Your Project Calculations

Project Name: MarkRobertsResidence-RevB

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

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=LxKoZ7FaABDGXAYLh0s1YFzbkHHjMeNtkJxCFROlDvkyENPFaC1T1UVwv5n1xVy8

Array Specification

Product:	Beam
Unique ID:	2P-17-8TOP-HD-57-L-4Hx5W-KHB8
Duty Classification:	HD
Module Width:	42.20 in
Module Length:	81.60in
Number of Rows:	4
Number of Columns:	5
Total Number of Modules:	20
Desired Tilt Angle:	30
Front Edge Clearance:	5
Total Array Height at Tilt:	12.07 ft
Total Frame Length:	34.00 ft
Frame Weight:	1598 lbs
Array Dimensions N/S:	14.23 ft
Array Dimensions E/W:	34.42 ft
Rail Length:	170.80 in
Rail Spacing:	3.40 ft
Rail Check:	

Support Specifications

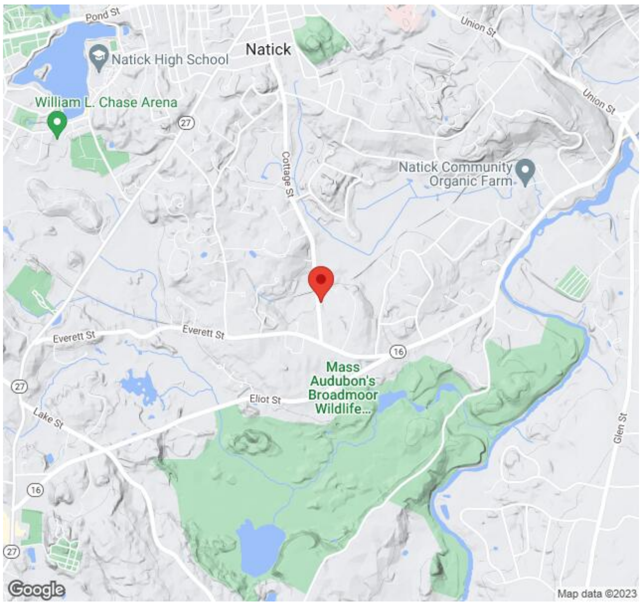
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	8.56 ft
Number of Poles:	2
Pole Spacing:	17 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 8.75 ft Pile 2: 8.75 ft
Foundation Volume:	4.581 y^3
Foundation Result:	PASSED
Mount Twist:	1.057143 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	166 Cottage St, Natick, MA 01760, USA
Wind Speed:	110 mph
Snow Load:	40 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.017594 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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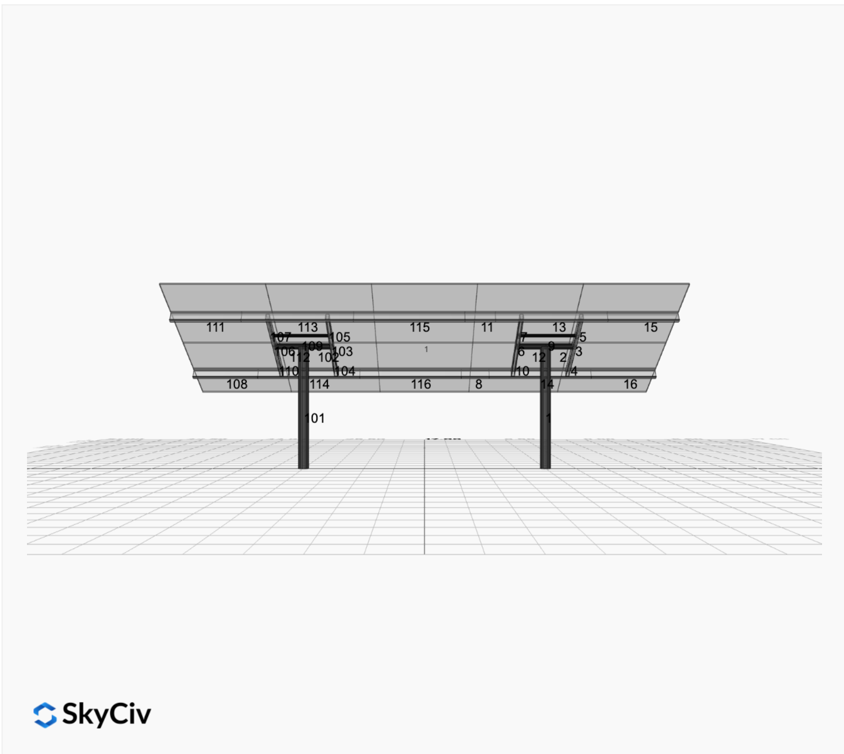
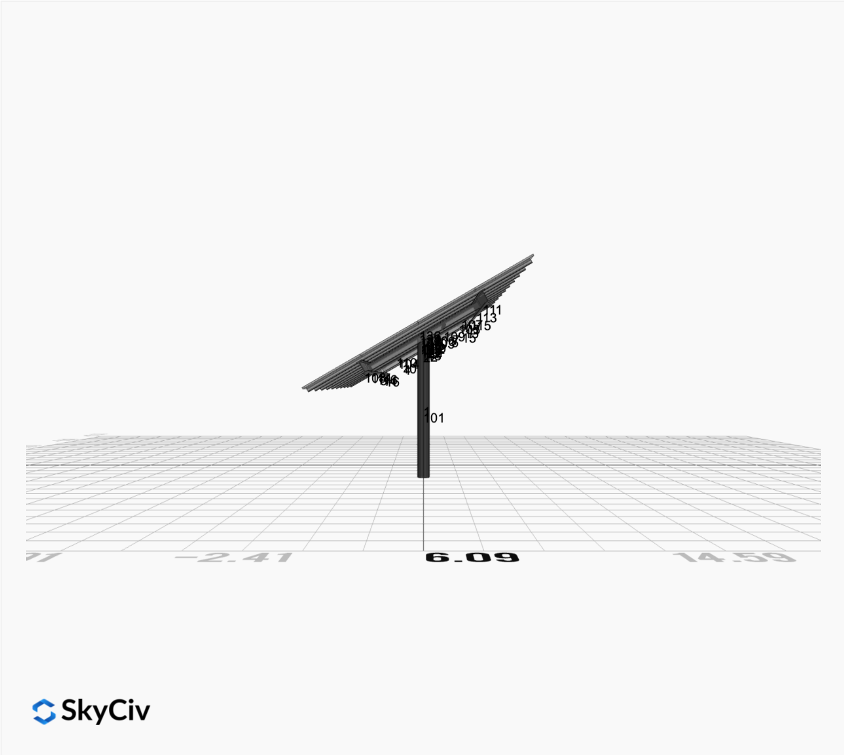
Design Notes:

