Your Project Calculations

Project Name: Elk Mountain-Cyber

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Elk%20Mountain-Cyber&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/7_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=NTheL4TJAdcw5JIJMUtSBfKSnzaFoKxlHkSabucM5wySzrBJjjSE1bmQKv8zPbRd

Array Specification

Product:	Cyber
Unique ID:	1P-0-6TOP-SD-24-L-3Hx2W-JIAJ
Duty Classification:	SD
Module Width:	41.00 in
Module Length:	74.00in
Number of Rows:	3
Number of Columns:	2
Total Number of Modules:	6
Desired Tilt Angle:	50
Front Edge Clearance:	8
Total Array Height at Tilt:	15.90 ft
Total Frame Length:	11.50 ft
Frame Weight:	434 lbs
Array Dimensions N/S:	10.38 ft
Array Dimensions E/W:	12.50 ft
Rail Length:	124.50 in
Rail Spacing:	3.08 ft
Rail Check:	Not Checked

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	11.97 ft
Number of Poles:	1
Pole Spacing:	0

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 6.00 ft
Foundation Volume:	3.556 y^3
Foundation Result:	PASSED
Mount Twist:	0.000002 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Medicine Bow Rd, Wyoming 82324, USA
Wind Speed:	130 mph
Snow Load:	107 psf
Design Uplift Pressure:	0.026979 ksf
Design Downforce Pressure:	-0.026979 ksf
Design Snow Pressure:	0.023532 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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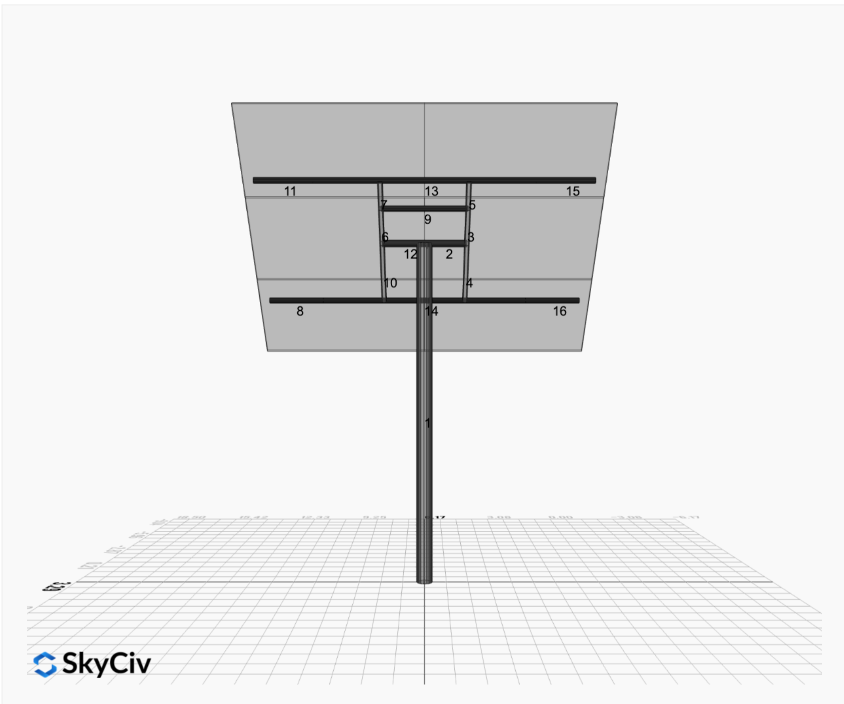
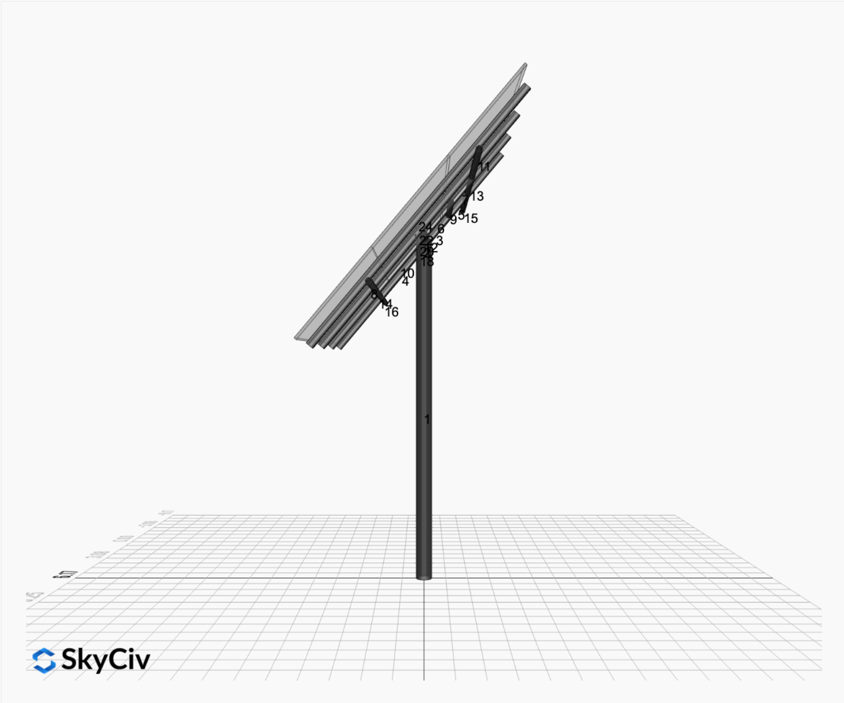
Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent

