Your Project Calculations

Project Name: TPMandGroundMount-RevB

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=TPMandGroundMount-RevB&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/3_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=rIyDDTgF6f4LG2zg36S2mkzSo2kgqS0lU2QqO11CMPeV6TQ684Dq8jffNOakM42Z

Array Specification

Product:	Beam
Unique ID:	3P-17-10TOP-XD-12-L-4Hx7W-FK70
Duty Classification:	XD
Module Width:	40.90 in
Module Length:	74.80in
Number of Rows:	4
Number of Columns:	7
Total Number of Modules:	28
Desired Tilt Angle:	45
Front Edge Clearance:	6
Total Array Height at Tilt:	15.70 ft
Total Frame Length:	43.50 ft
Frame Weight:	3720 lbs
Array Dimensions N/S:	13.80 ft
Array Dimensions E/W:	44.22 ft
Rail Length:	165.60 in
Rail Spacing:	3.12 ft
Rail Check:	

Support Specifications

Pole Size:	10in Pipe Sch 40
Pole Length above Grade:	10.88 ft
Number of Poles:	3
Pole Spacing:	17 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 9.00 ft Pile 2: 9.50 ft Pile 3: 9.00 ft
Foundation Volume:	7.199 y^3
Foundation Result:	PASSED

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	6950 Teepee Ridge Rd, Bozeman, MT 59715, USA
Wind Speed:	101 mph
Snow Load:	50 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.009720 ksf

Design Disclaimer

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

AutoDesigner Input


```
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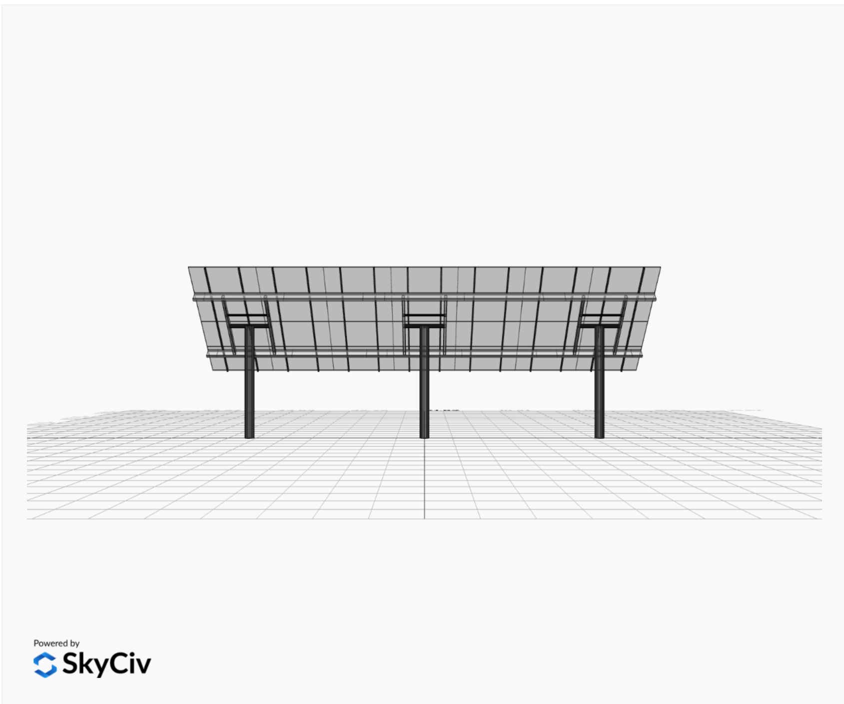
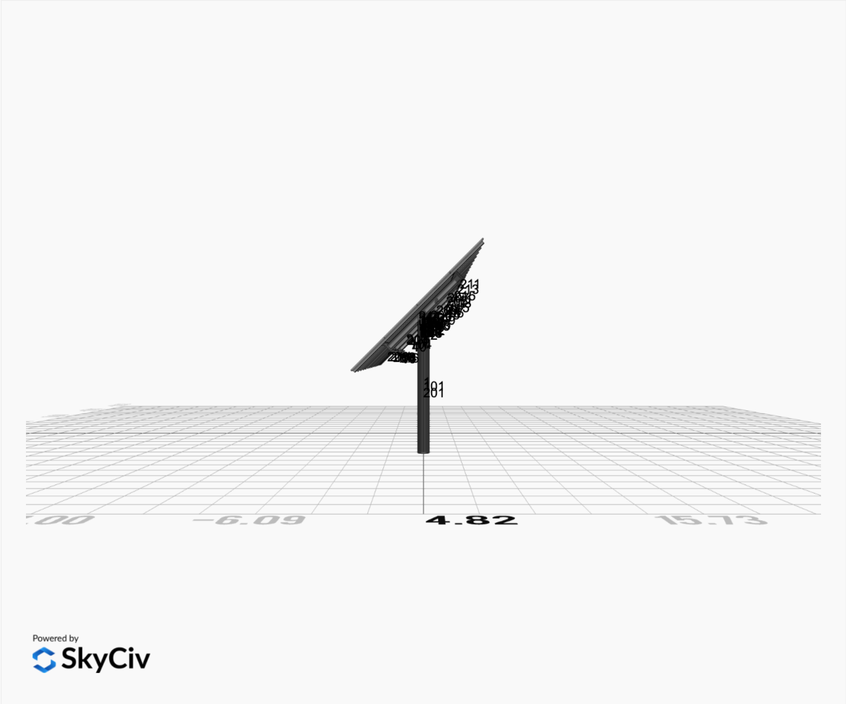
Design Notes:

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

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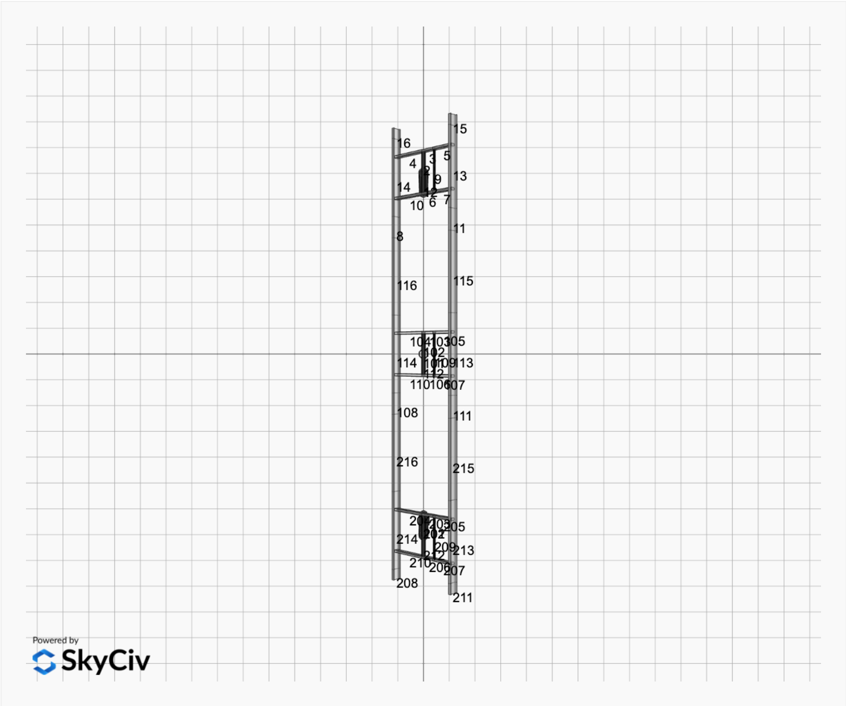
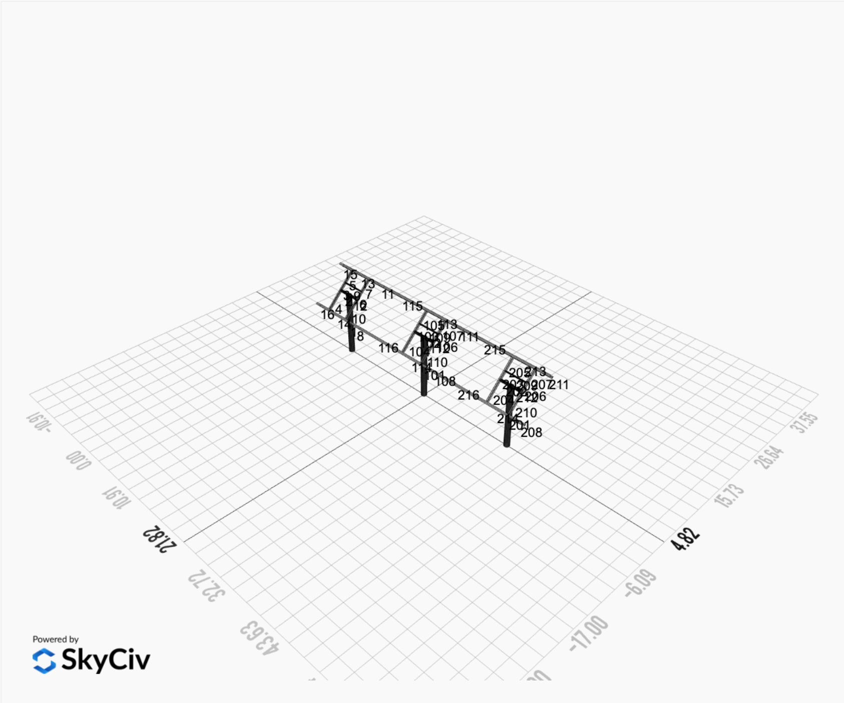
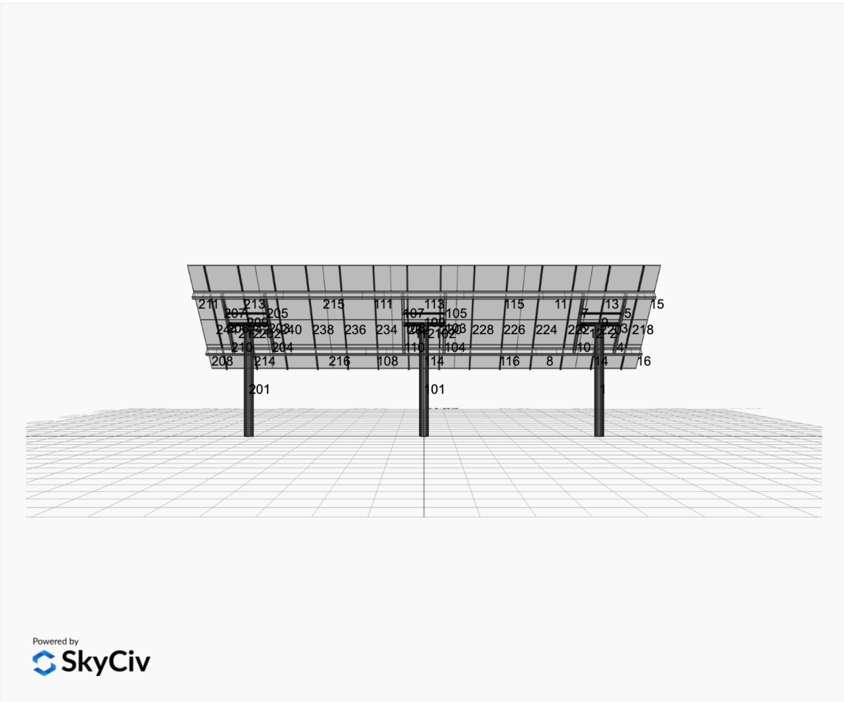
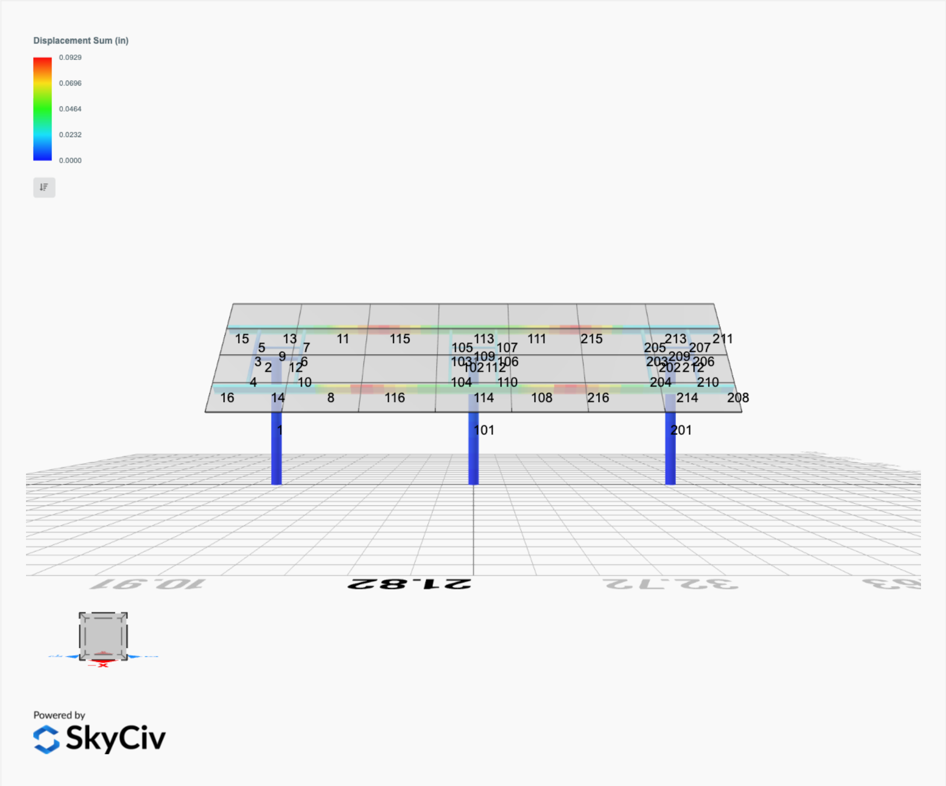
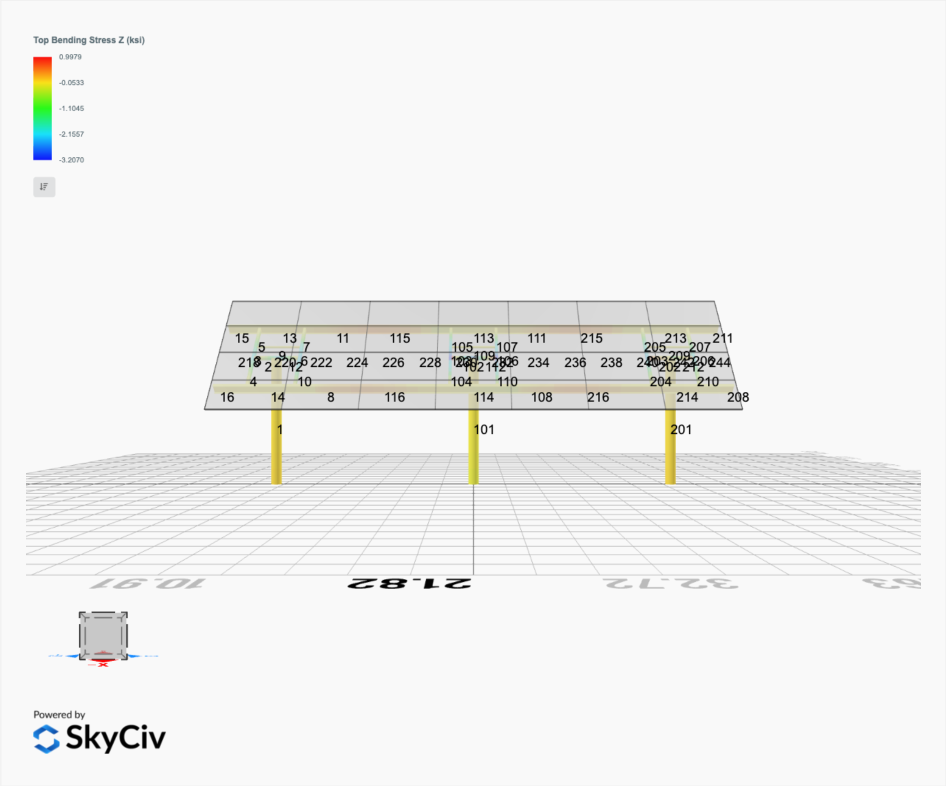


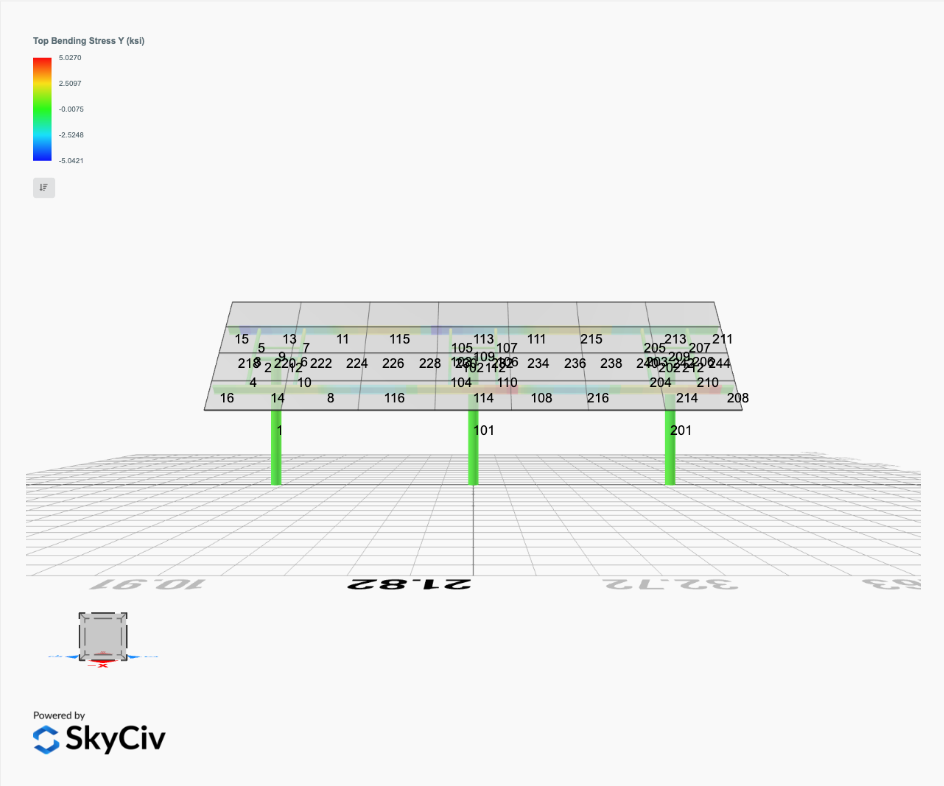




FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
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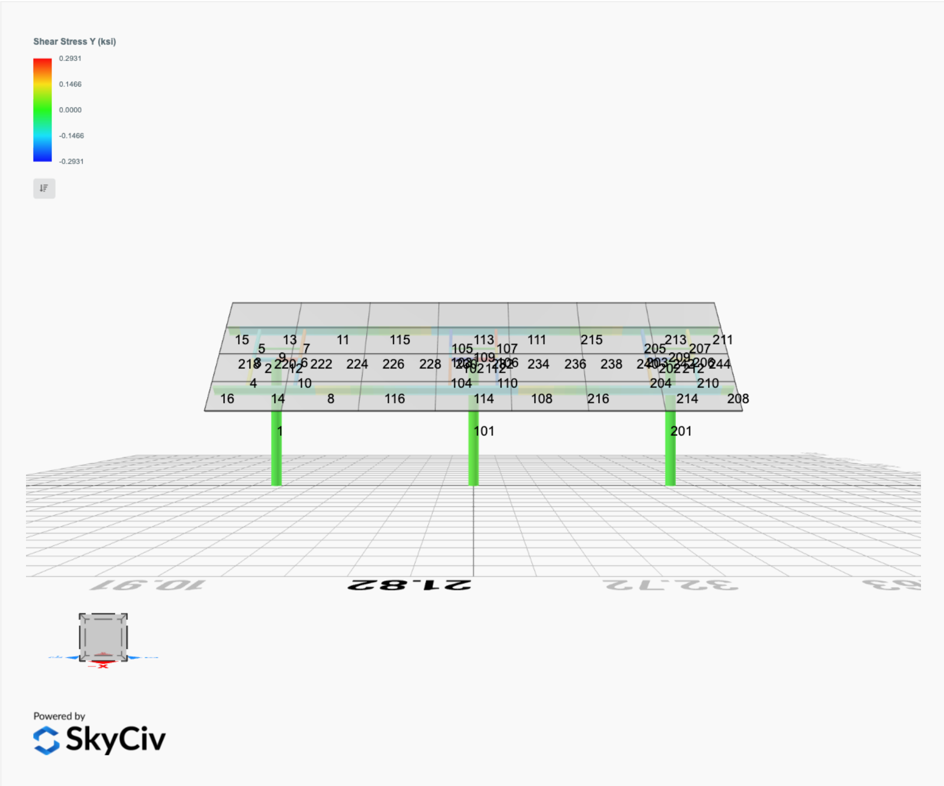
-0.0075
-2.5248
-5.0421
21.82
Powered by
SkyCiv


Shear Stress Y (ksi)
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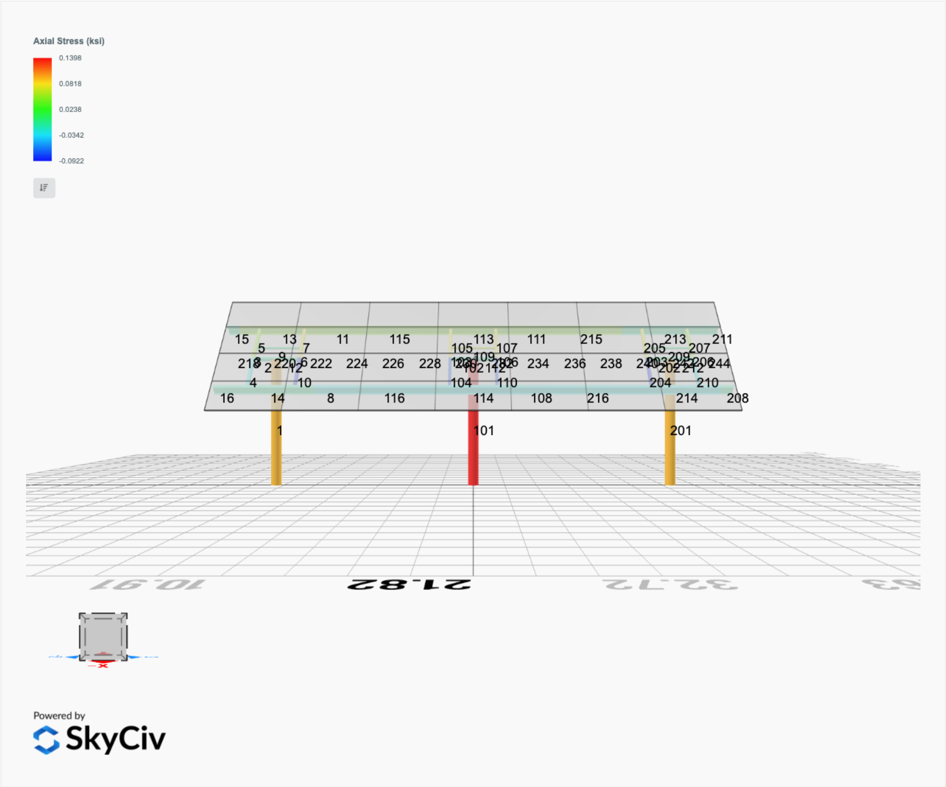
-0.1466
-0.2931
21.82
Powered by
SkyCiv


Axial Stress (ksi)
0.1398
0.0818
0.0238
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Powered by
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0215	1.8774	0.0546	0.1515	-0.0405	-0.1909
ULS: 2. D + L	0.0215	1.8774	0.0546	0.1515	-0.0405	-0.1909
ULS: 3. D + (S or Lr or R)	0.0444	3.1079	0.1124	0.3122	-0.0839	-0.4170
ULS: 3. D + (S or Lr or R)	0.0215	1.8774	0.0546	0.1515	-0.0405	-0.1909
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0387	2.8002	0.0979	0.2720	-0.0731	-0.3604
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0215	1.8774	0.0546	0.1515	-0.0405	-0.1909
ULS: 5b. D + 0.7E	0.0215	1.8774	0.0546	0.1515	-0.0405	-0.1909
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0387	2.8002	0.0979	0.2720	-0.0731	-0.3604
ULS: 8. 0.6D + 0.7E	0.0129	1.1264	0.0327	0.0909	-0.0243	-0.1145
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.3764	4.2387	0.2175	0.5507	-0.9571	27.0893
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.3764	4.2387	0.2175	0.5507	-0.9571	27.0893
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7505	0.1731	-0.0599	-0.1291	0.6033	-18.5573
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5669	0.3606	-0.0568	-0.1212	0.5909	-21.4620
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7598	4.5713	0.2201	0.5714	-0.7605	20.0997
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7598	4.5713	0.2201	0.5714	-0.7605	20.0997
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3354	1.5221	0.0121	0.0616	0.4098	-14.1352
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1977	1.6627	0.0144	0.0675	0.4004	-16.3138
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7769	3.6484	0.1768	0.4509	-0.7279	20.2693
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7769	3.6484	0.1768	0.4509	-0.7279	20.2693
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3182	0.5992	-0.0313	-0.0590	0.4424	-13.9657
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1806	0.7398	-0.0290	-0.0530	0.4330	-16.1442
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3850	3.4878	0.1957	0.4901	-0.9409	27.1656
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3850	3.4878	0.1957	0.4901	-0.9409	27.1656
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7419	-0.5778	-0.0818	-0.1897	0.6195	-18.4809
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5583	-0.3903	-0.0787	-0.1817	0.6071	-21.3857

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
Axial	6.8044
Shear X	-3.9966
Shear Z	0.3667
Moment X	0.9295
Moment Z	45.4669

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
Axial	4.5713
Shear X	-2.3850
Shear Z	0.2201
Moment X	0.5714
Moment Z	27.1656

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	-0.0431	2.2884	0.0000	0.0000	0.0000	0.4537
ULS: 2. D + L	-0.0431	2.2884	0.0000	0.0000	0.0000	0.4537
ULS: 3. D + (S or Lr or R)	-0.0888	3.9532	0.0000	0.0000	0.0000	0.9123
ULS: 3. D + (S or Lr or R)	-0.0431	2.2884	0.0000	0.0000	0.0000	0.4537
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0774	3.5370	0.0000	0.0000	0.0000	0.7977
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0431	2.2884	0.0000	0.0000	0.0000	0.4537
ULS: 5b. D + 0.7E	-0.0431	2.2884	0.0000	0.0000	0.0000	0.4537
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0774	3.5370	0.0000	0.0000	0.0000	0.7977

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 8. 0.6D + 0.7E	-0.0258	1.3730	0.0000	0.0000	0.0000	0.2722
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.2004	5.5190	0.0000	0.0000	0.0000	35.6099
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.2004	5.5190	0.0000	0.0000	0.0000	35.6099
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.2525	-0.0565	0.0000	0.0000	0.0000	-23.3738
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.9428	0.2454	0.0000	0.0000	0.0000	-26.3241
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4454	5.9599	0.0000	0.0000	0.0000	27.1648
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4454	5.9599	0.0000	0.0000	0.0000	27.1648
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6443	1.7783	0.0000	0.0000	0.0000	-17.0730
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.4120	2.0047	0.0000	0.0000	0.0000	-19.2857
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.4111	4.7114	0.0000	0.0000	0.0000	26.8208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.4111	4.7114	0.0000	0.0000	0.0000	26.8208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.6786	0.5297	0.0000	0.0000	0.0000	-17.4169
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.4463	0.7561	0.0000	0.0000	0.0000	-19.6297