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

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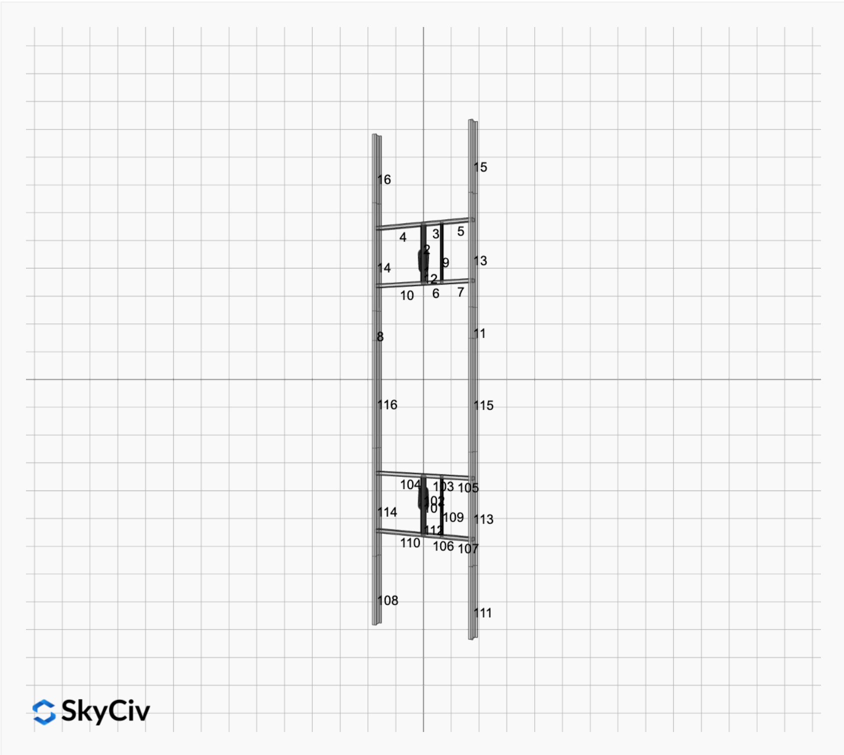
6.09
14.59
SkyCiv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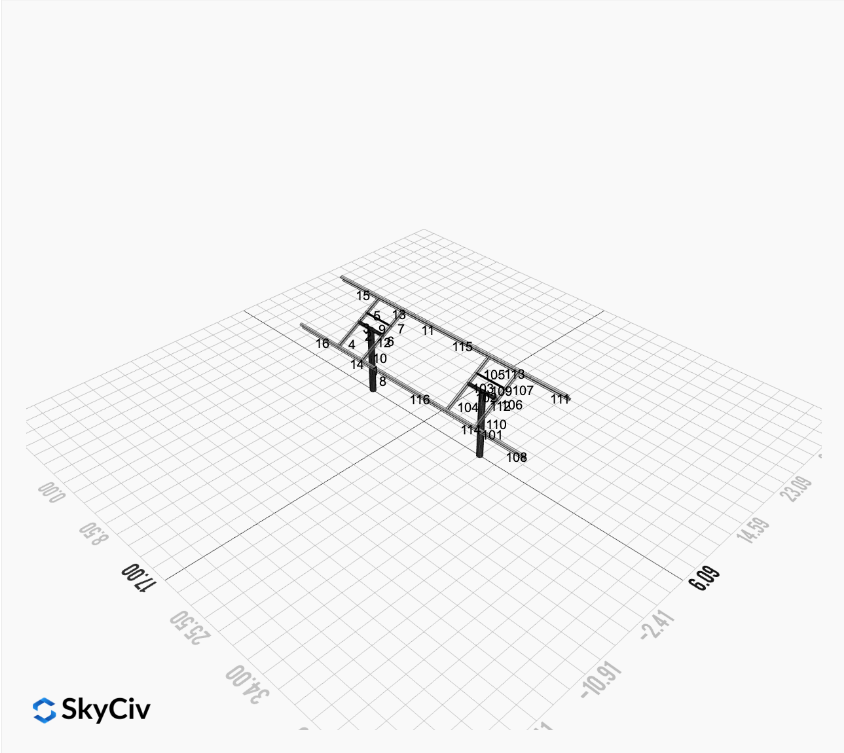
SkyCiv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