.553	#21	0.286	Not Required	Pass
314	0.007	0.205	0.441	0.055	0.024	0.567	#21	0.286	Not Required	Pass

315	0.010	0.222	0.243	0.039	0.019	0.404	#21	0.473	Not Required	Pass
316	0.005	0.207	0.240	0.040	0.019	0.388	#21	0.473	Not Required	Pass
401	0.023	0.496	0.029	0.034	0.003	0.516	#13	0.460	Not Required	Pass
402	0.001	0.302	0.308	0.072	0.060	0.610	#13	0.053	Not Required	Pass
403	0.012	0.583	0.108	0.060	0.029	0.653	#13	0.045	Not Required	Pass
404	0.013	0.556	0.180	0.056	0.039	0.591	#13	0.080	Not Required	Pass
405	0.013	0.362	0.185	0.058	0.045	0.387	#13	0.074	Not Required	Pass
406	0.007	0.383	0.028	0.037	0.001	0.396	#13	0.045	Not Required	Pass
407	0.006	0.238	0.063	0.038	0.016	0.243	#13	0.074	Not Required	Pass
408	0.000	0.016	0.043	0.013	0.006	0.055	#21	Not Required	Not Required	Pass
409	0.007	0.051	0.081	0.004	0.004	0.107	#13	0.204	Not Required	Pass
410	0.006	0.383	0.079	0.039	0.020	0.447	#13	0.080	Not Required	Pass
411	0.000	0.016	0.043	0.013	0.006	0.055	#21	Not Required	Not Required	Pass
412	0.002	0.148	0.178	0.040	0.040	0.318	#13	0.053	Not Required	Pass
413	0.008	0.100	0.441	0.050	0.024	0.488	#21	0.190	Not Required	Pass
414	0.005	0.092	0.435	0.047	0.024	0.461	#21	0.286	Not Required	Pass
415	0.010	0.312	0.243	0.038	0.019	0.464	#21	0.473	Not Required	Pass
416	0.004	0.307	0.240	0.036	0.019	0.455	#21	0.473	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

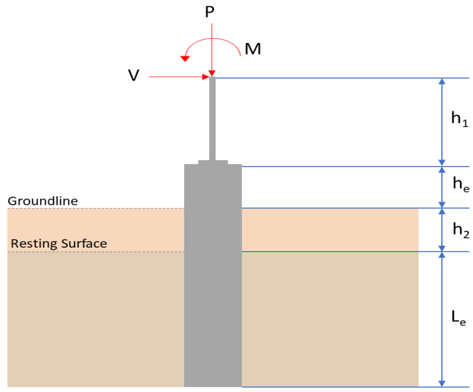
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.991	7.182
V_x (kip)	-3.486	-5.815
V_z (kip)	0.283	0.449
M_x (kipft)	0.748	1.151
M_z (kipft)	36.708	61.461

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.486\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.5551\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(36.708 \text{ kipft}) + ((-3.486 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.8452 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.3505 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.283 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.045064 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.748 \text{ kipft}) + ((0.283 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.11911 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.5405 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3505 \text{ ft}), (2.5405 \text{ ft})]$$

$$L_{e,req} = 6.35 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.35 \text{ ft})}{(7 \text{ ft})}$$

$$Ratio = 0.90714$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.991 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.31194 \text{ kip/ft}^2$$

$q = 0.31194\ \mathrm{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.31194\ \mathrm{kip/ft}^2\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.15597$$

Status: **PASS**
Ratio: **0.160**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 1.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.5551\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.8452\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.8452\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.5551\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (5.8452\ \mathrm{kipft/ft})) + (4 \times (-0.5551\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 4.8458\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.8452\ \mathrm{kipft/ft})) + (3 \times (-0.5551\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^2}{(7\ \mathrm{ft})^2 \times [(3 \times (5.8452\ \mathrm{kipft/ft})) + (2 \times (-0.5551\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = 0.21546\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (5.8452\ \mathrm{kipft/ft})) + ((-0.5551\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = 0.95569\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.8458\ \mathrm{ft})}{2}$$

$$p_a = 0.36343\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21546\ \mathrm{kip/ft}^2\right)}{\left(0.36343\ \mathrm{kip/ft}^2\right)}$$

$$Ratio = 0.59284$$

Status: **PASS**
Ratio: **0.590**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.95569\ \mathrm{kip/ft^2})}{(1.05\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.91018$$

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

Considering z-direction:

$H_o = 0.045064\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.11911\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.11911\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (0.11911\ \mathrm{kipft/ft})) + (4 \times (0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 5.0391\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.11911\ \mathrm{kipft/ft})) + (3 \times (0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^{\ 2}}{(7\ \mathrm{ft})^2 \times [(3 \times (0.11911\ \mathrm{kipft/ft})) + (2 \times (0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = 0.031353\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.11911\ \mathrm{kipft/ft})) + ((0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = 0.067795\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.0391\ \mathrm{ft})}{2}$$

$$p_a = 0.37793\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.031353\ \mathrm{kip/ft^2})}{(0.37793\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.08296$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