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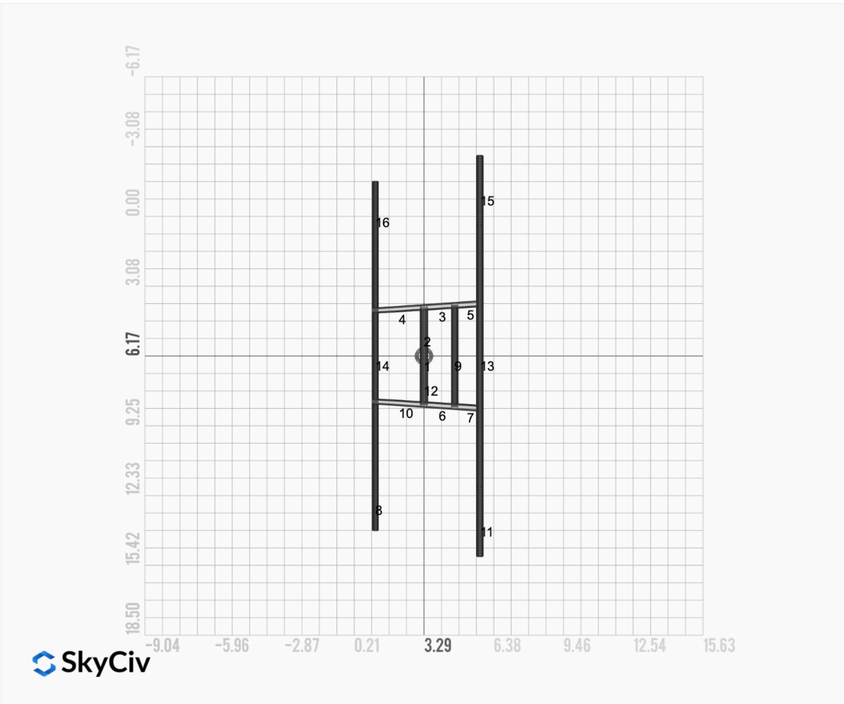
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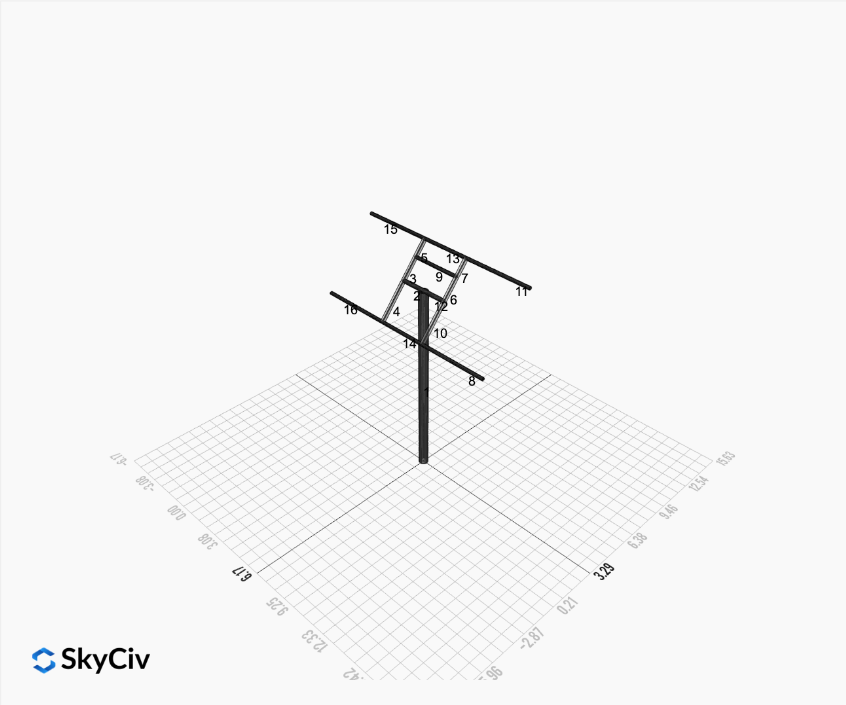