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.1832	4.6037	0.0000	0.0000	0.0000	35.4284
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.1832	4.6037	0.0000	0.0000	0.0000	35.4284
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.2697	-0.9719	0.0000	0.0000	0.0000	-23.5553
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.9600	-0.6700	0.0000	0.0000	0.0000	-26.5056

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
Axial	8.9613
Shear X	-5.3347
Shear Z	-0.0000
Moment X	0.0001
Moment Z	59.6400

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
Axial	5.9599
Shear X	-3.2004
Shear Z	0.0000
Moment X	0.0000
Moment Z	35.6099

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	0.0215	1.8774	-0.0546	-0.1515	0.0405	-0.1908
ULS: 2. D + L	0.0215	1.8774	-0.0546	-0.1515	0.0405	-0.1908
ULS: 3. D + (S or Lr or R)	0.0444	3.1079	-0.1124	-0.3122	0.0840	-0.4170
ULS: 3. D + (S or Lr or R)	0.0215	1.8774	-0.0546	-0.1515	0.0405	-0.1908
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0387	2.8002	-0.0979	-0.2720	0.0731	-0.3604
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0215	1.8774	-0.0546	-0.1515	0.0405	-0.1908
ULS: 5b. D + 0.7E	0.0215	1.8774	-0.0546	-0.1515	0.0405	-0.1908
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0387	2.8002	-0.0979	-0.2720	0.0731	-0.3604
ULS: 8. 0.6D + 0.7E	0.0129	1.1264	-0.0327	-0.0909	0.0243	-0.1145
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.3764	4.2387	-0.2175	-0.5507	0.9571	27.0893
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.3764	4.2387	-0.2175	-0.5507	0.9571	27.0893
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.7505	0.1731	0.0599	0.1292	-0.6033	-18.5572
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5669	0.3606	0.0568	0.1212	-0.5909	-21.4620
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7598	4.5713	-0.2201	-0.5714	0.7605	20.0997
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7598	4.5713	-0.2201	-0.5714	0.7605	20.0997
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3354	1.5221	-0.0121	-0.0616	-0.4097	-14.1352
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1977	1.6627	-0.0144	-0.0676	-0.4004	-16.3138
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.7769	3.6484	-0.1768	-0.4509	0.7279	20.2693
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.7769	3.6484	-0.1768	-0.4509	0.7279	20.2693

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 uplift Case A only	1.3182	0.5992	0.0313	0.0590	-0.4423	-13.9656
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1806	0.7398	0.0290	0.0530	-0.4330	-16.1442
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.3851	3.4878	-0.1957	-0.4901	0.9409	27.1656
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.3851	3.4878	-0.1957	-0.4901	0.9409	27.1656
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.7419	-0.5778	0.0818	0.1897	-0.6195	-18.4809
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5583	-0.3903	0.0787	0.1817	-0.6070	-21.3856

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
Axial	6.8044
Shear X	-3.9966
Shear Z	-0.3667
Moment X	-0.9294
Moment Z	45.4669

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
Axial	4.5713
Shear X	-2.3851
Shear Z	-0.2201
Moment X	-0.5714
Moment Z	27.1656

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)
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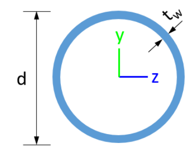
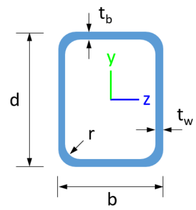
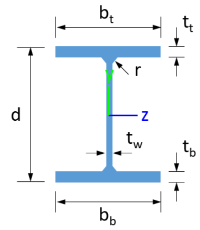
Section Dimensions



ID	Name	d (in)	t_w (in)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
11	10in Pipe Sch 40	10.75	0.36					



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



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

Section Properties								
ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
11	10in Pipe Sch 40	11.91	321.47	160.73	160.73	0.00	39.38	39.38

17	HSS5x3x1/4	3.37	11.00	4.81	10.70	62.42	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	11	22.85	22.85	10.88	-	300	200	1
2	6	1.30	1.30	2.00	-	300	200	1
3	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.17,1.17,1.16,1.17,1.17,1.17,1.16,1.17,1.18,1.18,1.21,1.11,1.18,1.18,1.14,1.16,1.17,1.17,1.17,1.17	300	200	1
4	17	2.44	2.44	3.75	1.71,1.69,1.71,1.68,1.70,1.71,1.67,1.67,1.65,2.14,1.67,1.67,1.65,1.55,1.67,1.67,1.81,1.69,1.68,1.68,1.63,1.78,1.67,1.67,1.66,1.62	300	200	1
5	17	1.52	1.52	2.33	1.69,1.68,1.69,1.68,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.72,1.60,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
6	17	0.92	0.92	1.42	1.20,1.19,1.20,1.19,1.19,1.20,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.15,1.19,1.19,1.17,1.17,1.18,1.18,1.18,1.18	300	200	1
7	17	1.52	1.52	2.33	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.71,1.63,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
8	20	1.33	1.33	2.05	1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.21,1.06,1.21,1.21,1.21,1.14,1.21,1.21,1.20,1.23,1.21,1.21,1.21,1.52,1.21,1.21,1.21,1.16	300	200	1
9	3	2.60	2.60	4.00	-	300	200	1
10	17	2.44	2.44	3.75	1.70,1.69,1.70,1.68,1.69,1.70,1.67,1.67,1.66,1.58,1.67,1.67,1.66,1.63,1.67,1.67,1.79,1.69,1.68,1.68,1.64,1.93,1.67,1.67,1.66,1.65	300	200	1
11	20	1.33	1.33	2.05	1.22,1.22,1.22,1.22,1.22,1.24,1.24,1.25,1.26,1.24,1.24,1.25,1.26,1.23,1.23,1.13,1.39,1.24,1.24,1.26,1.27,1.24,1.24,1.24,1.25	300	200	1
12	6	0.92	0.92	1.42	-	300	200	1
13	20	1.14	1.14	1.75	2.08,2.08,2.08,2.08,2.08,2.08,2.10,2.10,2.11,2.12,2.10,2.10,2.10,2.12,2.09,2.09,1.66,2.22,2.10,2.10,2.11,2.13,2.10,2.10,2.10,2.12	300	200	1
14	20	1.14	1.14	1.75	1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71	300	200	1
15	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	20	2.10	2.10	1.00	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
17	20	2.60	2.60	4.00	1.60,1.61,1.60,1.62,1.61,1.60,1.61,1.61,1.55,1.74,1.60,1.60,1.56,1.73,1.61,1.61,1.96,2.33,1.61,1.61,1.54,1.77,1.60,1.60,1.56,1.73	300	200	1
18	20	1.14	1.14	1.75	1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71	300	200	1
19	20	2.60	2.60	4.00	1.59,1.60,1.59,1.62,1.60,1.59,1.60,1.60,1.69,1.74,1.60,1.60,1.68,1.56,1.61,1.61,1.38,1.93,1.60,1.60,1.73,2.00,1.60,1.60,1.68,1.49	300	200	1
20	20	1.14	1.14	1.75	2.04,2.05,2.04,2.05,2.04,2.04,1.99,1.99,1.99,1.18,1.98,1.98,2.00,1.46,2.01,2.01,2.09,2.09,1.99,1.99,1.99,1.80,1.98,1.98,2.00,1.55	300	200	1
21	20	2.60	2.60	4.00	1.14,1.15,1.14,1.15,1.15,1.14,1.27,1.27,1.65,3.14,1.28,1.28,1.42,1.94,1.21,1.21,1.05,1.01,1.25,1.25,1.79,1.19,1.29,1.29,1.37,1.73	300	200	1
22	20	1.14	1.14	1.75	2.11,2.11,2.11,2.11,2.11,2.11,2.13,2.13,1.74,1.70,2.12,2.12,1.97,1.82,2.34,2.34,1.26,1.03,2.14,2.14,1.50,1.56,2.11,2.11,2.08,1.90	300	200	1
23	20	2.60	2.60	4.00	1.12,1.12,1.12,1.12,1.12,1.12,1.13,1.13,1.17,1.04,1.14,1.14,1.16,1.07,1.13,1.13,1.05,1.15,1.13,1.13,1.18,1.03,1.14,1.14,1.15,1.08	300	200	1