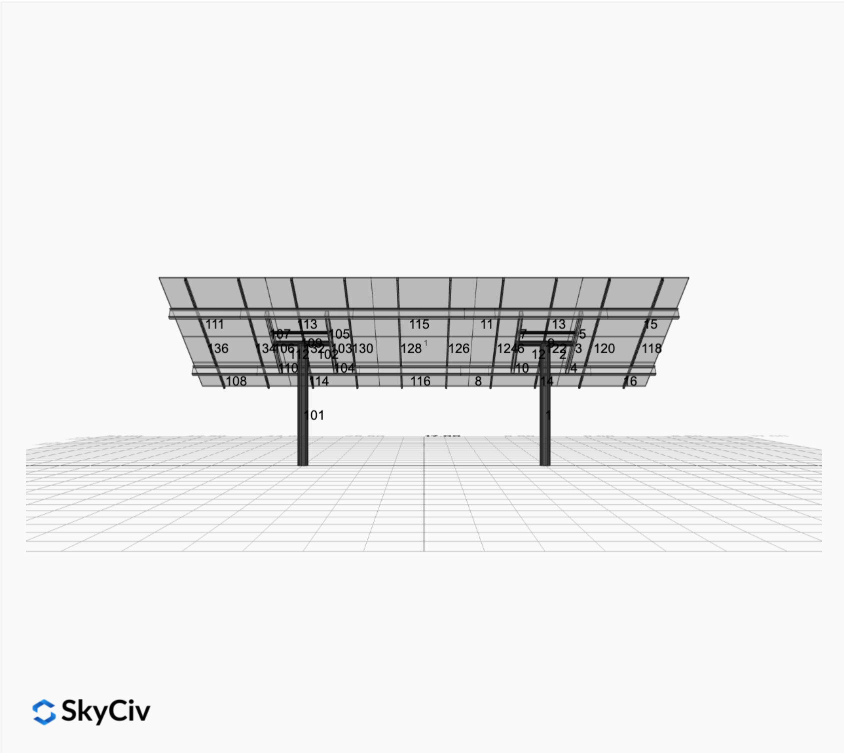
6.09
-2.41
-10.91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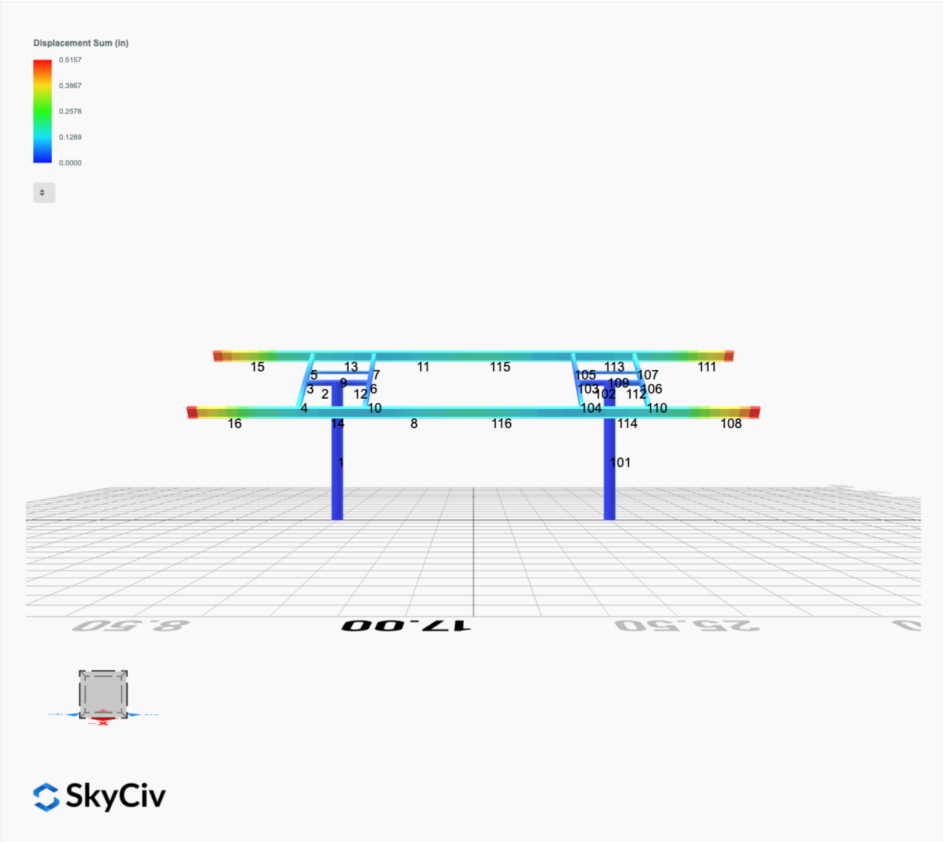
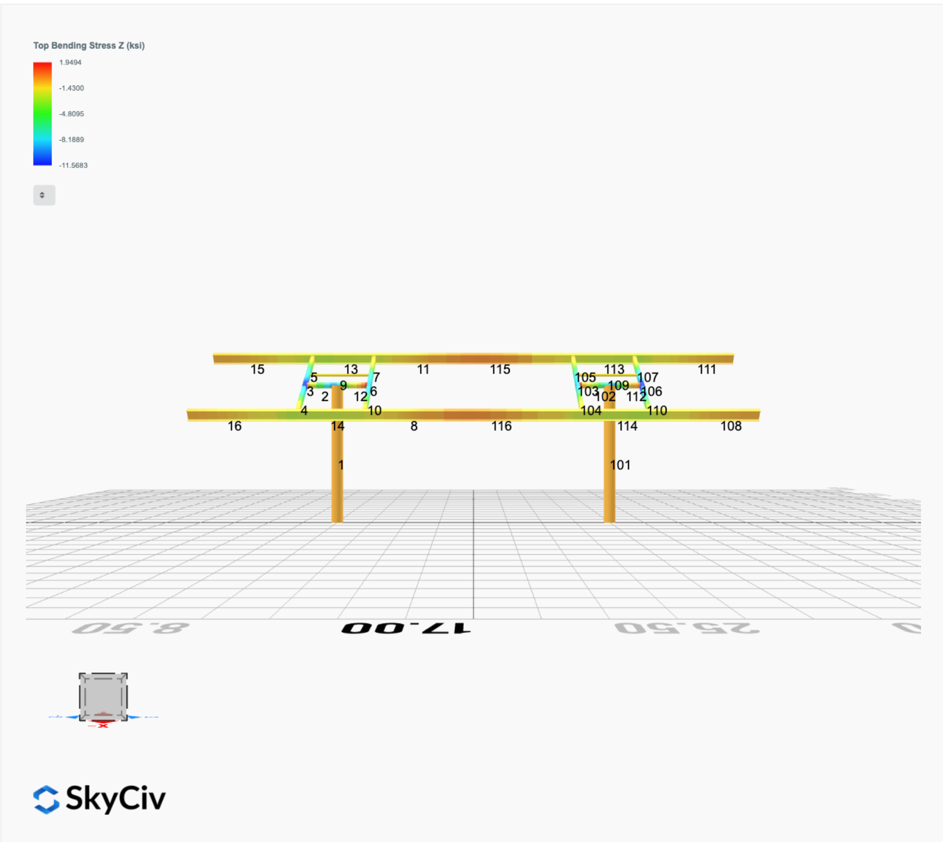
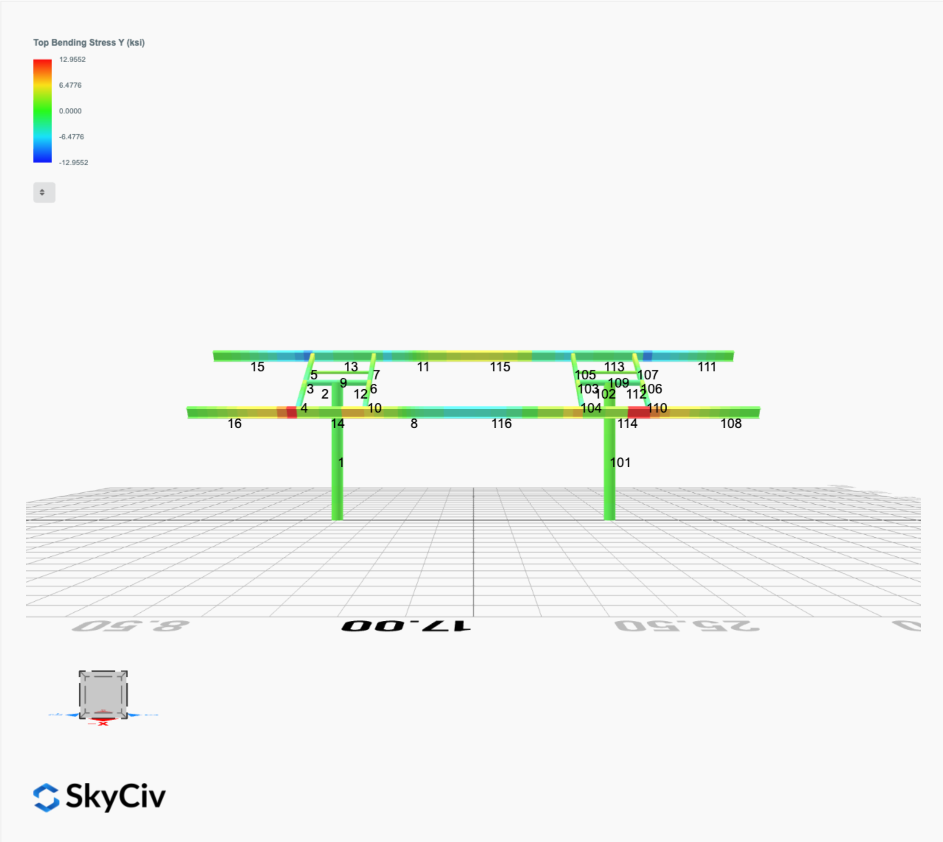
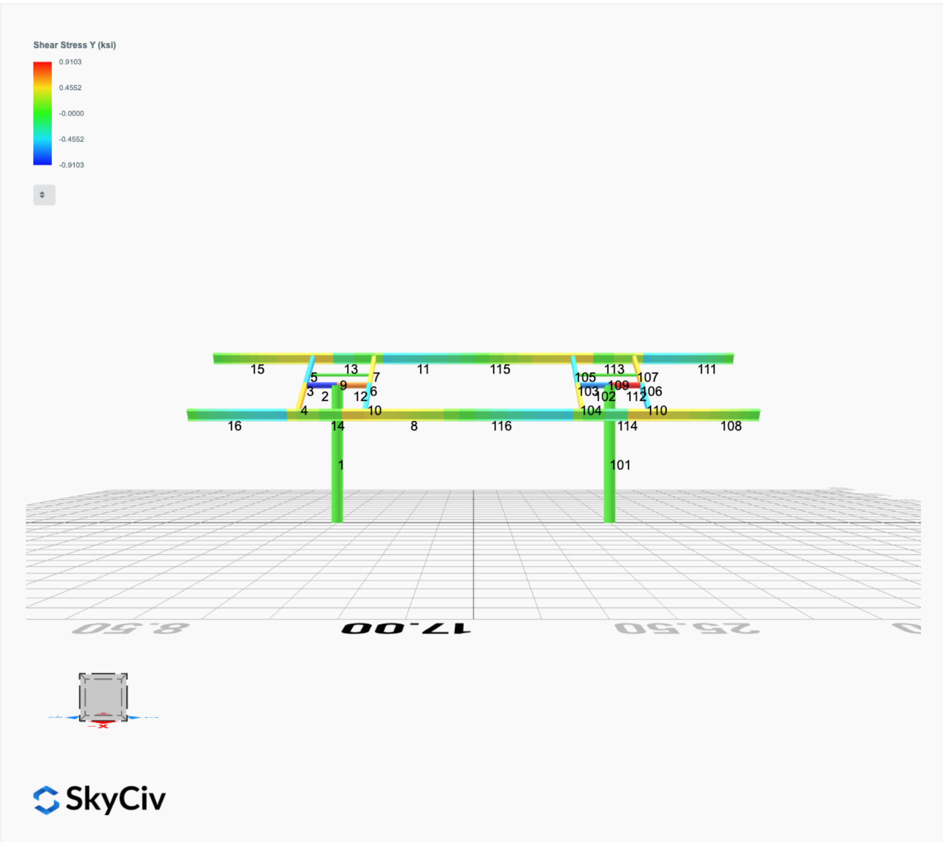
114
116
8
14
16
101