-3.08
0.00
3.08
6.17
9.25
12.33
15.42
18.50
-9.04
-5.96
-2.87
0.21
3.29
6.38
9.46
12.54
15.63
SkyCiv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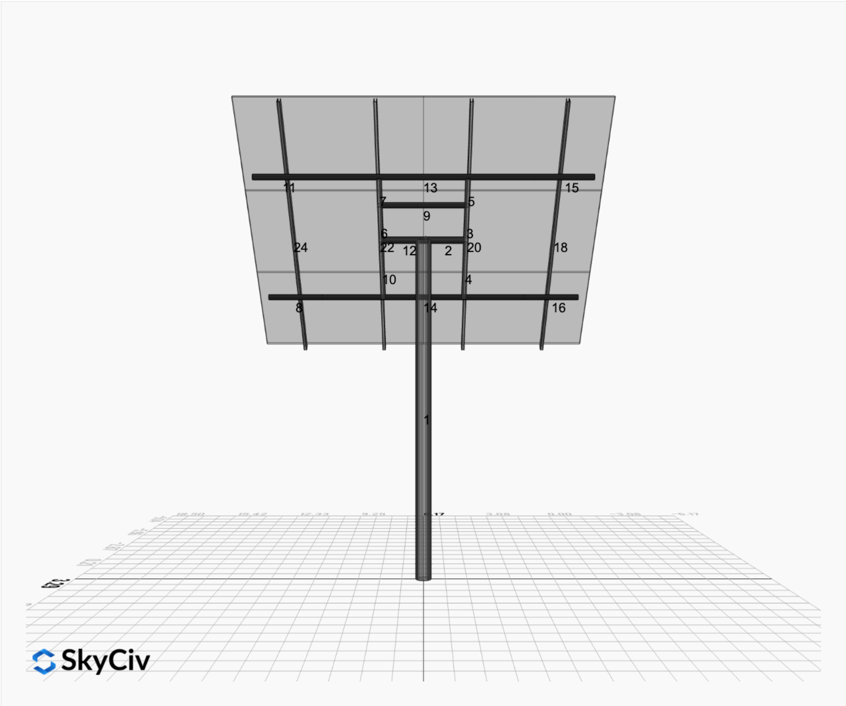
13
5
9
7
3
11
2
12
6
16
4
10
14
8
SkyCiv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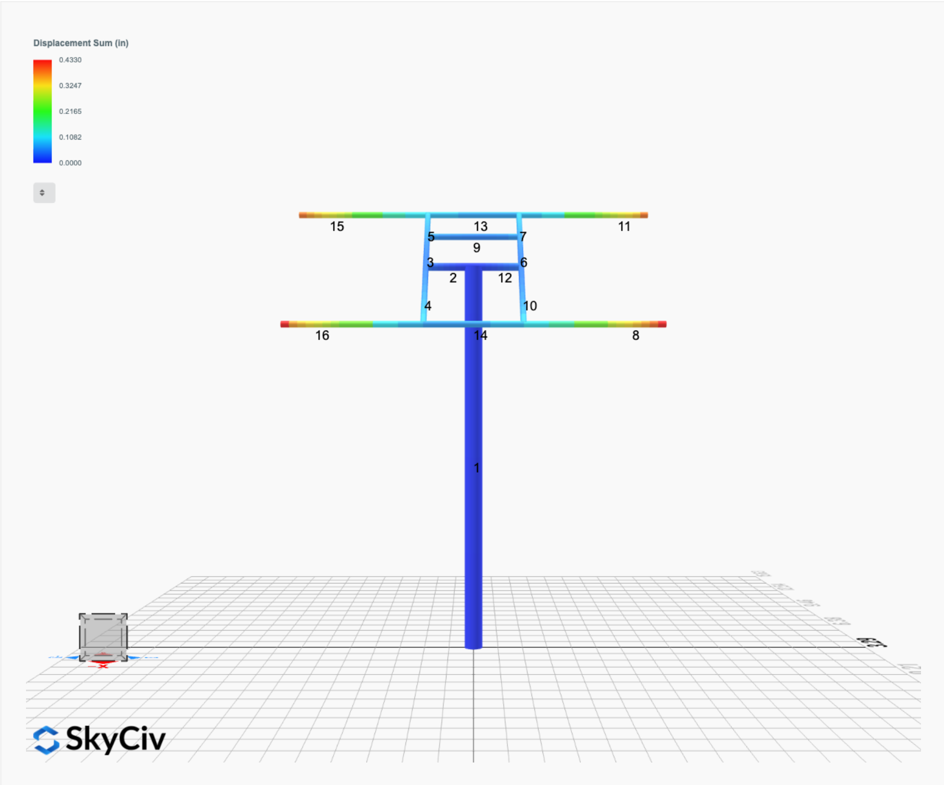