24	20	1.14	1.14	1.75	1.83,1.82,1.83,1.82,1.83,1.83,2.00,2.00,2.22,1.41,2.01,2.01,2.21,1.58,1.93,1.93,1.27,1.91,1.98,1.98,2.25,2.08,2.02,2.02,2.20,1.62	300	200	1
25	20	2.60	2.60	4.00	1.60,1.61,1.60,1.62,1.61,1.60,1.61,1.61,1.55,1.74,1.60,1.60,1.56,1.73,1.61,1.61,1.96,2.33,1.60,1.60,1.54,1.77,1.60,1.60,1.56,1.72	300	200	1
26	20	1.14	1.14	1.75	2.08,2.08,2.08,2.08,2.08,2.08,2.10,2.10,2.11,2.12,2.10,2.10,2.10,2.12,2.09,2.09,1.66,2.22,2.10,2.10,2.11,2.13,2.10,2.10,2.10,2.12	300	200	1
27	20	2.60	2.60	4.00	1.59,1.60,1.59,1.62,1.60,1.59,1.60,1.60,1.69,1.74,1.60,1.60,1.68,1.56,1.61,1.61,1.37,1.93,1.60,1.60,1.73,2.00,1.60,1.60,1.68,1.49	300	200	1
28	20	1.14	1.14	1.75	1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71	300	200	1
29	6	0.38	0.38	0.58	-	300	200	1
30	6	0.92	0.92	1.42	-	300	200	1
101	11	22.85	22.85	10.88	-	300	200	1
102	6	1.30	1.30	2.00	-	300	200	1
103	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.20,1.10,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
104	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.57,1.67,1.67,1.66,1.63,1.67,1.67,1.75,1.68,1.67,1.67,1.64,1.82,1.67,1.67,1.66,1.65	300	200	1
105	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.59,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
106	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.20,1.10,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.18	300	200	1
107	17	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.69,1.58,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
108	20	1.33	1.33	2.05	1.50,1.50,1.50,1.50,1.50,1.50,1.43,1.43,1.37,2.18,1.43,1.43,1.38,1.80,1.46,1.46,1.65,1.46,1.44,1.44,1.35,1.22,1.43,1.43,1.39,1.70	300	200	1
109	3	2.60	2.60	4.00	-	300	200	1
110	17	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.57,1.67,1.67,1.66,1.63,1.67,1.67,1.75,1.68,1.67,1.67,1.64,1.82,1.67,1.67,1.66,1.65	300	200	1
111	20	1.33	1.33	2.05	1.41,1.41,1.41,1.41,1.41,1.41,1.26,1.26,1.19,1.19,1.26,1.26,1.22,1.20,1.30,1.30,1.59,1.00,1.27,1.27,1.16,1.17,1.25,1.25,1.23,1.21	300	200	1
112	6	1.30	1.30	2.00	-	300	200	1
113	20	1.14	1.14	1.75	2.11,2.11,2.11,2.11,2.11,2.11,2.13,2.13,1.74,1.70,2.12,2.12,1.97,1.82,2.34,2.34,1.26,1.03,2.14,2.14,1.50,1.56,2.11,2.11,2.08,1.90	300	200	1
114	20	1.14	1.14	1.75	1.83,1.82,1.83,1.82,1.83,1.83,2.00,2.00,2.22,1.41,2.01,2.01,2.21,1.58,1.93,1.93,1.27,1.90,1.98,1.98,2.25,2.08,2.02,2.02,2.20,1.63	300	200	1
115	20	4.84	4.84	7.45	1.12,1.12,1.12,1.12,1.12,1.12,1.08,1.08,1.06,1.06,1.08,1.08,1.07,1.06,1.09,1.09,1.98,1.09,1.08,1.08,1.05,1.05,1.08,1.08,1.07,1.07	300	200	1
116	20	4.84	4.84	7.45	1.14,1.14,1.14,1.14,1.14,1.14,1.13,1.13,1.11,1.37,1.13,1.13,1.11,1.21,1.13,1.13,1.90,1.13,1.13,1.13,1.10,1.06,1.13,1.13,1.12,1.19	300	200	1
201	11	22.85	22.85	10.88	-	300	200	1
202	6	0.38	0.38	0.58	-	300	200	1
203	17	0.92	0.92	1.42	1.20,1.19,1.20,1.19,1.19,1.20,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.21,1.15,1.19,1.19,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1

204	17	2.44	2.44	3.75	1.70,1.69,1.70,1.68,1.69,1.70,1.67,1.67,1.66,1.58,1.67,1.66,1.63,1.67,1.67,1.79,1.69,1.68,1.68,1.64,1.93,1.67,1.67,1.66,1.65	300	200	1
205	17	1.52	1.52	2.33	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.71,1.63,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
206	17	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.17,1.17,1.16,1.17,1.17,1.17,1.16,1.17,1.18,1.18,1.21,1.11,1.18,1.18,1.14,1.16,1.17,1.17,1.17,1.17	300	200	1
207	17	1.52	1.52	2.33	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.72,1.60,1.67,1.67,1.64,1.65,1.67,1.67,1.66,1.66	300	200	1
208	20	2.10	2.10	1.00	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	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.71,1.69,1.71,1.68,1.70,1.71,1.67,1.67,1.65,2.14,1.67,1.67,1.65,1.55,1.67,1.67,1.81,1.69,1.68,1.68,1.63,1.78,1.67,1.67,1.66,1.62	300	200	1
211	20	2.10	2.10	1.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
212	6	1.30	1.30	2.00	-	300	200	1
213	20	1.14	1.14	1.75	1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71,1.71	300	200	1
214	20	1.14	1.14	1.75	2.04,2.05,2.04,2.05,2.04,2.04,1.98,1.98,1.99,1.18,1.98,1.98,2.00,1.46,2.01,2.01,2.09,2.09,1.99,1.99,1.99,1.79,1.98,1.98,2.00,1.55	300	200	1
215	20	4.84	4.84	7.45	1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.08,1.08,1.09,1.08,1.08,1.08,1.08,1.07,1.07,1.15,1.30,1.07,1.07,1.09,1.09,1.08,1.08,1.08,1.08	300	200	1
216	20	4.84	4.84	7.45	1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.06,1.06,1.06,1.06,1.06,1.06,1.13,1.06,1.06,1.06,1.06,1.14,1.06,1.06,1.06,1.06	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	535.87	356.65	147.68	147.68	160.76	160.76
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	142.47	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	142.47	46.90	6.46	56.26	44.91
12	251.01	249.94	27.16	27.16	75.30	75.30
13	159.30	143.45	46.90	6.46	56.26	44.91
14	159.30	143.45	46.90	6.46	56.26	44.91
15	159.30	137.23	46.90	6.46	56.26	44.91
16	159.30	137.23	46.90	6.46	56.26	44.91
17	159.30	132.71	46.90	6.46	56.26	44.91
18	159.30	143.45	46.90	6.46	56.26	44.91
19	159.30	132.71	46.90	6.46	56.26	44.91
20	159.30	143.45	46.90	6.46	56.26	44.91
21	159.30	132.71	43.34	6.46	56.26	44.91
22	159.30	143.45	46.90	6.46	56.26	44.91
23	159.30	132.71	44.20	6.46	56.26	44.91

23	159.30	132.71	[illegible]	6.46	56.26	44.91
24	159.30	143.45	46.90	6.46	56.26	44.91
25	159.30	132.71	46.90	6.46	56.26	44.91
26	159.30	143.45	46.90	6.46	56.26	44.91
27	159.30	132.71	46.90	6.46	56.26	44.91
28	159.30	143.45	46.90	6.46	56.26	44.91
29	251.01	250.83	27.16	27.16	75.30	75.30
30	251.01	249.94	27.16	27.16	75.30	75.30
101	535.87	356.65	147.68	147.68	160.76	160.76
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	142.47	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	142.47	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	143.45	46.90	6.46	56.26	44.91
114	159.30	143.45	46.90	6.46	56.26	44.91
115	159.30	104.63	32.27	6.46	56.26	44.91
116	159.30	104.63	32.58	6.46	56.26	44.91
201	535.87	356.65	147.68	147.68	160.76	160.76
202	251.01	250.83	27.16	27.16	75.30	75.30
203	151.65	150.70	20.17	14.14	54.12	28.95
204	151.65	145.15	20.17	14.14	54.12	28.95
205	151.65	149.10	20.17	14.14	54.12	28.95
206	151.65	150.70	20.17	14.14	54.12	28.95
207	151.65	149.10	20.17	14.14	54.12	28.95
208	159.30	137.23	46.90	6.46	56.26	44.91
209	75.10	66.32	4.25	4.25	22.53	22.53
210	151.65	145.15	20.17	14.14	54.12	28.95
211	159.30	137.23	46.90	6.46	56.26	44.91
212	251.01	248.88	27.16	27.16	75.30	75.30
213	159.30	143.45	46.90	6.46	56.26	44.91
214	159.30	143.45	46.90	6.46	56.26	44.91
215	159.30	104.63	32.58	6.46	56.26	44.91
216	159.30	104.63	32.58	6.46	56.26	44.91

Design Ratio

Member ID	P	M_z	M_y	V_y	V_z	(P,M_z,M_y)	Worst LC	KL/r	δ	Status
1	0.019	0.307	0.021	0.025	0.002	0.323	#13	0.373	Not Required	Pass
2	0.000	0.131	0.105	0.033	0.023	0.237	#13	0.054	Not Required	Pass