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
12.9552
6.4776
0.0000
-6.4776
-12.9552
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
SkyCiv


Shear Stress Y (ksi)
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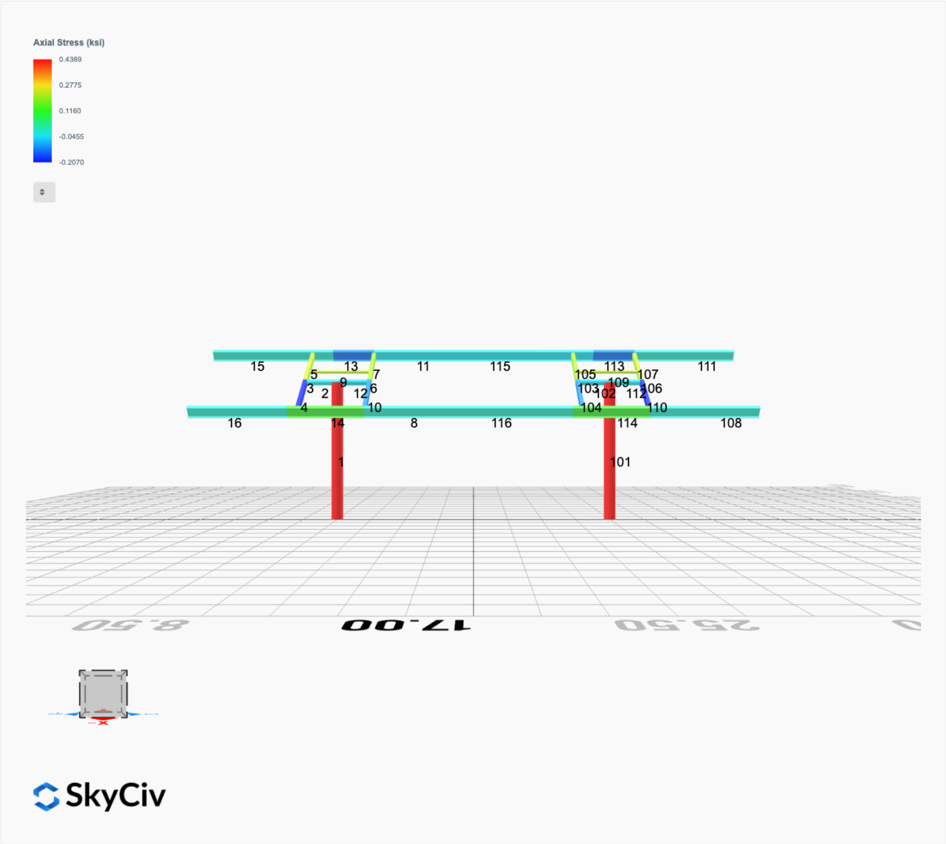
0.4552
-0.0000
-0.4552
-0.9103
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
SkyCiv



Axial Stress (ksi)
0.4389
0.2775
0.1160
-0.0455
-0.2070
15
13
11
115
105
113
107
111
5
9
7
3
2
12
6
103
109
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
17.00
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	0.0000	1.9286	-0.0526	-0.1030	0.0897	0.0263
ULS: 2. D + L	0.0000	1.9286	-0.0526	-0.1030	0.0897	0.0263
ULS: 3. D + (S or Lr or R)	-0.0000	5.6154	-0.1838	-0.3599	0.3130	0.0417
ULS: 3. D + (S or Lr or R)	0.0000	1.9286	-0.0526	-0.1030	0.0897	0.0263
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	4.6937	-0.1510	-0.2957	0.2572	0.0379
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	1.9286	-0.0526	-0.1030	0.0897	0.0263
ULS: 5b. D + 0.7E	0.0000	1.9286	-0.0526	-0.1030	0.0897	0.0263
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	4.6937	-0.1510	-0.2957	0.2572	0.0379
ULS: 8. 0.6D + 0.7E	0.0000	1.1571	-0.0315	-0.0618	0.0538	0.0158
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.9143	6.9763	-0.2784	-0.5310	0.5924	25.3251
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.9143	6.9763	-0.2784	-0.5310	0.5924	25.3251
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4980	-2.3980	0.1399	0.2614	-0.3406	-21.0979
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.0816	-1.6769	0.1090	0.2030	-0.2716	-27.8656
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1857	8.4795	-0.3204	-0.6167	0.6342	19.0119
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.1857	8.4795	-0.3204	-0.6167	0.6342	19.0119
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8735	1.4487	-0.0067	-0.0224	-0.0656	-15.8053
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5612	1.9896	-0.0298	-0.0662	-0.0137	-20.8811
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1857	5.7144	-0.2220	-0.4240	0.4667	19.0004
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.1857	5.7144	-0.2220	-0.4240	0.4667	19.0004
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8735	-1.3164	0.0918	0.1703	-0.2331	-15.8168
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5612	-0.7756	0.0686	0.1265	-0.1813	-20.8926
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.9143	6.2049	-0.2574	-0.4898	0.5565	25.3145
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.9143	6.2049	-0.2574	-0.4898	0.5565	25.3145
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4980	-3.1695	0.1609	0.3026	-0.3765	-21.1084
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.0816	-2.4484	0.1301	0.2442	-0.3074	-27.8761