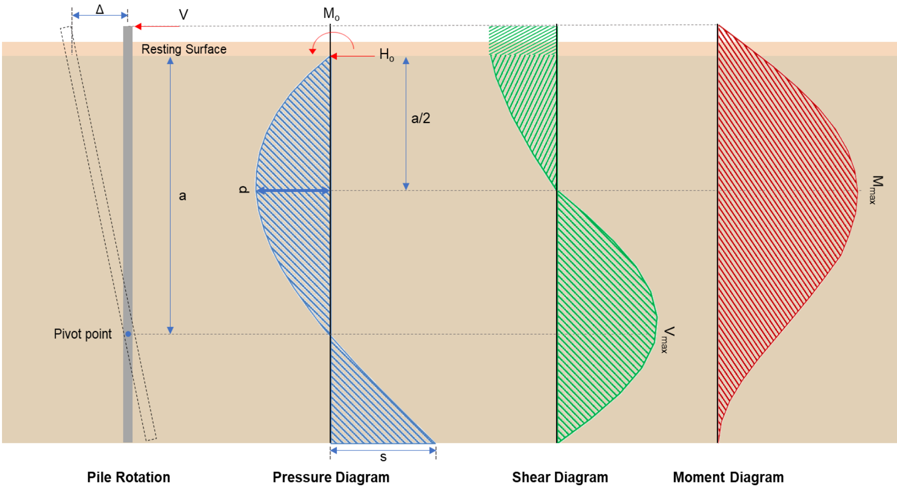
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.067795 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.064567$$

Status: **PASS**
Ratio: **0.060**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.815 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.92596 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(61.461 \text{ kipft}) + ((-5.815 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 9.7868 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.7868 \text{ kipft/ft})}{(-0.92596 \text{ kip/ft})}$$

$$E = 10.569 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.7868 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.92596 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (9.7868 \text{ kipft/ft})) + (4 \times (-0.92596 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8453 \text{ ft}$$

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

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

$$V_{max} = ((-0.92596 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.8453 \text{ ft})}{(7 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.569 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.8453 \text{ ft})}{(7 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 12.338 \text{ kip}$$

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

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

$$M_{max} = ((-0.92596\ \text{kip/ft})\times(48\ \text{in})\times(7\ \text{ft}))\times\left[\left(\frac{(10.569\ \text{ft})}{(7\ \text{ft})}+\frac{(4.8453\ \text{ft})}{2\times(7\ \text{ft})}\right) - \left[\left(\frac{4\times(10.569\ \text{ft})}{(7\ \text{ft})}+3\right)\times\left(\frac{(4.8453\ \text{ft})}{2\times(7\ \text{ft})}\right)^3\right]+\left[\left(\frac{3\times(10.569\ \text{ft})}{(7\ \text{ft})}+2\right)\times\left(\frac{(4.8453\ \text{ft})}{2\times(7\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 40.833\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.449\ \text{kip})}{1.57\times(48\ \text{in})}$$

$$H_o = 0.071497\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.151\ \text{kipft})+((0.449\ \text{kip})\times(0\ \text{ft}))}{1.57\times(48\ \text{in})}$$

$$M_o = 0.18328\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.18328\ \text{kipft/ft})}{(0.071497\ \text{kip/ft})}$$

$$E = 2.5635\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4\times(0.18328\ \text{kipft/ft})\times(7\ \text{ft}))+\left(3\times(0.071497\ \text{kip/ft})\times(7\ \text{ft})^2\right)}{(6\times(0.18328\ \text{kipft/ft}))+(4\times(0.071497\ \text{kip/ft})\times(7\ \text{ft}))}$$

$$a = 5.0432\ \text{ft}$$

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

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

$$V_{max} = ((0.071497\ \text{kip/ft})\times(48\ \text{in}))\times\left[1-\left[3\times\left(\frac{4\times(2.5635\ \text{ft})}{(7\ \text{ft})}+3\right)\times\left(\frac{(5.0432\ \text{ft})}{(7\ \text{ft})}\right)^2\right]+\left[4\times\left(\frac{3\times(2.5635\ \text{ft})}{(7\ \text{ft})}+2\right)\times\left(\frac{(5.0432\ \text{ft})}{(7\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.37679\ \text{kip}$$

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

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

$$M_{max} = ((0.071497\ \text{kip/ft})\times(48\ \text{in})\times(7\ \text{ft}))\times\left[\left(\frac{(2.5635\ \text{ft})}{(7\ \text{ft})}+\frac{(5.0432\ \text{ft})}{2\times(7\ \text{ft})}\right) - \left[\left(\frac{4\times(2.5635\ \text{ft})}{(7\ \text{ft})}+3\right)\times\left(\frac{(5.0432\ \text{ft})}{2\times(7\ \text{ft})}\right)^3\right]+\left[\left(\frac{3\times(2.5635\ \text{ft})}{(7\ \text{ft})}+2\right)\times\left(\frac{(5.0432\ \text{ft})}{2\times(7\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.1409 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.182 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.357 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.357 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

	Ties: **#3(0.375 in) - 10 in**	
22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(7.182\text{ kip})}{(2675.2\text{ kip})}$$ $$Ratio = 0.0026847$$	Status: **PASS** Ratio: **0.000**

22.5.2.2 22.5.5.1.3 22.5.5.1.1 22.5.5.1.1(a) 22.5.5.1.2	**Shear Strength (ACI 318-19, LRFD)** **Parameters:** $b_w = 48\text{ in}$ - Effective width, d - Effective depth $$d = 0.80\, D$$ $$d = 0.80 \times (48\text{ in})$$ $$d = 38.4\text{ in}$$ λ_s - size effect modification factor $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{d}{10}}}, 1\right]$$ $$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(38.4\text{ in})}{10}}}, 1\right]$$ $$\lambda_s = 0.64282$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\text{ psi})} \times (48\text{ in}) \times (38.4\text{ in})$$ $$V_{c,max} = 296.21\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 7.182\text{ kip} \rightarrow 7182\text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(7182\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$ $$V_{c,a} = 119.44\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + (0.05 \times (2500\text{ psi}))\right] \times (48\text{ in}) \times (38.4\text{ in})$$ $$V_{c,b} = 348.89\text{ kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(296.21\text{ kip}), (119.44\text{ kip}), (348.89\text{ kip})\right]$$ $$V_c = 119.44\text{ kip}$$	