3	0.003	0.292	0.018	0.028	0.004	0.300	#13	0.046	Not Required	Pass
4	0.003	0.256	0.033	0.026	0.008	0.289	#13	0.082	Not Required	Pass
5	0.003	0.180	0.015	0.029	0.004	0.185	#13	0.076	Not Required	Pass
6	0.006	0.414	0.057	0.042	0.017	0.455	#13	0.046	Not Required	Pass
7	0.006	0.257	0.069	0.041	0.017	0.266	#13	0.076	Not Required	Pass
8	0.002	0.072	0.063	0.019	0.010	0.118	#13	0.102	Not Required	Pass
9	0.001	0.032	0.045	0.002	0.002	0.078	#13	0.206	Not Required	Pass
10	0.006	0.358	0.067	0.036	0.016	0.366	#13	0.082	Not Required	Pass

11	0.003	0.083	0.061	0.024	0.010	0.125	#13	0.102	Not Required	Pass
12	0.001	0.244	0.164	0.050	0.031	0.408	#13	0.038	Not Required	Pass
13	0.003	0.037	0.198	0.032	0.013	0.203	#24	0.087	Not Required	Pass
14	0.000	0.021	0.054	0.013	0.006	0.069	#21	Not Required	Not Required	Pass
15	0.000	0.003	0.007	0.005	0.002	0.009	#21	Not Required	Not Required	Pass
16	0.000	0.003	0.007	0.005	0.002	0.009	#21	Not Required	Not Required	Pass
17	0.001	0.039	0.047	0.014	0.005	0.058	#13	0.199	Not Required	Pass
18	0.000	0.023	0.054	0.014	0.006	0.070	#21	Not Required	Not Required	Pass
19	0.002	0.033	0.065	0.012	0.006	0.081	#21	0.199	Not Required	Pass
20	0.002	0.036	0.197	0.027	0.013	0.202	#24	0.087	Not Required	Pass
21	0.001	0.039	0.045	0.010	0.004	0.079	#21	0.199	Not Required	Pass
22	0.003	0.033	0.207	0.033	0.014	0.234	#21	0.087	Not Required	Pass
23	0.003	0.063	0.048	0.009	0.004	0.098	#21	0.199	Not Required	Pass
24	0.002	0.050	0.207	0.032	0.014	0.247	#21	0.087	Not Required	Pass
25	0.001	0.039	0.047	0.014	0.005	0.058	#13	0.199	Not Required	Pass
26	0.003	0.037	0.198	0.032	0.013	0.203	#24	0.087	Not Required	Pass
27	0.002	0.033	0.065	0.012	0.006	0.081	#21	0.199	Not Required	Pass
28	0.000	0.021	0.054	0.013	0.006	0.069	#21	Not Required	Not Required	Pass
29	0.001	0.047	0.047	0.050	0.031	0.094	#13	0.016	Not Required	Pass
30	0.001	0.244	0.164	0.050	0.031	0.408	#13	0.038	Not Required	Pass
101	0.025	0.404	0.000	0.033	0.000	0.416	#13	0.373	Not Required	Pass
102	0.001	0.252	0.184	0.056	0.035	0.436	#13	0.054	Not Required	Pass
103	0.006	0.458	0.041	0.046	0.010	0.484	#13	0.046	Not Required	Pass
104	0.005	0.435	0.073	0.043	0.016	0.472	#13	0.082	Not Required	Pass
105	0.005	0.284	0.074	0.045	0.019	0.296	#13	0.076	Not Required	Pass
106	0.006	0.458	0.041	0.046	0.010	0.484	#13	0.046	Not Required	Pass
107	0.005	0.284	0.074	0.045	0.019	0.296	#13	0.076	Not Required	Pass
108	0.002	0.057	0.063	0.024	0.010	0.092	#21	0.102	Not Required	Pass
109	0.004	0.028	0.031	0.001	0.000	0.061	#13	0.206	Not Required	Pass
110	0.005	0.435	0.073	0.044	0.016	0.472	#13	0.082	Not Required	Pass
111	0.003	0.080	0.063	0.024	0.010	0.106	#21	0.102	Not Required	Pass
112	0.001	0.252	0.184	0.056	0.035	0.436	#13	0.054	Not Required	Pass
113	0.003	0.033	0.207	0.033	0.014	0.234	#21	0.087	Not Required	Pass
114	0.002	0.050	0.207	0.032	0.014	0.247	#21	0.087	Not Required	Pass
115	0.004	0.141	0.108	0.024	0.010	0.211	#21	0.370	Not Required	Pass
116	0.002	0.114	0.108	0.024	0.010	0.192	#21	0.370	Not Required	Pass
201	0.019	0.307	0.021	0.025	0.002	0.323	#13	0.373	Not Required	Pass
202	0.001	0.047	0.047	0.050	0.031	0.094	#13	0.016	Not Required	Pass
203	0.006	0.414	0.057	0.042	0.017	0.455	#13	0.046	Not Required	Pass
204	0.006	0.358	0.067	0.036	0.016	0.366	#13	0.082	Not Required	Pass
205	0.006	0.257	0.069	0.041	0.017	0.266	#13	0.076	Not Required	Pass
206	0.003	0.292	0.018	0.028	0.004	0.300	#13	0.046	Not Required	Pass
207	0.003	0.180	0.015	0.029	0.004	0.185	#13	0.076	Not Required	Pass
208	0.000	0.003	0.007	0.005	0.002	0.009	#21	Not Required	Not Required	Pass
209	0.001	0.032	0.045	0.002	0.002	0.078	#13	0.206	Not Required	Pass
210	0.003	0.256	0.033	0.026	0.008	0.289	#13	0.082	Not Required	Pass
211	0.000	0.003	0.007	0.005	0.002	0.009	#21	Not Required	Not Required	Pass
212	0.000	0.131	0.105	0.033	0.023	0.237	#13	0.054	Not Required	Pass
213	0.000	0.023	0.054	0.014	0.006	0.070	#21	Not Required	Not Required	Pass
214	0.002	0.036	0.197	0.027	0.013	0.202	#24	0.087	Not Required	Pass
215	0.004	0.149	0.108	0.024	0.010	0.213	#21	0.370	Not Required	Pass
216	0.002	0.122	0.108	0.019	0.010	0.199	#21	0.370	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

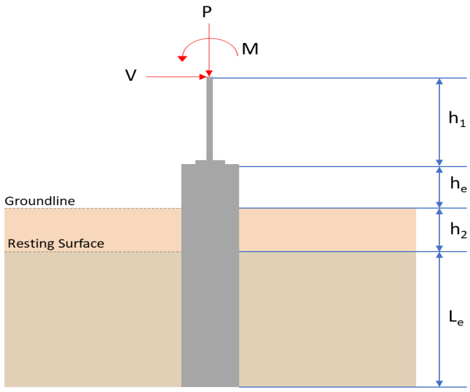
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 9\ \mathrm{ft}$ - 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)	4.571	6.804
V_x (kip)	-2.385	-3.997
V_z (kip)	0.220	0.367
M_x (kipft)	0.571	0.929
M_z (kipft)	27.166	45.467

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.385\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.795\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.166 \text{ kipft}) + ((-2.385 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 9.0553 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.0981 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.22 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.073333 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.571 \text{ kipft}) + ((0.22 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.19033 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,z} = 3.6657 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.0981 \text{ ft}), (3.6657 \text{ ft})]$$

$$L_{e,req} = 8.098 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.098 \text{ ft})}{(9 \text{ ft})}$$

$$Ratio = 0.89978$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(4.571 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 0.64666\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.64666\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.32333$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 3$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.795\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.0553\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.0553\ \text{kipft/ft}) \times (9\ \text{ft})) + \left(3 \times (-0.795\ \text{kip/ft}) \times (9\ \text{ft})^2\right)}{(6 \times (9.0553\ \text{kipft/ft})) + (4 \times (-0.795\ \text{kip/ft}) \times (9\ \text{ft}))}$$

$$a = 6.2588\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (9.0553\ \text{kipft/ft})) + (3 \times (-0.795\ \text{kip/ft}) \times (9\ \text{ft}))]^2}{(9\ \text{ft})^2 \times [(3 \times (9.0553\ \text{kipft/ft})) + (2 \times (-0.795\ \text{kip/ft}) \times (9\ \text{ft}))]}$$

$$p = 0.24633\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (9.0553\ \text{kipft/ft})) + ((-0.795\ \text{kip/ft}) \times (9\ \text{ft}))]}{(9\ \text{ft})^2}$$

$$s = 1.2748\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.2588\ \text{ft})}{2}$$

$$p_a = 0.46941\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.24633\ \text{kip/ft}^2)}{(0.46941\ \text{kip/ft}^2)}$$

$$Ratio = 0.52476$$

Status: **PASS**