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	12.5706
Shear X	-4.8572
Shear Z	-0.5060
Moment X	-0.9672
Moment Y (Twist)	1.0571
Moment Z	46.8563

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	8.4795
Shear X	-2.9143
Shear Z	-0.3204
Moment X	-0.6167
Moment Y (Twist)	0.6342
Moment Z	27.8761

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	-0.0000	1.9286	0.0526	0.1030	-0.0897	0.0263
ULS: 2. D + L	-0.0000	1.9286	0.0526	0.1030	-0.0897	0.0263
ULS: 3. D + (S or Lr or R)	0.0000	5.6154	0.1838	0.3600	-0.3130	0.0417
ULS: 3. D + (S or Lr or R)	-0.0000	1.9286	0.0526	0.1030	-0.0897	0.0263
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	4.6937	0.1510	0.2957	-0.2572	0.0378
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	1.9286	0.0526	0.1030	-0.0897	0.0263
ULS: 5b. D + 0.7E	-0.0000	1.9286	0.0526	0.1030	-0.0897	0.0263

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	4.6937	0.1510	0.2957	-0.2572	0.0378
ULS: 8. 0.6D + 0.7E	-0.0000	1.1571	0.0315	0.0618	-0.0538	0.0158
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.9143	6.9763	0.2784	0.5310	-0.5924	25.3251
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.9143	6.9763	0.2784	0.5310	-0.5924	25.3251
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.4980	-2.3980	-0.1399	-0.2614	0.3406	-21.0979
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.0816	-1.6769	-0.1090	-0.2030	0.2716	-27.8656
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1857	8.4795	0.3204	0.6167	-0.6342	19.0119
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.1857	8.4795	0.3204	0.6167	-0.6342	19.0119
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8735	1.4487	0.0067	0.0224	0.0655	-15.8053
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5612	1.9896	0.0298	0.0662	0.0137	-20.8811
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1857	5.7144	0.2220	0.4240	-0.4667	19.0004
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.1857	5.7144	0.2220	0.4240	-0.4667	19.0004
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8735	-1.3164	-0.0918	-0.1703	0.2331	-15.8168
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.5612	-0.7756	-0.0686	-0.1265	0.1813	-20.8926
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.9143	6.2049	0.2574	0.4898	-0.5565	25.3145
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.9143	6.2049	0.2574	0.4898	-0.5565	25.3145
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.4980	-3.1695	-0.1609	-0.3026	0.3765	-21.1084
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.0816	-2.4484	-0.1301	-0.2442	0.3074	-27.8761

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	12.5706
Shear X	-4.8572
Shear Z	0.5060
Moment X	0.9674
Moment Y (Twist)	1.0571
Moment Z	46.8573

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	8.4795
Shear X	-2.9143
Shear Z	0.3204
Moment X	0.6167
Moment Y (Twist)	0.6342
Moment Z	27.8761

Project Details

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

Design Input Information

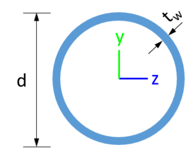
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

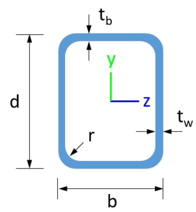
Design Materials

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

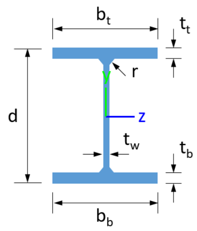
Section Dimensions



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



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



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	0.30

Section Properties

ID	Name	A (in^2)	J (in^4)	I_{yp} (in^4)	I_{zp} (in^4)	I_w (in^6)	S_{yp} (in^3)	S_{zp} (in^3)
2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85

9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	92.39	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	9	17.97	17.97	8.56	-	300	200	1
2	5	4.20	4.20	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.77,1.67,1.67,1.66,1.65	300	200	1
5	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
6	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.70,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
8	19	1.33	1.33	2.05	2.03,2.03,2.03,2.03,2.03,2.03,2.01,2.01,2.00,1.95,2.01,2.01,2.00,2.14,2.02,2.02,2.07,2.03,2.01,2.01,1.99,1.97,2.01,2.01,2.01,2.11	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.59,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.73,1.67,1.67,1.66,1.64	300	200	1
11	19	1.33	1.33	2.05	2.06,2.05,2.06,2.05,2.05,2.05,2.04,2.04,2.02,2.01,2.03,2.03,2.02,2.02,2.04,2.04,2.09,2.26,2.04,2.04,2.02,2.01,2.03,2.03,2.03,2.02	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.14,1.10,1.10,1.10,1.13,1.10,1.10,1.10,1.15,1.10,1.10,1.10,1.14,1.10,1.10,1.10,1.12	300	200	1
14	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,2.26,1.10,1.10,1.10,1.18,1.10,1.10,1.10,1.11,1.10,1.10,1.10,2.41,1.10,1.10,1.10,1.16	300	200	1
15	19	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	9	17.97	17.97	8.56	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17	300	200	1
104	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.70,1.67,1.67,1.66,1.59,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.73,1.67,1.67,1.66,1.64	300	200	1
105	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.67,1.70,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66	300	200	1
106	16	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.20,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.69,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	30	20	1

						0	0	
108	19	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.67,1.66,1.72,1.67,1.67,1.66,1.64,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.77,1.67,1.67,1.66,1.65	300	200	1
111	19	9.97	9.97	4.75	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
112	5	4.20	4.20	2.00	-	300	200	1
113	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.14,1.10,1.10,1.10,1.13,1.10,1.10,1.10,1.15,1.10,1.10,1.10,1.14,1.10,1.10,1.10,1.12	300	200	1
114	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,2.26,1.10,1.10,1.10,1.18,1.10,1.10,1.10,1.11,1.10,1.10,1.10,2.40,1.10,1.10,1.10,1.17	300	200	1
115	19	4.84	4.84	7.45	1.76,1.76,1.76,1.76,1.76,1.76,1.79,1.79,1.82,1.84,1.79,1.79,1.81,1.83,1.78,1.78,1.70,1.45,1.79,1.79,1.83,1.84,1.79,1.79,1.81,1.82	300	200	1
116	19	4.84	4.84	7.45	1.79,1.80,1.79,1.80,1.80,1.79,1.83,1.83,1.86,1.97,1.84,1.84,1.85,1.61,1.82,1.82,1.74,1.81,1.83,1.83,1.87,1.94,1.84,1.84,1.84,1.66	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	377.97	254.87	83.29	83.29	113.39	113.39
2	198.33	182.14	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	126.01	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	126.01	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	25.21	6.12	40.24	43.62
14	133.20	104.94	25.21	6.12	40.24	43.62
15	133.20	32.95	32.87	6.12	40.24	43.62
16	133.20	32.95	32.87	6.12	40.24	43.62
101	377.97	254.87	83.29	83.29	113.39	113.39
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	32.95	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	32.95	32.87	6.12	40.24	43.62
112	198.33	182.14	21.95	21.95	59.50	59.50
113	133.20	104.94	25.21	6.12	40.24	43.62
114	133.20	104.94	25.21	6.12	40.24	43.62