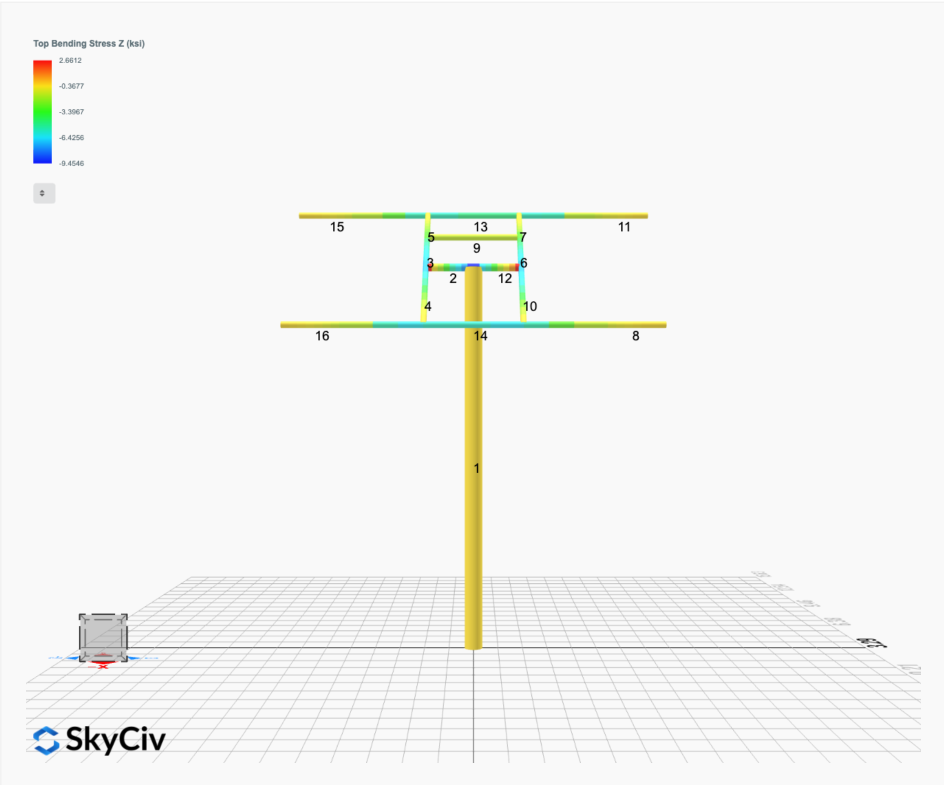
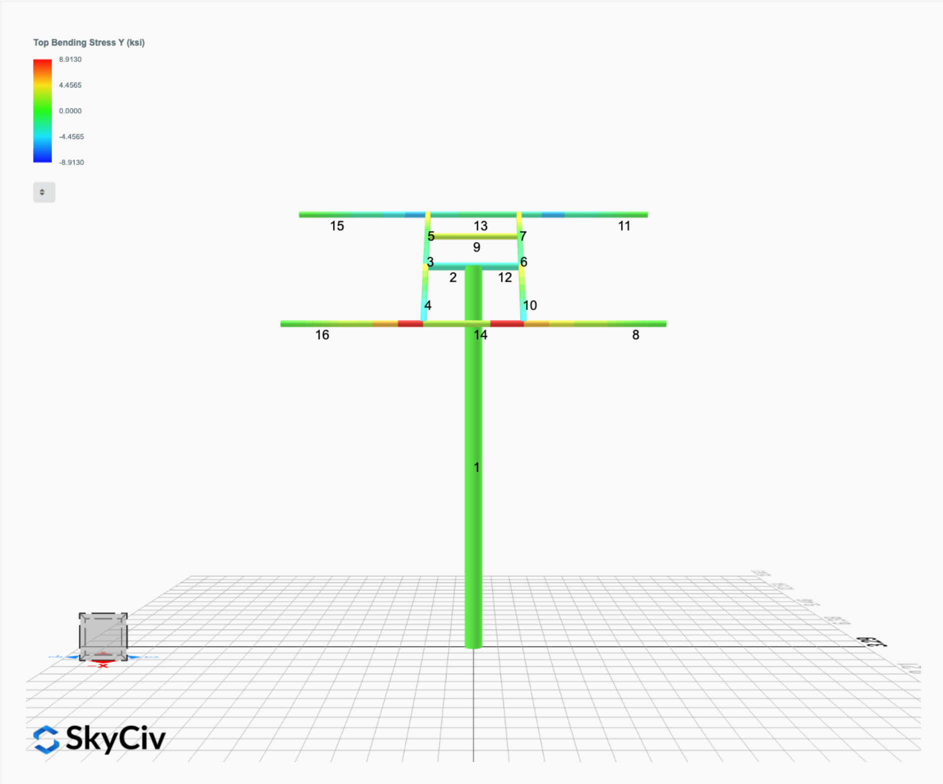
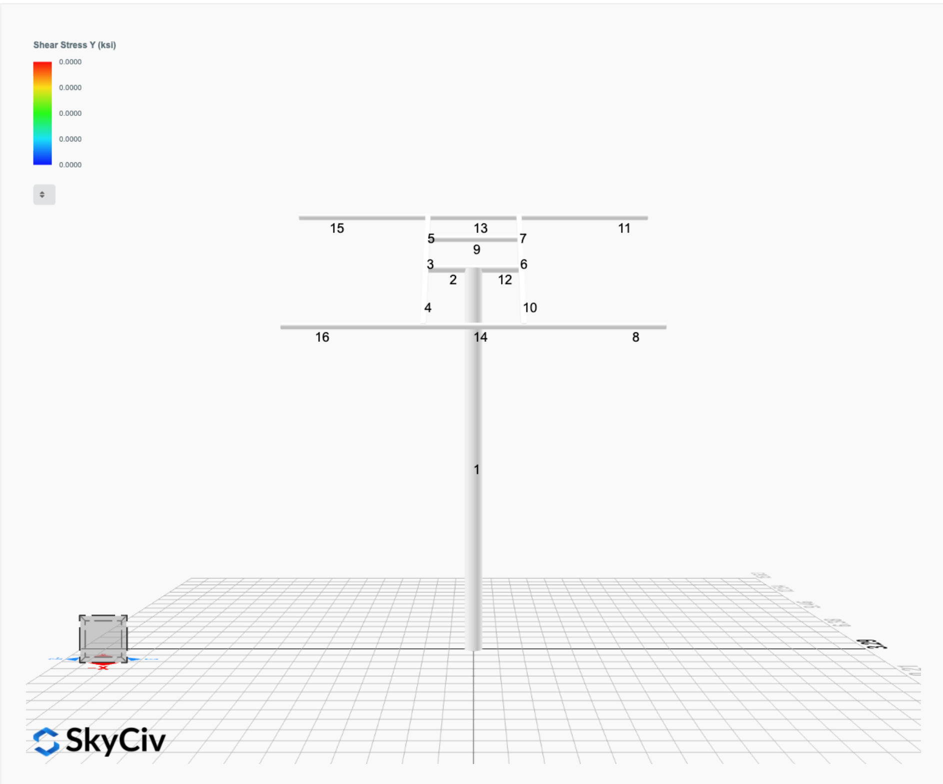
13
15
7
5
9
6
3
24
22
12
2
20
18
10
4
8
14
16
1
SkyCiv