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\ b_w\ d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 737.28\ \text{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\ d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\ A_v\ f_{ywk}\ d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((119.44\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 110.72\ \text{kip}$$ **Considering x-direction:** $V_{max} = 12.338\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(12.338\ \text{kip})}{(110.72\ \text{kip})}$$ $$Ratio = 0.11144$$	Status: **PASS** Ratio: **0.110**
	Considering z-direction: $V_{max} = 0.37679\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.37679\ \text{kip})}{(110.72\ \text{kip})}$$ $$Ratio = 0.0034031$$	Status: **PASS** Ratio: **0.000**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\ D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$	

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 40.833\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(40.833\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.16359$$	Status: **PASS** Ratio: **0.160**
	Considering z-direction: $M_{max} = 1.1409\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.1409\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.0045709$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

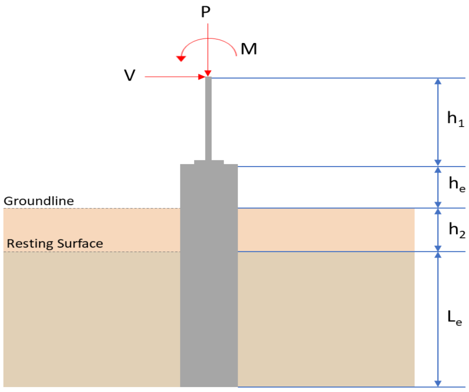
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 7\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.991	7.182
V_x (kip)	-3.486	-5.815
V_z (kip)	-0.283	-0.449
M_x (kipft)	-0.748	-1.151
M_z (kipft)	36.708	61.462

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.486\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.5551\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(36.708\ \text{kipft}) + ((-3.486\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 5.8452\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.3505\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.283\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.045064\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.748\ \text{kipft}) + ((-0.283\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.11911\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.7017\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.3505\ \text{ft}), (1.7017\ \text{ft})]$$

$$L_{e,req} = 6.35\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.35\ \text{ft})}{(7\ \text{ft})}$$

$$Ratio = 0.90714$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(4.991\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.31194\ \text{kip/ft}^2$$

$q = 0.31194\ \mathrm{kip/ft^2}$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.31194\ \mathrm{kip/ft^2}\right)}{\left(2000\ \mathrm{psf}\right)}$$

$$Ratio = 0.15597$$

Status: **PASS**
Ratio: **0.160**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{\left(7\ \mathrm{ft}\right)}{\left(48\ \mathrm{in}\right)}$$

$$L/D = 1.75$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.5551\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 5.8452\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{\left(4 \times \left(5.8452\ \mathrm{kipft/ft}\right) \times \left(7\ \mathrm{ft}\right)\right) + \left(3 \times \left(-0.5551\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)^2\right)}{\left(6 \times \left(5.8452\ \mathrm{kipft/ft}\right)\right) + \left(4 \times \left(-0.5551\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)\right)}$$

$$a = 4.8458\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times \left[\left(4 \times \left(5.8452\ \mathrm{kipft/ft}\right)\right) + \left(3 \times \left(-0.5551\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)\right)\right]^{\,2}}{\left(7\ \mathrm{ft}\right)^2 \times \left[\left(3 \times \left(5.8452\ \mathrm{kipft/ft}\right)\right) + \left(2 \times \left(-0.5551\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)\right)\right]}$$

$$p = 0.21546\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times \left[\left(2 \times \left(5.8452\ \mathrm{kipft/ft}\right)\right) + \left(\left(-0.5551\ \mathrm{kip/ft}\right) \times \left(7\ \mathrm{ft}\right)\right)\right]}{\left(7\ \mathrm{ft}\right)^2}$$

$$s = 0.95569\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = \left(150\ \mathrm{psf/ft}\right) \times \frac{\left(4.8458\ \mathrm{ft}\right)}{2}$$

$$p_a = 0.36343\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.21546\ \mathrm{kip/ft^2}\right)}{\left(0.36343\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.59284$$

Status: **PASS**
Ratio: **0.590**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.95569\ \mathrm{kip/ft^2})}{(1.05\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.91018$$

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

Considering z-direction:

$H_o = -0.045064\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.11911\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.11911\ \mathrm{kipft/ft}) \times (7\ \mathrm{ft})) + \left(3 \times (-0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft})^2\right)}{(6 \times (0.11911\ \mathrm{kipft/ft})) + (4 \times (-0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))}$$

$$a = 5.0391\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.11911\ \mathrm{kipft/ft})) + (3 \times (-0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]^2}{(7\ \mathrm{ft})^2 \times [(3 \times (0.11911\ \mathrm{kipft/ft})) + (2 \times (-0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}$$

$$p = -0.012354\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.11911\ \mathrm{kipft/ft})) + ((-0.045064\ \mathrm{kip/ft}) \times (7\ \mathrm{ft}))]}{(7\ \mathrm{ft})^2}$$

$$s = -0.0094566\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.0391\ \mathrm{ft})}{2}$$

$$p_a = 0.37793\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.012354\ \mathrm{kip/ft^2})}{(0.37793\ \mathrm{kip/ft^2})}$$

$$Ratio = -0.03269$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7\ \mathrm{ft})$$