115	133.20	93.89	32.87	6.12	40.24	43.62
116	133.20	93.89	32.87	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	0.049	0.563	0.040	0.043	0.004	0.571	#32	0.367	Not Required	Pass
2	0.002	0.564	0.245	0.114	0.044	0.809	#13	0.171	Not Required	Pass
3	0.009	0.844	0.077	0.086	0.016	0.892	#13	0.045	Not Required	Pass
4	0.010	0.841	0.151	0.085	0.031	0.857	#13	0.080	Not Required	Pass
5	0.009	0.522	0.166	0.084	0.042	0.547	#13	0.074	Not Required	Pass
6	0.008	0.696	0.038	0.069	0.003	0.702	#13	0.045	Not Required	Pass
7	0.008	0.433	0.111	0.070	0.029	0.441	#13	0.074	Not Required	Pass
8	0.002	0.078	0.075	0.045	0.012	0.137	#21	0.095	Not Required	Pass
9	0.010	0.094	0.073	0.003	0.003	0.168	#13	0.204	Not Required	Pass
10	0.007	0.693	0.130	0.070	0.030	0.766	#13	0.080	Not Required	Pass
11	0.003	0.077	0.076	0.045	0.012	0.134	#21	0.095	Not Required	Pass
12	0.004	0.412	0.197	0.092	0.037	0.610	#13	0.053	Not Required	Pass
13	0.007	0.324	0.389	0.061	0.017	0.673	#21	0.286	Not Required	Pass
14	0.007	0.330	0.389	0.061	0.017	0.673	#21	0.190	Not Required	Pass
15	0.000	0.130	0.208	0.045	0.012	0.324	#21	Not Required	Not Required	Pass
16	0.000	0.130	0.208	0.045	0.012	0.324	#21	Not Required	Not Required	Pass
101	0.049	0.563	0.040	0.043	0.004	0.571	#32	0.367	Not Required	Pass
102	0.004	0.412	0.197	0.092	0.037	0.610	#13	0.053	Not Required	Pass
103	0.008	0.696	0.038	0.069	0.003	0.702	#13	0.045	Not Required	Pass
104	0.007	0.693	0.130	0.070	0.030	0.766	#13	0.080	Not Required	Pass
105	0.008	0.433	0.111	0.070	0.029	0.441	#13	0.074	Not Required	Pass
106	0.009	0.844	0.077	0.086	0.016	0.892	#13	0.045	Not Required	Pass
107	0.009	0.522	0.166	0.084	0.042	0.547	#13	0.074	Not Required	Pass
108	0.000	0.130	0.208	0.045	0.012	0.324	#21	Not Required	Not Required	Pass
109	0.010	0.094	0.073	0.003	0.003	0.168	#13	0.204	Not Required	Pass
110	0.010	0.841	0.151	0.085	0.031	0.857	#13	0.080	Not Required	Pass
111	0.000	0.130	0.208	0.045	0.012	0.324	#21	Not Required	Not Required	Pass
112	0.002	0.564	0.245	0.114	0.044	0.809	#13	0.171	Not Required	Pass
113	0.007	0.324	0.389	0.061	0.017	0.673	#21	0.190	Not Required	Pass
114	0.007	0.330	0.389	0.061	0.017	0.673	#21	0.286	Not Required	Pass
115	0.003	0.077	0.143	0.045	0.012	0.192	#21	0.346	Not Required	Pass
116	0.002	0.078	0.143	0.045	0.012	0.188	#21	0.346	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/comresssion)
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

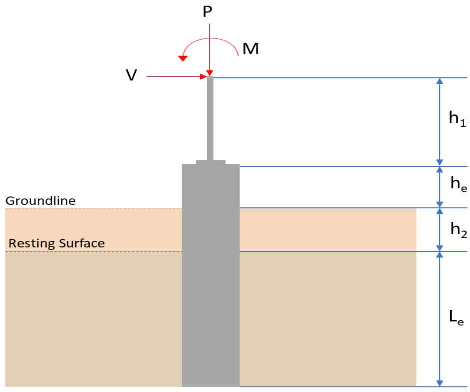
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 8.75 \text{ ft}$ - 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)	8.479	12.571
V_x (kip)	-2.914	-4.857
V_z (kip)	-0.320	-0.506
M_x (kipft)	-0.617	-0.967
M_z (kipft)	27.876	46.856

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,

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

$$H_o = \frac{(-2.914 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.97133 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.876\ \text{kipft}) + ((-2.914\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 9.292\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.7227\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.32\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.10667\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.617\ \text{kipft}) + ((-0.32\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.20567\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.8943\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7227\ \text{ft}), (1.8943\ \text{ft})]$$

$$L_{e,req} = 7.723\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.723\ \text{ft})}{(8.75\ \text{ft})}$$

$$Ratio = 0.88263$$

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

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

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

$$q = \frac{(8.479\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 1.1995\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.1995\ \mathrm{kip/ft^2})}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.59977$$

Status: **PASS**
Ratio: **0.600**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.97133\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.292\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.292\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (9.292\ \mathrm{kipft/ft})) + (4 \times (-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.1095\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (9.292\ \mathrm{kipft/ft})) + (3 \times (-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^2}{(8.75\ \mathrm{ft})^2 \times [(3 \times (9.292\ \mathrm{kipft/ft})) + (2 \times (-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.19265\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (9.292\ \mathrm{kipft/ft})) + ((-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 1.2415\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.1095\ \mathrm{ft})}{2}$$

$$p_a = 0.45822\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.19265\ \mathrm{kip/ft^2})}{(0.45822\ \mathrm{kip/ft^2})}$$

$$Ratio = 0.42044$$

Status: **PASS**
Ratio: **0.420**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2415\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94588$$

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

Considering z-direction:

$H_o = -0.10667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.20567\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.20567\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.20567\ \mathrm{kipft/ft})) + (4 \times (-0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.3814\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.20567\ \mathrm{kipft/ft})) + (3 \times (-0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^2}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.20567\ \mathrm{kipft/ft})) + (2 \times (-0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = -0.048139\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.20567\ \mathrm{kipft/ft})) + ((-0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = -0.064259\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.3814\ \mathrm{ft})}{2}$$

$$p_a = 0.4786\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.048139\ \mathrm{kip/ft^2}\right)}{\left(0.4786\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.10058$$

Status: **PASS**
Ratio: **-0.100**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