Ratio: **0.520**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2748\ \text{kip/ft}^2\right)}{\left(1.35\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.94428$$

Status: PASS
Ratio: 0.940

Considering z-direction:

$H_o = 0.073333\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.19033\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.19033\ \text{kipft/ft}) \times (9\ \text{ft})) + \left(3 \times (0.073333\ \text{kip/ft}) \times (9\ \text{ft})^2\right)}{(6 \times (0.19033\ \text{kipft/ft})) + (4 \times (0.073333\ \text{kip/ft}) \times (9\ \text{ft}))}$$

$$a = 6.5235\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.19033\ \text{kipft/ft})) + (3 \times (0.073333\ \text{kip/ft}) \times (9\ \text{ft}))]^{\ 2}}{(9\ \text{ft})^2 \times [(3 \times (0.19033\ \text{kipft/ft})) + (2 \times (0.073333\ \text{kip/ft}) \times (9\ \text{ft}))]}$$

$$p = 0.057795\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.19033\ \text{kipft/ft})) + ((0.073333\ \text{kip/ft}) \times (9\ \text{ft}))]}{(9\ \text{ft})^2}$$

$$s = 0.12109\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.5235\ \text{ft})}{2}$$

$$p_a = 0.48926\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.057795\ \text{kip/ft}^2\right)}{\left(0.48926\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.11813$$

Status: PASS
Ratio: 0.120

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

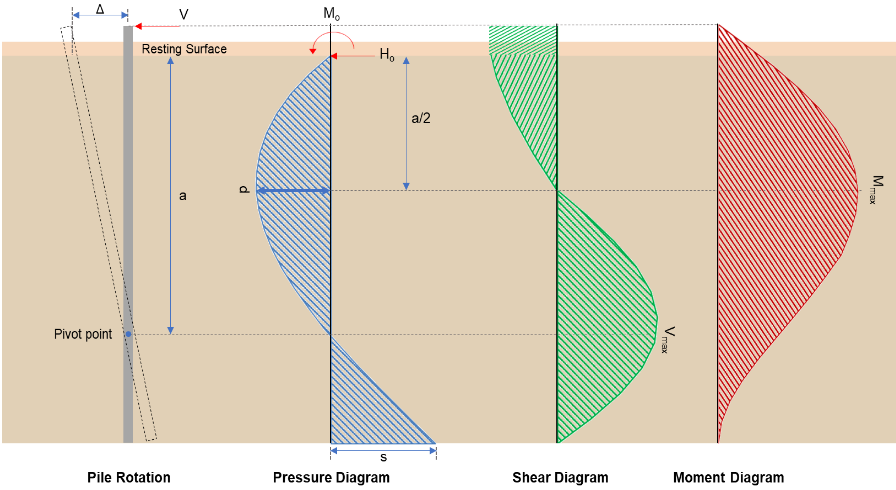
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{(0.12109 \text{ kip/ft}^2)}{(1.35 \text{ kip/ft}^2)}$$

$$Ratio = 0.089696$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.997 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -1.3323 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(45.467 \text{ kipft}) + ((-3.997 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 15.156 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.156 \text{ kipft/ft})}{(-1.3323 \text{ kip/ft})}$$

$$E = 11.375 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.156 \text{ kipft/ft}) \times (9 \text{ ft})) + \left(3 \times (-1.3323 \text{ kip/ft}) \times (9 \text{ ft})^2\right)}{(6 \times (15.156 \text{ kipft/ft})) + (4 \times (-1.3323 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.259 \text{ ft}$$

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

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

$$V_{max} = ((-1.3323 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.375 \text{ ft})}{(9 \text{ ft})} + 3\right) \times \left(\frac{(6.259 \text{ ft})}{(9 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.375 \text{ ft})}{(9 \text{ ft})} + 2\right) \times \left(\frac{(6.259 \text{ ft})}{(9 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 11.576 \text{ kip}$$

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

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

$$M_{max} = ((-1.3323 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(11.375 \text{ ft})}{(9 \text{ ft})} + \frac{(6.259 \text{ ft})}{2 \times (9 \text{ ft})}\right) - \left[\left(\frac{4 \times (11.375 \text{ ft})}{(9 \text{ ft})} + 3\right) \times \left(\frac{(6.259 \text{ ft})}{2 \times (9 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.375 \text{ ft})}{(9 \text{ ft})} + 2\right) \times \left(\frac{(6.259 \text{ ft})}{2 \times (9 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 48.838 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.367 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.12233 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.929 \text{ kipft}) + ((0.367 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.30967 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.30967 \text{ kipft/ft})}{(0.12233 \text{ kip/ft})}$$

$$E = 2.5313 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.30967 \text{ kipft/ft}) \times (9 \text{ ft})) + \left(3 \times (0.12233 \text{ kip/ft}) \times (9 \text{ ft})^2\right)}{(6 \times (0.30967 \text{ kipft/ft})) + (4 \times (0.12233 \text{ kip/ft}) \times (9 \text{ ft}))}$$

$$a = 6.5275 \text{ ft}$$

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

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

$$V_{max} = ((0.12233 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.5313 \text{ ft})}{(9 \text{ ft})} + 3\right) \times \left(\frac{(6.5275 \text{ ft})}{(9 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.5313 \text{ ft})}{(9 \text{ ft})} + 2\right) \times \left(\frac{(6.5275 \text{ ft})}{(9 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.42934 \text{ kip}$$

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

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

$$M_{max} = ((0.12233 \text{ kip/ft}) \times (36 \text{ in}) \times (9 \text{ ft})) \times \left[\left(\frac{(2.5313 \text{ ft})}{(9 \text{ ft})} + \frac{(6.5275 \text{ ft})}{2 \times (9 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.5313 \text{ ft})}{(9 \text{ ft})} + 3\right) \times \left(\frac{(6.5275 \text{ ft})}{2 \times (9 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.5313 \text{ ft})}{(9 \text{ ft})} + 2\right) \times \left(\frac{(6.5275 \text{ ft})}{2 \times (9 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.6395 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(6.804 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.966 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-44.966 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

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 center-to-center spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.804\ \text{kip})}{(1492.5\ \text{kip})}$$

$$Ratio = 0.0045588$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 203.86\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 6.804\ \text{kip} \rightarrow 6804\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + \frac{(6804\ \text{lbf})}{6 \times \left(1017.9\ \text{in}^2\right)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 82.698\ \text{kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + (0.05 \times (3000\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 237.06\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \text{kip}), (82.698\ \text{kip}), (237.06\ \text{kip})\right]$$

$$V_c = 82.698\ \text{kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 454.3\ \text{kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((82.698\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 78.564\ \text{kip}$$

Considering x-direction:

$V_{max} = 11.576\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.576\ \text{kip})}{(78.564\ \text{kip})}$$

$$Ratio = 0.14734$$

Status: **PASS**
Ratio: **0.150**

Considering z-direction:

$V_{max} = 0.42934\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.42934\ \text{kip})}{(78.564\ \text{kip})}$$

$$Ratio = 0.0054648$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