$$p_s = 1.05\ \mathrm{kip/ft^2}$$

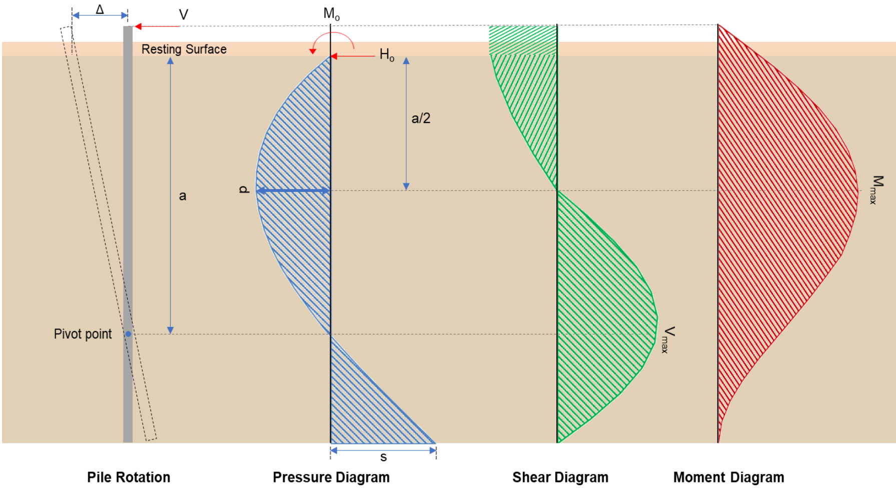
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.0094566\ \text{kip/ft}^2)}{(1.05\ \text{kip/ft}^2)}$$

$$Ratio = -0.0090063$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.815\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.92596\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(61.462\ \text{kipft}) + ((-5.815\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 9.7869\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.7869\ \text{kipft/ft})}{(-0.92596\ \text{kip/ft})}$$

$$E = 10.57\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.7869\ \text{kipft/ft}) \times (7\ \text{ft})) + \left(3 \times (-0.92596\ \text{kip/ft}) \times (7\ \text{ft})^2\right)}{(6 \times (9.7869\ \text{kipft/ft})) + (4 \times (-0.92596\ \text{kip/ft}) \times (7\ \text{ft}))}$$

$$a = 4.8453\ \text{ft}$$

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

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

$$V_{max} = ((-0.92596\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.57\ \text{ft})}{(7\ \text{ft})} + 3\right) \times \left(\frac{(4.8453\ \text{ft})}{(7\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.57\ \text{ft})}{(7\ \text{ft})} + 2\right) \times \left(\frac{(4.8453\ \text{ft})}{(7\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.338\ \text{kip}$$

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

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

$$M_{max} = ((-0.92596 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(10.57 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (10.57 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.57 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(4.8453 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 40.834 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.449 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.071497 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.151 \text{ kipft}) + ((-0.449 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.18328 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.18328 \text{ kipft/ft})}{(-0.071497 \text{ kip/ft})}$$

$$E = 2.5635 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.18328 \text{ kipft/ft}) \times (7 \text{ ft})) + \left(3 \times (-0.071497 \text{ kip/ft}) \times (7 \text{ ft})^2\right)}{(6 \times (0.18328 \text{ kipft/ft})) + (4 \times (-0.071497 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0432 \text{ ft}$$

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

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

$$V_{max} = ((-0.071497 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.5635 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(5.0432 \text{ ft})}{(7 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.5635 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(5.0432 \text{ ft})}{(7 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.37679 \text{ kip}$$

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

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

$$M_{max} = ((-0.071497 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(2.5635 \text{ ft})}{(7 \text{ ft})} + \frac{(5.0432 \text{ ft})}{2 \times (7 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.5635 \text{ ft})}{(7 \text{ ft})} + 3\right) \times \left(\frac{(5.0432 \text{ ft})}{2 \times (7 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.5635 \text{ ft})}{(7 \text{ ft})} + 2\right) \times \left(\frac{(5.0432 \text{ ft})}{2 \times (7 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.1409 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(7.182 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.357 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.357 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(7.182 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0026847$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80 \, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.182 \text{ kip} \rightarrow 7182 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(7182 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.44 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.44 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.44 \text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.44\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 110.72\ \text{kip}$$

Considering x-direction:

$V_{max} = 12.338\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.338\ \text{kip})}{(110.72\ \text{kip})}$$

$$Ratio = 0.11144$$

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

Considering z-direction:

$V_{max} = 0.37679\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.37679\ \text{kip})}{(110.72\ \text{kip})}$$

$$Ratio = 0.0034031$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_{ck}\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6 \text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 40.834 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(40.834 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.1636$$	Status: **PASS** Ratio: **0.160**
	Considering z-direction: $M_{max} = 1.1409 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.1409 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0045709$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

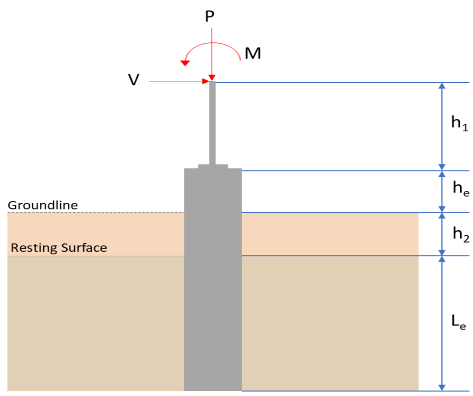
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.303	9.091
V_x (kip)	-4.565	-7.611
V_z (kip)	-0.008	-0.014
M_x (kipft)	-0.021	-0.034
M_z (kipft)	48.076	80.814