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
8.9130
4.4565
0.0000
-4.4565
-8.9130
15
13
11
5
7
9
3
6
2
12
4
10
16
14
8
1
SkyCiv


Shear Stress Y (ksi)
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0.0000
0.0000
0.0000
0.0000
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13
11
5
7
9
3
6
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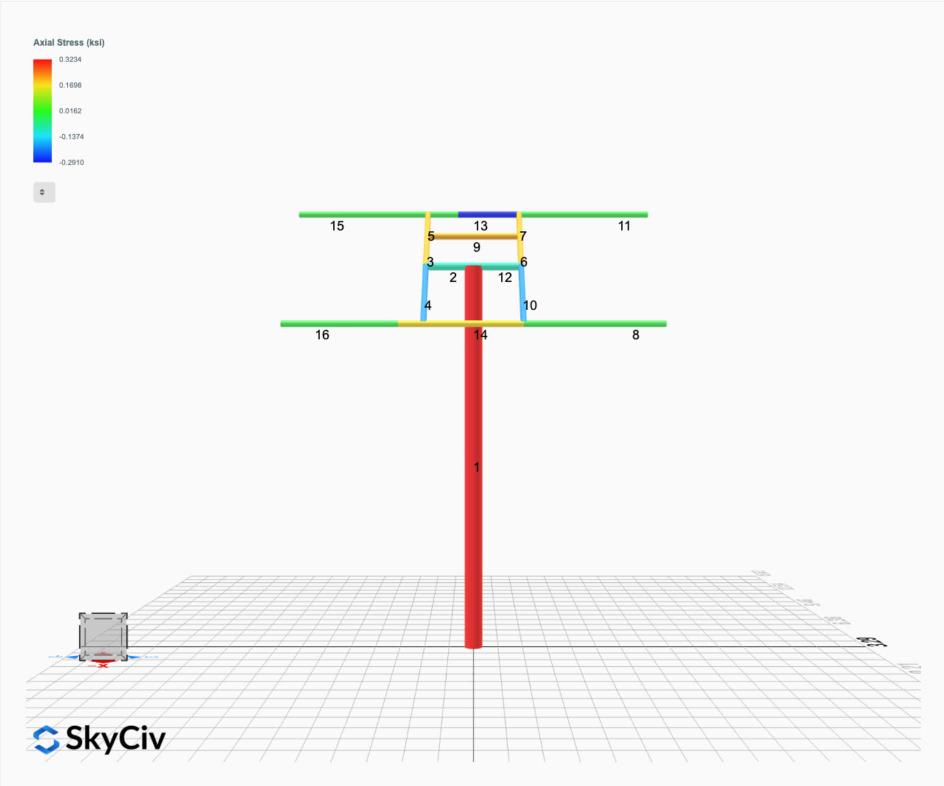
12
4
10
16
14
8
1
SkyCiv