	$S_m = 4580.4\ \text{in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442in^3$$ $$\phi M_{n,1} = 67.947kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (3\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$ $$\phi M_{n,2} = 632.67\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(67.947\ \text{kipft}), (632.67\ \text{kipft})]$$ $$\phi M_n = 67.947\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 48.838\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(48.838\ \text{kipft})}{(67.947\ \text{kipft})}$$ $$Ratio = 0.71877$$	Status: **PASS** Ratio: **0.720**
	Considering z-direction: $M_{max} = 1.6395\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(1.6395\ \text{kipft})}{(67.947\ \text{kipft})}$$ $$Ratio = 0.024129$$	Status: **PASS** Ratio: **0.020**

REFERENCES	CALCULATIONS	RESULTS

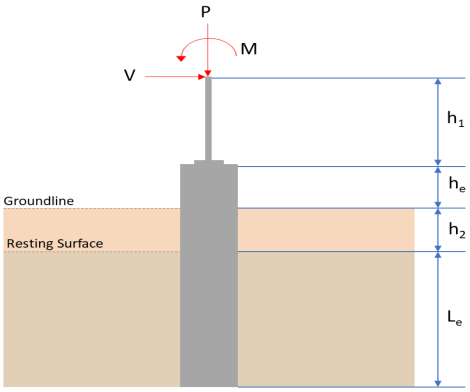
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \text{in}$ - Pile diameter
$L = 9\ \text{ft}$ - 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)	4.571	6.804
V_x (kip)	-2.385	-3.997
V_z (kip)	-0.220	-0.367
M_x (kipft)	-0.571	-0.929
M_z (kipft)	27.166	45.467

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.385\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.795\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.166\ \mathrm{kipft}) + ((-2.385\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 9.0553\ \mathrm{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.0981\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.22\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.073333\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.571\ \mathrm{kipft}) + ((-0.22\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 0.19033\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 2.107\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(8.0981\ \mathrm{ft}), (2.107\ \mathrm{ft})]$$

$$L_{e,req} = 8.098\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.098\ \mathrm{ft})}{(9\ \mathrm{ft})}$$

$$Ratio = 0.89978$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(4.571\ \mathrm{kip})}{(7.0686\ \mathrm{ft}^2)}$$

$$q = 0.64666\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.64666\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.32333$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 3$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.795\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.0553\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.0553\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (-0.795\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (9.0553\ \mathrm{kipft/ft})) + (4 \times (-0.795\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$

$$a = 6.2588\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (9.0553\ \mathrm{kipft/ft})) + (3 \times (-0.795\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]^2}{(9\ \mathrm{ft})^2 \times [(3 \times (9.0553\ \mathrm{kipft/ft})) + (2 \times (-0.795\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}$$

$$p = 0.24633\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (9.0553\ \mathrm{kipft/ft})) + ((-0.795\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))]}{(9\ \mathrm{ft})^2}$$

$$s = 1.2748\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.2588\ \mathrm{ft})}{2}$$

$$p_a = 0.46941\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24633\ \mathrm{kip/ft^2}\right)}{\left(0.46941\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.52476$$

Status: **PASS**
Ratio: **0.520**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2748\ \text{kip/ft}^2\right)}{\left(1.35\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.94428$$

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

Considering z-direction:

$H_o = -0.073333\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.19033\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.19033\ \text{kipft/ft}) \times (9\ \text{ft})) + \left(3 \times (-0.073333\ \text{kip/ft}) \times (9\ \text{ft})^2\right)}{(6 \times (0.19033\ \text{kipft/ft})) + (4 \times (-0.073333\ \text{kip/ft}) \times (9\ \text{ft}))}$$

$$a = 6.5235\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.19033\ \text{kipft/ft})) + (3 \times (-0.073333\ \text{kip/ft}) \times (9\ \text{ft}))]^{\,2}}{(9\ \text{ft})^2 \times [(3 \times (0.19033\ \text{kipft/ft})) + (2 \times (-0.073333\ \text{kip/ft}) \times (9\ \text{ft}))]}$$

$$p = -0.028837\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.19033\ \text{kipft/ft})) + ((-0.073333\ \text{kip/ft}) \times (9\ \text{ft}))]}{(9\ \text{ft})^2}$$

$$s = -0.032503\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.5235\ \text{ft})}{2}$$

$$p_a = 0.48926\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.028837\ \text{kip/ft}^2\right)}{\left(0.48926\ \text{kip/ft}^2\right)}$$

$$Ratio = -0.058939$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

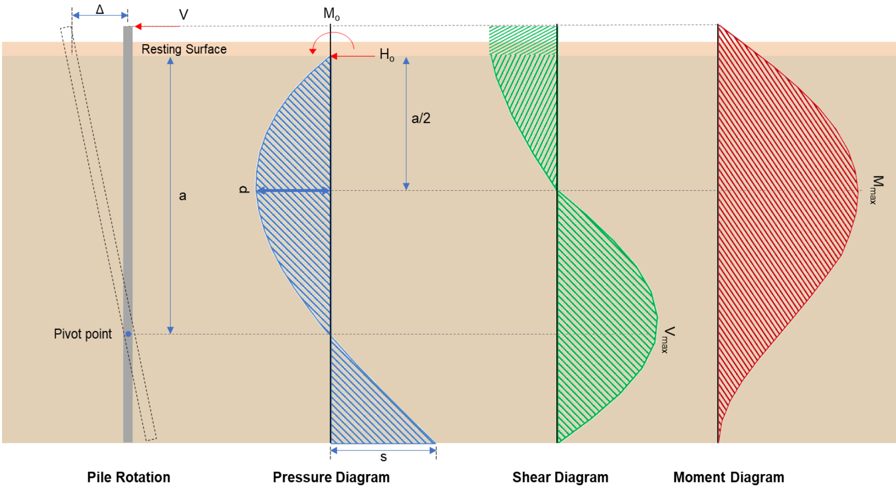
$$Ratio = \frac{s}{\cdots}$$

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

$$Ratio = \frac{\left(-0.032503\ \mathrm{kip/ft^2}\right)}{\left(1.35\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.024076$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.997\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.3323\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(45.467\ \mathrm{kipft}) + ((-3.997\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 15.156\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.156\ \mathrm{kipft/ft})}{(-1.3323\ \mathrm{kip/ft})}$$

$$E = 11.375\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.156\ \mathrm{kipft/ft}) \times (9\ \mathrm{ft})) + \left(3 \times (-1.3323\ \mathrm{kip/ft}) \times (9\ \mathrm{ft})^2\right)}{(6 \times (15.156\ \mathrm{kipft/ft})) + (4 \times (-1.3323\ \mathrm{kip/ft}) \times (9\ \mathrm{ft}))}$$

$$a = 6.259\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.3323\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.375\ \mathrm{ft})}{(9\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.259\ \mathrm{ft})}{(9\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.375\ \mathrm{ft})}{(9\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.259\ \mathrm{ft})}{(9\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 11.576\ \text{kip}$$

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

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