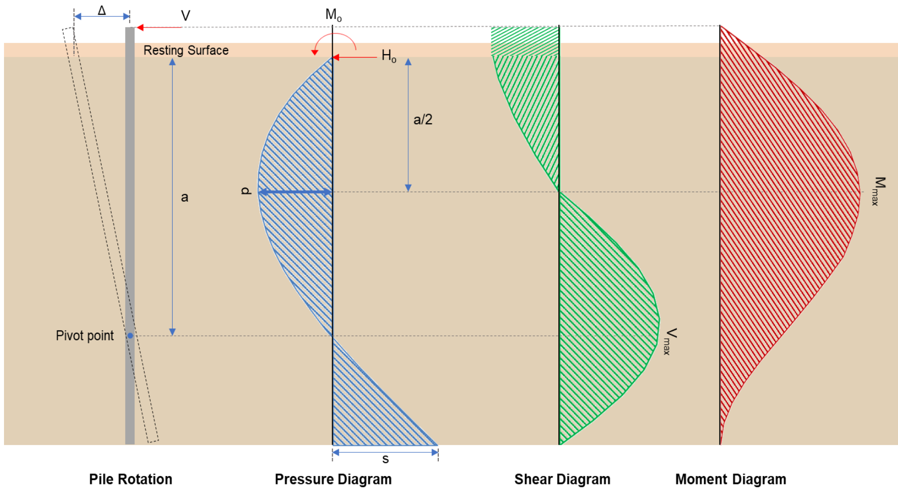
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.064259\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.048959$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.857\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.619\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(46.856\ \mathrm{kipft}) + ((-4.857\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 15.619\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.619\ \mathrm{kipft/ft})}{(-1.619\ \mathrm{kip/ft})}$$

$$E = 9.6471\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.619\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-1.619\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (15.619\ \mathrm{kipft/ft})) + (4 \times (-1.619\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.1081\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.619\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.6471\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1081\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.6471\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1081\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.681 \text{ kip}$$

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

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

$$M_{max} = ((-1.619 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(9.6471 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.1081 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (9.6471 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.1081 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (9.6471 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.1081 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 51.646 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.506 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.16867 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.967 \text{ kipft}) + ((-0.506 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.32233 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.32233 \text{ kipft/ft})}{(-0.16867 \text{ kip/ft})}$$

$$E = 1.9111 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.32233 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (-0.16867 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (0.32233 \text{ kipft/ft})) + (4 \times (-0.16867 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.3826 \text{ ft}$$

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

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

$$V_{max} = ((-0.16867 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.9111 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.3826 \text{ ft})}{(8.75 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (1.9111 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.3826 \text{ ft})}{(8.75 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.5369 \text{ kip}$$

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

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

$$M_{max} = ((-0.16867 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(1.9111 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.3826 \text{ ft})}{2 \times (8.75 \text{ ft})} \right) - \left[\left(\frac{4 \times (1.9111 \text{ ft})}{(8.75 \text{ ft})} + 3 \right) \times \left(\frac{(6.3826 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (1.9111 \text{ ft})}{(8.75 \text{ ft})} + 2 \right) \times \left(\frac{(6.3826 \text{ ft})}{2 \times (8.75 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.9578 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.571 \text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (3 \text{ ksi}) \times \left(1017.9 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -44.784 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-44.784 \text{ in}^2\right), \left(0.0018 \times \left(1017.9 \text{ in}^2\right)\right)\right]$$

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

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

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

$$Ratio = \frac{(12.571\ \text{kip})}{(1492.5\ \text{kip})}$$

$$Ratio = 0.0084228$$

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 $f'_{ck} = 3\ \text{ksi} \rightarrow 3000\ \text{psi}$, $P = 12.571\ \text{kip} \rightarrow 12571\ \text{lbf}$,
22.5.5.1.1(a) $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \text{psi})} + \frac{(12571\ \text{lbf})}{6 \times \left(1017.9\ \text{in}^2\right)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 83.677\ \text{kip}$$

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

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

$$V_c = Min\left[(203.86\ \text{kip}), (83.677\ \text{kip}), (237.06\ \text{kip})\right]$$

	$$V_c = 83.677 \text{ kip}$$ 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 $$\phi V_n = \phi\, (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((83.677 \text{ kip}) + (38.17 \text{ kip}))$$ $$\phi V_n = 79.201 \text{ kip}$$ **Considering x-direction:** $V_{max} = 12.681 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(12.681 \text{ kip})}{(79.201 \text{ kip})}$$ $$Ratio = 0.16012$$	Status: **PASS** Ratio: **0.160**
	Considering z-direction: $V_{max} = 0.5369 \text{ kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.5369 \text{ kip})}{(79.201 \text{ kip})}$$ $$Ratio = 0.006779$$	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:

$M_{max} = 51.646 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(51.646 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.7601$$

Status: **PASS**
Ratio: **0.760**

Considering z-direction:

$M_{max} = 1.9578 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.9578 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.028813$$

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

REFERENCES	CALCULATIONS	RESULTS

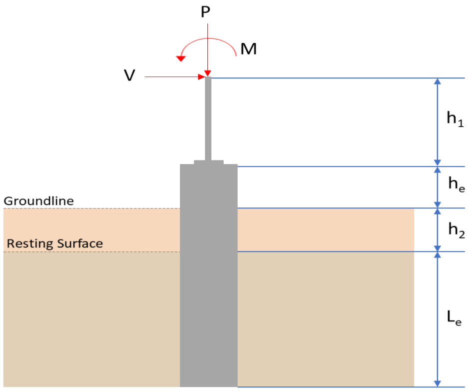
SkyCiv Foundation Design

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
$L = 8.75\ \mathrm{ft}$ - 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)	8.480	12.571
V_x (kip)	-2.914	-4.857
V_z (kip)	0.320	0.506
M_x (kipft)	0.617	0.967
M_z (kipft)	27.876	46.857

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,

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

$$H_o = \frac{(-2.914\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.97133\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(27.876 \text{ kipft}) + ((-2.914 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 9.292 \text{ kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.7227 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.32 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.10667 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.617 \text{ kipft}) + ((0.32 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.20567 \text{ kipft/ft}$$

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:
$L_{e,z} = 4.0536 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.7227 \text{ ft}), (4.0536 \text{ ft})]$$

$$L_{e,req} = 7.723 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

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

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

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.723 \text{ ft})}{(8.75 \text{ ft})}$$

$$Ratio = 0.88263$$

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

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

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

$$q = \frac{(8.48 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

$$q = 1.1997\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.1997\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.59984$$

Status: **PASS**
Ratio: **0.600**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 2.9167$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.97133\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 9.292\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.292\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (9.292\ \mathrm{kipft/ft})) + (4 \times (-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.1095\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (9.292\ \mathrm{kipft/ft})) + (3 \times (-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\ 2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (9.292\ \mathrm{kipft/ft})) + (2 \times (-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.19265\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (9.292\ \mathrm{kipft/ft})) + ((-0.97133\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 1.2415\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.1095\ \mathrm{ft})}{2}$$

$$p_a = 0.45822\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.19265\ \mathrm{kip/ft^2}\right)}{\left(0.45822\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.42044$$