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.565\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.72691\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(48.076\ \text{kipft}) + ((-4.565\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 7.6554\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.8078\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.008\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0012739\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.021\ \text{kipft}) + ((-0.008\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.0033439\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.60471\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8078\ \text{ft}), (0.60471\ \text{ft})]$$

$$L_{e,req} = 6.808\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.808\ \text{ft})}{(7.5\ \text{ft})}$$

$$Ratio = 0.90773$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.303\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.39394\ \text{kip/ft}^2$$

$$q = 0.39394 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.39394 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.19697$$

Status: **PASS**
Ratio: **0.200**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.72691 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.6554 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.6554 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.72691 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (7.6554 \text{ kipft/ft})) + (4 \times (-0.72691 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.2012 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.6554 \text{ kipft/ft})) + (3 \times (-0.72691 \text{ kip/ft}) \times (7.5 \text{ ft}))]^2}{(7.5 \text{ ft})^2 \times [(3 \times (7.6554 \text{ kipft/ft})) + (2 \times (-0.72691 \text{ kip/ft}) \times (7.5 \text{ ft}))]}$$

$$p = 0.22496 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (7.6554 \text{ kipft/ft})) + ((-0.72691 \text{ kip/ft}) \times (7.5 \text{ ft}))]}{(7.5 \text{ ft})^2}$$

$$s = 1.0516 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.2012 \text{ ft})}{2}$$

$$p_a = 0.39009 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.22496 \text{ kip/ft}^2)}{(0.39009 \text{ kip/ft}^2)}$$

$$Ratio = 0.5767$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (7.5\ \text{ft})$$

$$p_s = 1.125\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0516\ \text{kip/ft}^2\right)}{\left(1.125\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.93478$$

Status: PASS
Ratio: 0.930

Considering z-direction:

$H_o = -0.0012739\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0033439\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0033439\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.0012739\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (0.0033439\ \text{kipft/ft})) + (4 \times (-0.0012739\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.4098\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0033439\ \text{kipft/ft})) + (3 \times (-0.0012739\ \text{kip/ft}) \times (7.5\ \text{ft})]^2}{(7.5\ \text{ft})^2 \times [(3 \times (0.0033439\ \text{kipft/ft})) + (2 \times (-0.0012739\ \text{kip/ft}) \times (7.5\ \text{ft}))]}$$

$$p = -0.00034328\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0033439\ \text{kipft/ft})) + ((-0.0012739\ \text{kip/ft}) \times (7.5\ \text{ft}))]}{(7.5\ \text{ft})^2}$$

$$s = -0.00030573\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.4098\ \text{ft})}{2}$$

$$p_a = 0.40574\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00034328\ \text{kip/ft}^2\right)}{\left(0.40574\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.00084606$$

Status: PASS
Ratio: 0.000

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (7.5\ \text{ft})$$

$$p_s = 1.125\ \text{kip/ft}^2$$

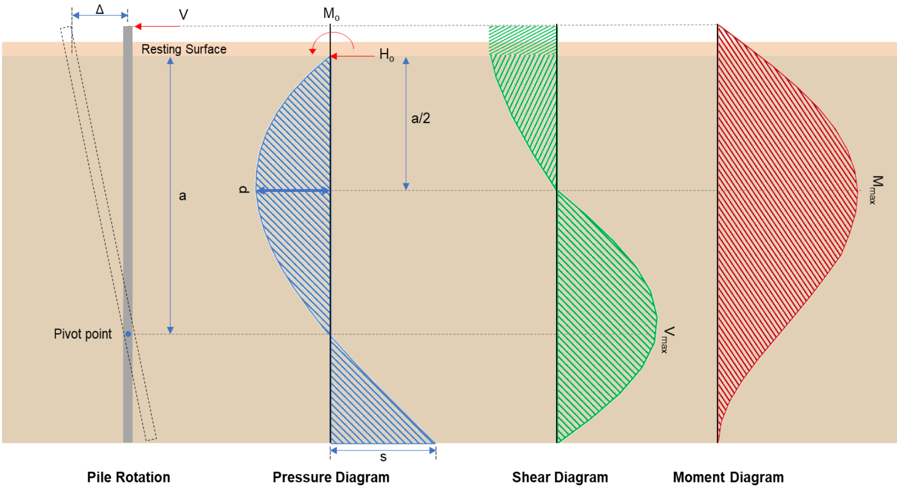
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00030573\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.00027176$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.611\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.2119\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(80.814\ \mathrm{kipft}) + ((-7.611\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 12.868\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.868\ \mathrm{kipft/ft})}{(-1.2119\ \mathrm{kip/ft})}$$

$$E = 10.618\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.868\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-1.2119\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (12.868\ \mathrm{kipft/ft})) + (4 \times (-1.2119\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2001\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.2119\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.618\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.2001\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.618\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.2001\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.341\ \mathrm{kip}$$

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

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

$$M_{max} = ((-1.2119\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(10.618\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.2001\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (10.618\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.2001\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.618\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.2001\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 54.236\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

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

$$H_o = -0.0022293\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.034\ \text{kipft}) + ((-0.014\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.005414\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.005414\ \text{kipft/ft})}{(-0.0022293\ \text{kip/ft})}$$

$$E = 2.4286\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.005414\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.0022293\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (0.005414\ \text{kipft/ft})) + (4 \times (-0.0022293\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.4207\ \text{ft}$$