$$M_{max} = ((-1.3323\ \text{kip/ft}) \times (36\ \text{in}) \times (9\ \text{ft})) \times \left[\left(\frac{(11.375\ \text{ft})}{(9\ \text{ft})} + \frac{(6.259\ \text{ft})}{2 \times (9\ \text{ft})}\right) - \left[\left(\frac{4 \times (11.375\ \text{ft})}{(9\ \text{ft})} + 3\right) \times \left(\frac{(6.259\ \text{ft})}{2 \times (9\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.375\ \text{ft})}{(9\ \text{ft})} + 2\right) \times \left(\frac{(6.259\ \text{ft})}{2 \times (9\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 48.838\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.367\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.12233\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.929\ \text{kipft}) + ((-0.367\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.30967\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.30967\ \text{kipft/ft})}{(-0.12233\ \text{kip/ft})}$$

$$E = 2.5313\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.30967\ \text{kipft/ft}) \times (9\ \text{ft})) + \left(3 \times (-0.12233\ \text{kip/ft}) \times (9\ \text{ft})^2\right)}{(6 \times (0.30967\ \text{kipft/ft})) + (4 \times (-0.12233\ \text{kip/ft}) \times (9\ \text{ft}))}$$

$$a = 6.5275\ \text{ft}$$

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

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

$$V_{max} = ((-0.12233\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.5313\ \text{ft})}{(9\ \text{ft})} + 3\right) \times \left(\frac{(6.5275\ \text{ft})}{(9\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.5313\ \text{ft})}{(9\ \text{ft})} + 2\right) \times \left(\frac{(6.5275\ \text{ft})}{(9\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.42934\ \text{kip}$$

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

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

$$M_{max} = ((-0.12233\ \text{kip/ft}) \times (36\ \text{in}) \times (9\ \text{ft})) \times \left[\left(\frac{(2.5313\ \text{ft})}{(9\ \text{ft})} + \frac{(6.5275\ \text{ft})}{2 \times (9\ \text{ft})}\right) - \left[\left(\frac{4 \times (2.5313\ \text{ft})}{(9\ \text{ft})} + 3\right) \times \left(\frac{(6.5275\ \text{ft})}{2 \times (9\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.5313\ \text{ft})}{(9\ \text{ft})} + 2\right) \times \left(\frac{(6.5275\ \text{ft})}{2 \times (9\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 1.6395 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(6.804 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (3 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -44.966 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-44.966 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

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 center-to-center spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.804\ \mathrm{kip})}{(1492.5\ \mathrm{kip})}$$

$$Ratio = 0.0045588$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \mathrm{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,max} = 203.86\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 6.804\ \mathrm{kip} \rightarrow 6804\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(6804\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 82.698\ \mathrm{kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + (0.05 \times (3000\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,b} = 237.06\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\ \mathrm{kip}), (82.698\ \mathrm{kip}), (237.06\ \mathrm{kip})\right]$$

$$V_c = 82.698\ \mathrm{kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(3000\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{s,a} = 454.3\ \mathrm{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \mathrm{in}^2\right) \times (60\ \mathrm{ksi}) \times (28.8\ \mathrm{in})}{(10\ \mathrm{in})}$$

$$V_{s,b} = 38.17\ \mathrm{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3\ \mathrm{kip}), (38.17\ \mathrm{kip})\right]$$

$$V_s = 38.17\ \mathrm{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((82.698\ \mathrm{kip}) + (38.17\ \mathrm{kip}))$$

$$\phi V_n = 78.564\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 11.576\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(11.576\ \mathrm{kip})}{(78.564\ \mathrm{kip})}$$

$$Ratio = 0.14734$$

Status: **PASS**
Ratio: **0.150**

Considering z-direction:

$V_{max} = 0.42934\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.42934\ \mathrm{kip})}{(78.564\ \mathrm{kip})}$$

$$Ratio = 0.0054648$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \mathrm{in})^3}{32}$$

$$S_m = 4580.4\ \mathrm{in}^3$$

$$S_m = 4580.4 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 67.947kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3 \text{ ksi}) \times \left(4580.4 \text{ in}^3\right)$$

$$\phi M_{n,2} = 632.67 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947 \text{ kipft}), (632.67 \text{ kipft})]$$

$$\phi M_n = 67.947 \text{ kipft}$$

Considering x-direction:

$M_{max} = 48.838 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(48.838 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.71877$$

Status: **PASS**
Ratio: **0.720**

Considering z-direction:

$M_{max} = 1.6395 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.6395 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.024129$$

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

REFERENCES	CALCULATIONS	RESULTS

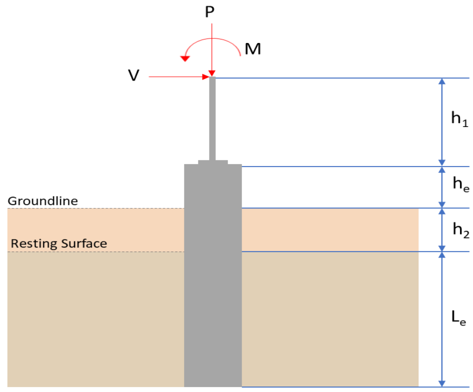
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 9.5\ \mathrm{ft}$ - 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)	5.960	8.961
V_x (kip)	-3.200	-5.335
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	35.610	59.640

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.2\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.0667\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(35.61\ \text{kipft}) + ((-3.2\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 11.87\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 8.5716\ \text{ft}$ - 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,

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

$$L_{e,req} = MAX[(8.5716\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 8.572\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (9.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 9.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(8.572\ \text{ft})}{(9.5\ \text{ft})}$$

$$Ratio = 0.90232$$

Status: PASS
Ratio: 0.900

End-bearing Capacity (ASD)

A - Pile cros-section area

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

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

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

q - End-bearing pressure

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

$$q = \frac{(5.96\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.84317\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.84317\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.42158$$

Status: PASS
Ratio: 0.420

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(9.5\ \text{ft})}{(36\ \text{in})}$$