Axial Stress (ksi)
0.3234
0.1698
0.0162
-0.1374
-0.2910
15
13
11
5
7
9
3
6
2
12
4
10
16
14
8
1
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	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 2. D + L	-0.0000	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 3. D + (S or Lr or R)	-0.0000	2.8770	0.0000	0.0000	-0.0000	0.0206
ULS: 3. D + (S or Lr or R)	-0.0000	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	2.4258	0.0000	0.0000	-0.0000	0.0191
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 5b. D + 0.7E	-0.0000	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	2.4258	0.0000	0.0000	-0.0000	0.0191
ULS: 8. 0.6D + 0.7E	-0.0000	0.6434	-0.0000	0.0000	-0.0000	0.0088
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.6082	2.4217	0.0000	0.0000	-0.0000	19.6443
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0000	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.6082	-0.2772	-0.0000	0.0000	-0.0000	-18.8843
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0000	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2061	3.4379	0.0000	0.0000	-0.0000	14.7413
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	2.4258	0.0000	0.0000	-0.0000	0.0191
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2061	1.4138	0.0000	0.0000	-0.0000	-14.1551
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	2.4258	0.0000	0.0000	-0.0000	0.0191
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2061	2.0843	0.0000	0.0000	-0.0000	14.7368
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.2061	0.0602	-0.0000	0.0000	-0.0000	-14.1596
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	1.0723	-0.0000	0.0000	-0.0000	0.0146
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.6082	1.9928	0.0000	0.0000	-0.0000	19.6384
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0000	0.6434	-0.0000	0.0000	-0.0000	0.0088
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.6082	-0.7061	-0.0000	0.0000	-0.0000	-18.8902
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0000	0.6434	-0.0000	0.0000	-0.0000	0.0088