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

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

$$V_{max} = ((-0.0022293\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4286\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.4207\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.4286\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.4207\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.011091\ \text{kip}$$

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

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

$$M_{max} = ((-0.0022293\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(2.4286\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.4207\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.4286\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.4207\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.4286\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.4207\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.035657 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.091 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.294 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.294 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.091\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0033983$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\,D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 9.091\text{ kip} \rightarrow 9091\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(9091\text{ lbf})}{6 \times \left(2304\text{ in}^2\right)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 119.7\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\text{ kip}), (119.7\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 119.7\text{ kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.7 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.88 \text{ kip}$$

Considering x-direction:

$V_{max} = 15.341 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.341 \text{ kip})}{(110.88 \text{ kip})}$$

$$Ratio = 0.13835$$

Status: **PASS**
Ratio: **0.140**

Considering z-direction:

$V_{max} = 0.011091 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.011091 \text{ kip})}{(110.88 \text{ kip})}$$

$$Ratio = 0.00010002$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 54.236\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(54.236\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.21729$$	Status: **PASS** Ratio: **0.220**
	Considering z-direction: $M_{max} = 0.035657\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.035657\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.00014286$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

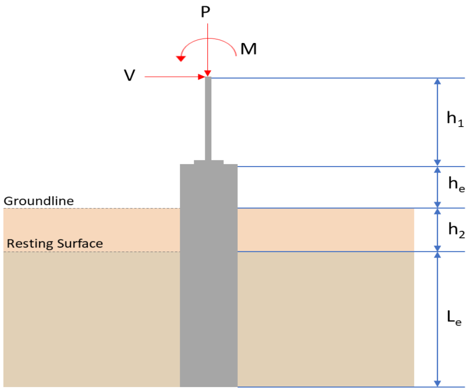
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.247	9.015
V_x (kip)	-4.517	-7.530
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	47.989	80.667

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.517\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.71927\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(47.989 \text{ kipft}) + ((-4.517 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.6416 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.8188 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

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

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8188 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 6.819 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.819 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.9092$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.247 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.39044 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.39044 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.19522$$

Status: **PASS**
Ratio: **0.200**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.71927\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.6416\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.6416\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.71927\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (7.6416\ \mathrm{kipft/ft})) + (4 \times (-0.71927\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.2\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.6416\ \mathrm{kipft/ft})) + (3 \times (-0.71927\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\,2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (7.6416\ \mathrm{kipft/ft})) + (2 \times (-0.71927\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.22728\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (7.6416\ \mathrm{kipft/ft})) + ((-0.71927\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 1.0548\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.2\ \mathrm{ft})}{2}$$

$$p_a = 0.39\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.22728\ \mathrm{kip/ft^2}\right)}{\left(0.39\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.58276$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

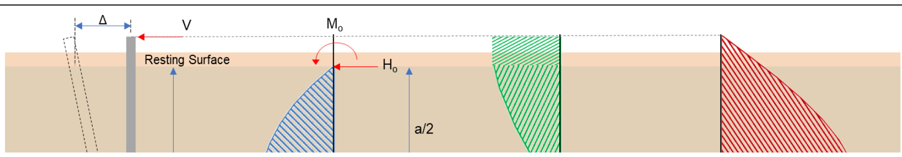
$Ratio$ - Lateral soil capacity

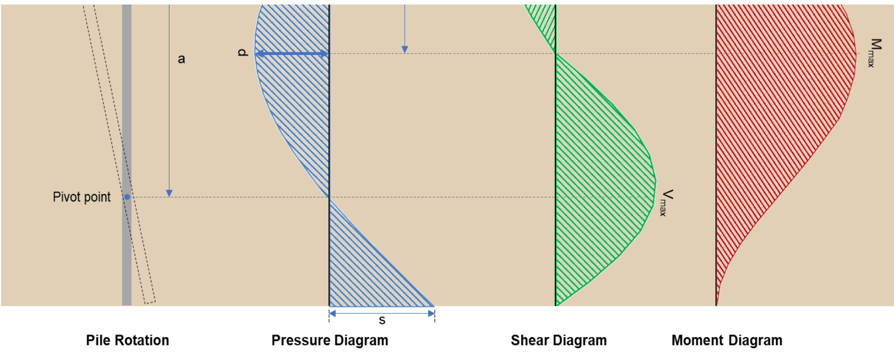
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.0548\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93759$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.53\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -1.199\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(80.667\text{ kipft}) + ((-7.53\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 12.845\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.845\text{ kipft/ft})}{(-1.199\text{ kip/ft})}$$

$$E = 10.713\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.845\text{ kipft/ft}) \times (7.5\text{ ft})) + \left(3 \times (-1.199\text{ kip/ft}) \times (7.5\text{ ft})^2\right)}{(6 \times (12.845\text{ kipft/ft})) + (4 \times (-1.199\text{ kip/ft}) \times (7.5\text{ ft}))}$$

$$a = 5.1989\text{ ft}$$

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

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

$$V_{max} = ((-1.199\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.713\text{ ft})}{(7.5\text{ ft})} + 3\right) \times \left(\frac{(5.1989\text{ ft})}{(7.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.713\text{ ft})}{(7.5\text{ ft})} + 2\right) \times \left(\frac{(5.1989\text{ ft})}{(7.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 15.285\text{ kip}$$