Status: **PASS**
Ratio: **0.420**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.2415\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.94588$$

Status: PASS
Ratio: 0.950

Considering z-direction:

$H_o = 0.10667\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.20567\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.20567\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (0.20567\ \mathrm{kipft/ft})) + (4 \times (0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.3814\ \mathrm{ft}$$

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

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

$$p = \frac{1.178 \times [(4 \times (0.20567\ \mathrm{kipft/ft})) + (3 \times (0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]^{\,2}}{(8.75\ \mathrm{ft})^2 \times [(3 \times (0.20567\ \mathrm{kipft/ft})) + (2 \times (0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}$$

$$p = 0.0813\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{9.425 \times [(2 \times (0.20567\ \mathrm{kipft/ft})) + ((0.10667\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))]}{(8.75\ \mathrm{ft})^2}$$

$$s = 0.16553\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(6.3814\ \mathrm{ft})}{2}$$

$$p_a = 0.4786\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0813\ \mathrm{kip/ft^2}\right)}{\left(0.4786\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.16987$$

Status: PASS
Ratio: 0.170

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

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

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

$Ratio$ - Lateral soil capacity

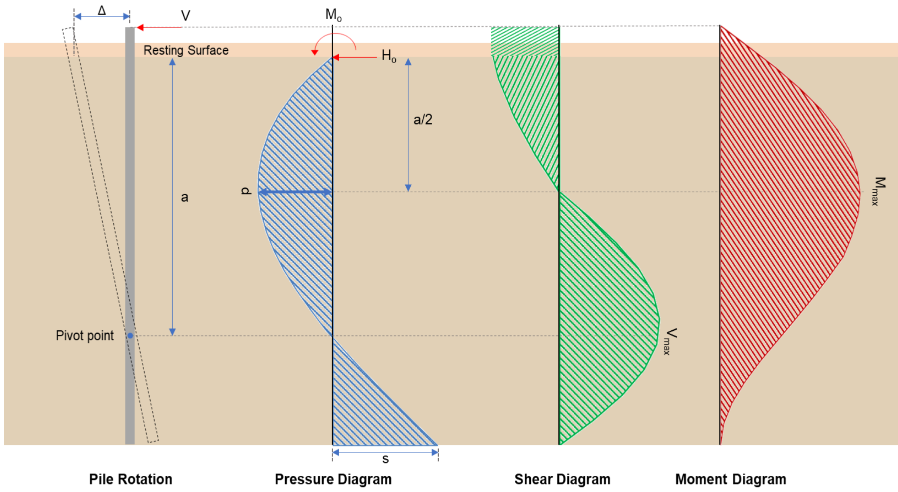
$$Ratio = \frac{s}{\ldots}$$

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

$$Ratio = \frac{\left(0.16553\ \mathrm{kip/ft^2}\right)}{\left(1.3125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.12612$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.857\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.619\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(46.857\ \mathrm{kipft}) + ((-4.857\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 15.619\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.619\ \mathrm{kipft/ft})}{(-1.619\ \mathrm{kip/ft})}$$

$$E = 9.6473\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.619\ \mathrm{kipft/ft}) \times (8.75\ \mathrm{ft})) + \left(3 \times (-1.619\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft})^2\right)}{(6 \times (15.619\ \mathrm{kipft/ft})) + (4 \times (-1.619\ \mathrm{kip/ft}) \times (8.75\ \mathrm{ft}))}$$

$$a = 6.1081\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.619\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.6473\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 3\right) \times \left(\frac{(6.1081\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.6473\ \mathrm{ft})}{(8.75\ \mathrm{ft})} + 2\right) \times \left(\frac{(6.1081\ \mathrm{ft})}{(8.75\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.682 \text{ kip}$$

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

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

$$M_{max} = ((-1.619 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(9.6473 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.1081 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (9.6473 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.1081 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.6473 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.1081 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 51.647 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.506 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.16867 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.967 \text{ kipft}) + ((0.506 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.32233 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.32233 \text{ kipft/ft})}{(0.16867 \text{ kip/ft})}$$

$$E = 1.9111 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.32233 \text{ kipft/ft}) \times (8.75 \text{ ft})) + \left(3 \times (0.16867 \text{ kip/ft}) \times (8.75 \text{ ft})^2\right)}{(6 \times (0.32233 \text{ kipft/ft})) + (4 \times (0.16867 \text{ kip/ft}) \times (8.75 \text{ ft}))}$$

$$a = 6.3826 \text{ ft}$$

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

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

$$V_{max} = ((0.16867 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (1.9111 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.3826 \text{ ft})}{(8.75 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (1.9111 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.3826 \text{ ft})}{(8.75 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.5369 \text{ kip}$$

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

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

$$M_{max} = ((0.16867 \text{ kip/ft}) \times (36 \text{ in}) \times (8.75 \text{ ft})) \times \left[\left(\frac{(1.9111 \text{ ft})}{(8.75 \text{ ft})} + \frac{(6.3826 \text{ ft})}{2 \times (8.75 \text{ ft})}\right) - \left[\left(\frac{4 \times (1.9111 \text{ ft})}{(8.75 \text{ ft})} + 3\right) \times \left(\frac{(6.3826 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (1.9111 \text{ ft})}{(8.75 \text{ ft})} + 2\right) \times \left(\frac{(6.3826 \text{ ft})}{2 \times (8.75 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.9578 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(12.571 \text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (3 \text{ ksi}) \times (1017.9 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (1017.9 \text{ in}^2))\right]$$

$$A_{st,required} = -44.784 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-44.784 \text{ in}^2), (0.0018 \times (1017.9 \text{ in}^2))\right]$$

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

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

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

$$Ratio = \frac{(12.571\ \mathrm{kip})}{(1492.5\ \mathrm{kip})}$$

$$Ratio = 0.0084228$$

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

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 $f'_{ck} = 3\ \mathrm{ksi} \rightarrow 3000\ \mathrm{psi}$, $P = 12.571\ \mathrm{kip} \rightarrow 12571\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(3000\ \mathrm{psi})} + \frac{(12571\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 83.677\ \mathrm{kip}$$

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

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

$$V_c = Min\left[(203.86\ \mathrm{kip}), (83.677\ \mathrm{kip}), (237.06\ \mathrm{kip})\right]$$

$$V_c = 83.677\ \mathrm{kip}$$

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

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

$$\phi V_n = (0.65) \times ((83.677\ \mathrm{kip}) + (38.17\ \mathrm{kip}))$$

$$\phi V_n = 79.201\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 12.682\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.682\ \mathrm{kip})}{(79.201\ \mathrm{kip})}$$

$$Ratio = 0.16012$$

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

Considering z-direction:

$V_{max} = 0.5369\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.5369\ \mathrm{kip})}{(79.201\ \mathrm{kip})}$$

$$Ratio = 0.006779$$

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:

$M_{max} = 51.647 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(51.647 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.76011$$

Status: **PASS**
Ratio: **0.760**

Considering z-direction:

$M_{max} = 1.9578 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.9578 \text{ kipft})}{(67.947 \text{ kipft})}$$

$$Ratio = 0.028813$$

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