$$L/D = 3.1667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -1.0667\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 11.87\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.87\ \text{kipft/ft}) \times (9.5\ \text{ft})) + \left(3 \times (-1.0667\ \text{kip/ft}) \times (9.5\ \text{ft})^2\right)}{(6 \times (11.87\ \text{kipft/ft})) + (4 \times (-1.0667\ \text{kip/ft}) \times (9.5\ \text{ft}))}$$

$$a = 6.6205\ \text{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (11.87\ \text{kipft/ft})) + (3 \times (-1.0667\ \text{kip/ft}) \times (9.5\ \text{ft}))]^2}{(9.5\ \text{ft})^2 \times [(3 \times (11.87\ \text{kipft/ft})) + (2 \times (-1.0667\ \text{kip/ft}) \times (9.5\ \text{ft}))]}$$

$$p = 0.24817\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (11.87\ \text{kipft/ft})) + ((-1.0667\ \text{kip/ft}) \times (9.5\ \text{ft}))]}{(9.5\ \text{ft})^2}$$

$$s = 1.421\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(6.6205\ \text{ft})}{2}$$

$$p_a = 0.49654\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24817\ \text{kip/ft}^2\right)}{\left(0.49654\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.49981$$

Status: **PASS**
Ratio: **0.500**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\ L_e$$

$$p_s = (150\ \text{psf/ft}) \times (9.5\ \text{ft})$$

$$p_s = 1.425\ \text{kip/ft}^2$$

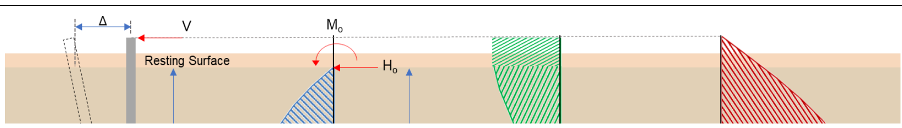
$Ratio$ - Lateral soil capacity

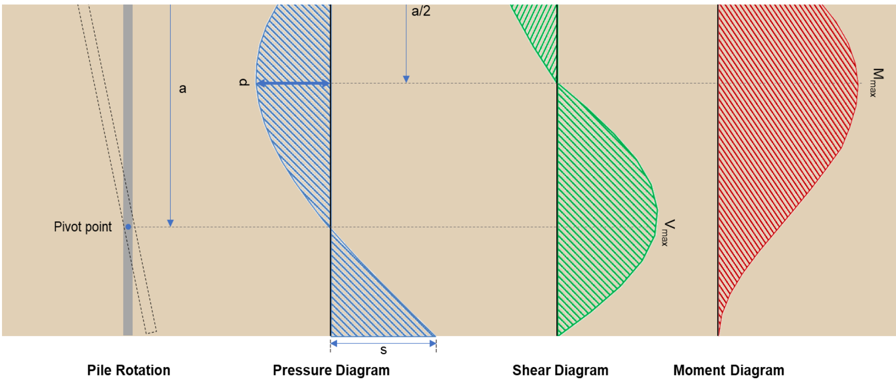
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.421\ \text{kip/ft}^2\right)}{\left(1.425\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.99717$$

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-5.335\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -1.7783\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(59.64\ \text{kipft}) + ((-5.335\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 19.88\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(19.88\ \text{kipft/ft})}{(-1.7783\ \text{kip/ft})}$$

$$E = 11.179\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (19.88\ \text{kipft/ft}) \times (9.5\ \text{ft})) + \left(3 \times (-1.7783\ \text{kip/ft}) \times (9.5\ \text{ft})^2\right)}{(6 \times (19.88\ \text{kipft/ft})) + (4 \times (-1.7783\ \text{kip/ft}) \times (9.5\ \text{ft}))}$$

$$a = 6.6196\ \text{ft}$$

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

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

$$V_{max} = ((-1.7783\ \text{kip/ft}) \times (36\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.179\ \text{ft})}{(9.5\ \text{ft})} + 3\right) \times \left(\frac{(6.6196\ \text{ft})}{(9.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.179\ \text{ft})}{(9.5\ \text{ft})} + 2\right) \times \left(\frac{(6.6196\ \text{ft})}{(9.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 14.629\ \text{kip}$$

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

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

$$M_{max} = ((-1.7783\ \text{kip/ft}) \times (36\ \text{in}) \times (9.5\ \text{ft})) \times \left[\left(\frac{(11.179\ \text{ft})}{(9.5\ \text{ft})} + \frac{(6.6196\ \text{ft})}{2 \times (9.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (11.179\ \text{ft})}{(9.5\ \text{ft})} + 3\right) \times \left(\frac{(6.6196\ \text{ft})}{2 \times (9.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.179\ \text{ft})}{(9.5\ \text{ft})} + 2\right) \times \left(\frac{(6.6196\ \text{ft})}{2 \times (9.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 64.909 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(8.961 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (3 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -44.898 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-44.898 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.99533$$

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

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 center-to-center spacing of ties,

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

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

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

Summary:

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (3\text{ ksi}) \times \left[\left(1017.9\text{ in}^2\right) - \left(1.8408\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(1.8408\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 1492.5\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(8.961\text{ kip})}{(1492.5\text{ kip})}$$

$$Ratio = 0.0060041$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.71796$$

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

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(3000\text{ psi})} \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,max} = 203.86\text{ kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$, $P = 8.961\text{ kip} \rightarrow 8961\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\text{ psi})} + \frac{(8961\text{ lbf})}{6 \times \left(1017.9\text{ in}^2\right)}\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,a} = 83.064\text{ kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(3000\text{ psi})} + (0.05 \times (3000\text{ psi}))\right] \times (36\text{ in}) \times (28.8\text{ in})$$

$$V_{c,b} = 237.06\text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(203.86\text{ kip}), (83.064\text{ kip}), (237.06\text{ kip})\right]$$

$$V_c = 83.064 \text{ kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (36 \text{ in}) \times (28.8 \text{ in})$$

$$V_{s,a} = 454.3 \text{ kip}$$

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)

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (28.8 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 38.17 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(454.3 \text{ kip}), (38.17 \text{ kip})\right]$$

$$V_s = 38.17 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((83.064 \text{ kip}) + (38.17 \text{ kip}))$$

$$\phi V_n = 78.802 \text{ kip}$$

Considering x-direction:

$V_{max} = 14.629 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(14.629 \text{ kip})}{(78.802 \text{ kip})}$$

$$Ratio = 0.18564$$

Status: **PASS**
Ratio: **0.190**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36 \text{ in})^3}{32}$$

$$S_m = 4580.4 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 4580.442 in^3$$

$$\phi M_{n,1} = 67.947 kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (3\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$

$$\phi M_{n,2} = 632.67\ \text{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(67.947\ \text{kipft}), (632.67\ \text{kipft})]$$

$$\phi M_n = 67.947\ \text{kipft}$$

Considering x-direction:

$M_{max} = 64.909\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(64.909\ \text{kipft})}{(67.947\ \text{kipft})}$$

$$Ratio = 0.95528$$

Status: **PASS**
Ratio: **0.960**