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

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

$$M_{max} = ((-1.199\text{ kip/ft}) \times (48\text{ in}) \times (7.5\text{ ft})) \times \left[\left(\frac{(10.713\text{ ft})}{(7.5\text{ ft})} + \frac{(5.1989\text{ ft})}{2 \times (7.5\text{ ft})}\right) - \left[\left(\frac{4 \times (10.713\text{ ft})}{(7.5\text{ ft})} + 3\right) \times \left(\frac{(5.1989\text{ ft})}{2 \times (7.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (10.713\text{ ft})}{(7.5\text{ ft})} + 2\right) \times \left(\frac{(5.1989\text{ ft})}{2 \times (7.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 54.06 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.015 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.297 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.297 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.015\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0033699$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 9.015\ \text{kip} \rightarrow 9015\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(9015\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 119.69\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (119.69\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 119.69\ \text{kip}$$

	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$,	
22.5.1.2	$V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$ $$V_{s,a} = 737.28\ \text{kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$ $$A_v = 0.11045\ \text{in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$ $$V_{s,b} = 50.894\ \text{kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$ $$V_s = 50.894\ \text{kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\ (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((119.69\ \text{kip}) + (50.894\ \text{kip}))$$ $$\phi V_n = 110.88\ \text{kip}$$ **Considering x-direction:** $V_{max} = 15.285\ \text{kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(15.285\ \text{kip})}{(110.88\ \text{kip})}$$ $$Ratio = 0.13785$$	Status: **PASS** Ratio: **0.140**
	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $$S_m = \frac{b\, D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001 in^3$$ $$\phi M_{n,1} = 249.600 kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_c\, S_m$$	

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 54.06\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(54.06\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.21659$$

Status: **PASS**
Ratio: **0.220**

REFERENCES	CALCULATIONS	RESULTS

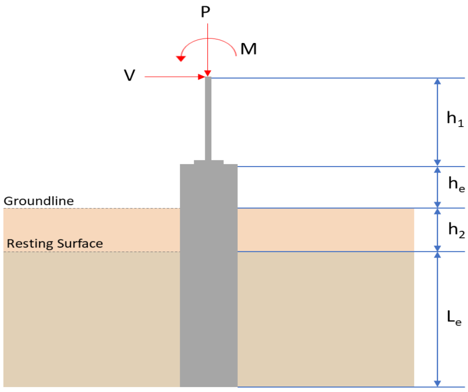
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48\ \text{in}$ - Pile width

$D = 48\ \text{in}$ - Pile depth

$L = 7.5\ \text{ft}$ - Total pile length

$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,

$h_2 = 0\ \text{ft}$ - Depth to resisting surface

$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

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

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	6.303	9.091
V_x (kip)	-4.565	-7.611
V_z (kip)	0.008	0.014
M_x (kipft)	0.020	0.034
M_z (kipft)	48.076	80.814

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.565\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.72691\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(48.076 \text{ kipft}) + ((-4.565 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 7.6554 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 6.8078 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.008 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0012739 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.02 \text{ kipft}) + ((0.008 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0031847 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 0.67367 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.8078 \text{ ft}), (0.67367 \text{ ft})]$$

$$L_{e,req} = 6.808 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.808 \text{ ft})}{(7.5 \text{ ft})}$$

$$Ratio = 0.90773$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\, D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(6.303 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.39394 \text{ kip/ft}^2$$

$q = 0.39394\ \text{kip/ft}^2$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.39394\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.19697$$

Status: **PASS**
Ratio: **0.200**

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Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.72691\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.6554\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.6554\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.72691\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (7.6554\ \text{kipft/ft})) + (4 \times (-0.72691\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.2012\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (7.6554\ \text{kipft/ft})) + (3 \times (-0.72691\ \text{kip/ft}) \times (7.5\ \text{ft}))]^2}{(7.5\ \text{ft})^2 \times [(3 \times (7.6554\ \text{kipft/ft})) + (2 \times (-0.72691\ \text{kip/ft}) \times (7.5\ \text{ft}))]}$$

$$p = 0.22496\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (7.6554\ \text{kipft/ft})) + ((-0.72691\ \text{kip/ft}) \times (7.5\ \text{ft}))]}{(7.5\ \text{ft})^2}$$

$$s = 1.0516\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.2012\ \text{ft})}{2}$$

$$p_a = 0.39009\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.22496\ \text{kip/ft}^2\right)}{\left(0.39009\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.5767$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0516\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.93478$$

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

Considering z-direction:

$H_o = 0.0012739\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.0031847\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0031847\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.0012739\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.0031847\ \mathrm{kipft/ft})) + (4 \times (0.0012739\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.4167\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0031847\ \mathrm{kipft/ft})) + (3 \times (0.0012739\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.0031847\ \mathrm{kipft/ft})) + (2 \times (0.0012739\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.00079736\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.0031847\ \mathrm{kipft/ft})) + ((0.0012739\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.0016985\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.4167\ \mathrm{ft})}{2}$$

$$p_a = 0.40625\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.00079736\ \mathrm{kip/ft^2}\right)}{\left(0.40625\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0019627$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

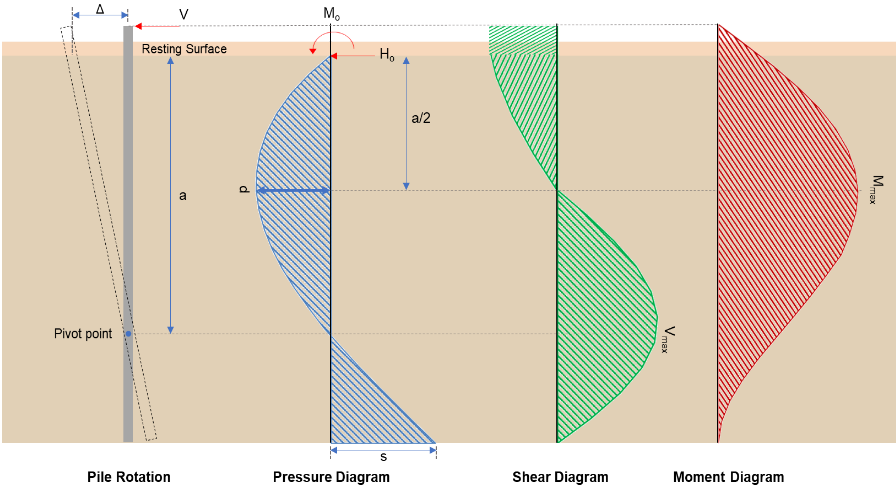
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0016985\ \text{kip/ft}^2)}{(1.125\ \text{kip/ft}^2)}$$

$$Ratio = 0.0015098$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.611\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.2119\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(80.814\ \text{kipft}) + ((-7.611\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 12.868\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(12.868\ \text{kipft/ft})}{(-1.2119\ \text{kip/ft})}$$

$$E = 10.618\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (12.868\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-1.2119\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (12.868\ \text{kipft/ft})) + (4 \times (-1.2119\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.2001\ \text{ft}$$

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

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

$$V_{max} = ((-1.2119\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (10.618\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.2001\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (10.618\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.2001\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.341\ \text{kip}$$

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

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

$$M_{max} = ((-1.2119\text{ kip/ft})\times(48\text{ in})\times(7.5\text{ ft}))\times\left[\left(\frac{(10.618\text{ ft})}{(7.5\text{ ft})}+\frac{(5.2001\text{ ft})}{2\times(7.5\text{ ft})}\right) - \left[\left(\frac{4\times(10.618\text{ ft})}{(7.5\text{ ft})}+3\right)\times\left(\frac{(5.2001\text{ ft})}{2\times(7.5\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(10.618\text{ ft})}{(7.5\text{ ft})}+2\right)\times\left(\frac{(5.2001\text{ ft})}{2\times(7.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 54.236\text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

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

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

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.034\text{ kipft})+((0.014\text{ kip})\times(0\text{ ft}))}{1.57\times(48\text{ in})}$$

$$M_o = 0.005414\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.005414\text{ kipft/ft})}{(0.0022293\text{ kip/ft})}$$

$$E = 2.4286\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4\times(0.005414\text{ kipft/ft})\times(7.5\text{ ft}))+\left(3\times(0.0022293\text{ kip/ft})\times(7.5\text{ ft})^2\right)}{(6\times(0.005414\text{ kipft/ft}))+(4\times(0.0022293\text{ kip/ft})\times(7.5\text{ ft}))}$$

$$a = 5.4207\text{ ft}$$

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

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

$$V_{max} = ((0.0022293\text{ kip/ft})\times(48\text{ in}))\times\left[1-\left[3\times\left(\frac{4\times(2.4286\text{ ft})}{(7.5\text{ ft})}+3\right)\times\left(\frac{(5.4207\text{ ft})}{(7.5\text{ ft})}\right)^2\right]+\left[4\times\left(\frac{3\times(2.4286\text{ ft})}{(7.5\text{ ft})}+2\right)\times\left(\frac{(5.4207\text{ ft})}{(7.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.011091\text{ kip}$$

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

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

$$M_{max} = ((0.0022293\text{ kip/ft})\times(48\text{ in})\times(7.5\text{ ft}))\times\left[\left(\frac{(2.4286\text{ ft})}{(7.5\text{ ft})}+\frac{(5.4207\text{ ft})}{2\times(7.5\text{ ft})}\right) - \left[\left(\frac{4\times(2.4286\text{ ft})}{(7.5\text{ ft})}+3\right)\times\left(\frac{(5.4207\text{ ft})}{2\times(7.5\text{ ft})}\right)^3\right]+\left[\left(\frac{3\times(2.4286\text{ ft})}{(7.5\text{ ft})}+2\right)\times\left(\frac{(5.4207\text{ ft})}{2\times(7.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.035657 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(9.091 \text{ kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.294 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.294 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

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

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

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.091\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$

$$Ratio = 0.0033983$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 9.091\ \mathrm{kip} \rightarrow 9091\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(9091\ \mathrm{lbf})}{6 \times \left(2304\ \mathrm{in}^2\right)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.7\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.7\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.7\ \mathrm{kip}$$

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

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.7\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 110.88\ \text{kip}$$

Considering x-direction:

$V_{max} = 15.341\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.341\ \text{kip})}{(110.88\ \text{kip})}$$

$$Ratio = 0.13835$$

Status: **PASS**
Ratio: **0.140**

Considering z-direction:

$V_{max} = 0.011091\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.011091\ \text{kip})}{(110.88\ \text{kip})}$$

$$Ratio = 0.00010002$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

	$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f_{ck}'\, S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\text{ ksi}) \times \left(18432\text{ in}^3\right)$$ $$\phi M_{n,2} = 2121.6\text{ kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\text{ kipft}), (2121.6\text{ kipft})]$$ $$\phi M_n = 249.6\text{ kipft}$$ **Considering x-direction:** $M_{max} = 54.236\text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(54.236\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.21729$$	Status: **PASS** Ratio: **0.220**
	Considering z-direction: $M_{max} = 0.035657\text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.035657\text{ kipft})}{(249.6\text{ kipft})}$$ $$Ratio = 0.00014286$$	Status: **PASS** Ratio: **0.000**