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	5.2988
Shear X	-2.6803
Shear Z	0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	33.3949

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	3.4379
Shear X	-1.6082
Shear Z	0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	19.6443

Project Details

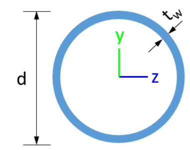
Design Code:	AISC 360-16 LRFD
Provision:	LRFD
Country:	United States
User Name:	sales@mtsolar.us
Unit System:	imperial

Design Input Information

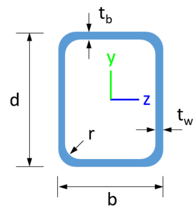
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
7	6in Pipe Sch 40	6.63	0.28					
28	2.5in Pipe Sch 80	2.88	0.28					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
30	HSS3x2x3/16	3.00	2.00	0.17	0.17	0.17		

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
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28
28	2.5in Pipe Sch 80	2.25	3.85	1.92	1.92	0.00	1.87	1.87
30	HSS3x2x3/16	1.54	2.05	0.93	1.77	1.95	1.12	1.48

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	7	25.15	25.15	11.97	-	300	200	1
2	28	0.98	0.98	1.50	-	30	20	1

						0	0	
3	30	0.92	0.92	1.42	1.31,1.30,1.31,1.30,1.30,1.31,1.29,1.30,1.29,1.30,1.30,1.31,1.29,1.31,1.29,1.30,1.31,1.30,1.30,1.31,1.29,1.31,1.29,1.31,1.29,1.31	300	200	1
4	30	1.63	1.63	2.50	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
5	30	0.70	0.70	1.08	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
6	30	0.92	0.92	1.42	1.31,1.30,1.31,1.30,1.30,1.31,1.29,1.30,1.29,1.30,1.30,1.31,1.29,1.31,1.29,1.30,1.31,1.30,1.30,1.31,1.29,1.31,1.29,1.31,1.29,1.31	300	200	1
7	30	0.70	0.70	1.08	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
8	2	4.20	4.20	2.00	-	300	200	1
9	2	1.95	1.95	3.00	-	300	200	1
10	30	1.63	1.63	2.50	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
11	2	4.20	4.20	2.00	-	300	200	1
12	28	0.98	0.98	1.50	-	300	200	1
13	2	4.88	3.00	7.50	-	300	200	1
14	2	4.88	3.00	7.50	-	300	200	1
15	2	4.20	4.20	2.00	-	300	200	1
16	2	4.20	4.20	2.00	-	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	251.16	69.83	42.30	42.30	75.35	75.35
2	101.41	100.23	7.02	7.02	30.42	30.42
3	69.30	68.29	5.55	4.20	23.28	13.89
4	69.30	66.19	5.55	4.20	23.28	13.89
5	69.30	68.70	5.55	4.20	23.28	13.89
6	69.30	68.29	5.55	4.20	23.28	13.89
7	69.30	68.70	5.55	4.20	23.28	13.89
8	66.48	48.46	3.82	3.82	19.94	19.94
9	66.48	62.10	3.82	3.82	19.94	19.94
10	69.30	66.19	5.55	4.20	23.28	13.89
11	66.48	48.46	3.82	3.82	19.94	19.94
12	101.41	100.23	7.02	7.02	30.42	30.42
13	66.48	43.42	3.82	3.82	19.94	19.94
14	66.48	43.42	3.82	3.82	19.94	19.94
15	66.48	48.46	3.82	3.82	19.94	19.94
16	66.48	48.46	3.82	3.82	19.94	19.94

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	0.076	0.789	0.000	0.036	0.000	0.821	#13	0.672	Not Required	Pass
2	0.004	0.449	0.341	0.083	0.044	0.751	#13	0.042	Not Required	Pass
3	0.011	0.535	0.075	0.051	0.013	0.576	#13	0.071	Not Required	Pass
4	0.011	0.532	0.188	0.050	0.039	0.621	#21	0.084	Not Required	Pass
5	0.011	0.231	0.205	0.050	0.065	0.246	#13	0.054	Not Required	Pass
6	0.011	0.535	0.075	0.051	0.013	0.576	#13	0.071	Not Required	Pass
7	0.011	0.231	0.205	0.050	0.065	0.246	#13	0.054	Not Required	Pass
8	0.000	0.106	0.066	0.020	0.013	0.162	#21	Not Required	Not Required	Pass
9	0.011	0.113	0.146	0.001	0.000	0.262	#13	0.153	Not Required	Pass
10	0.011	0.532	0.188	0.050	0.039	0.621	#21	0.084	Not Required	Pass
11	0.000	0.106	0.066	0.020	0.013	0.162	#21	Not Required	Not Required	Pass
12	0.004	0.449	0.341	0.083	0.044	0.751	#13	0.042	Not Required	Pass
13	0.014	0.480	0.299	0.043	0.027	0.730	#21	0.254	Not Required	Pass
14	0.013	0.480	0.299	0.043	0.027	0.730	#21	0.254	Not Required	Pass
15	0.000	0.106	0.066	0.020	0.013	0.162	#21	Not Required	Not Required	Pass
16	0.000	0.106	0.066	0.020	0.013	0.162	#21	Not Required	Not Required	Pass

Definitions

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

REFERENCES	CALCULATIONS	RESULTS

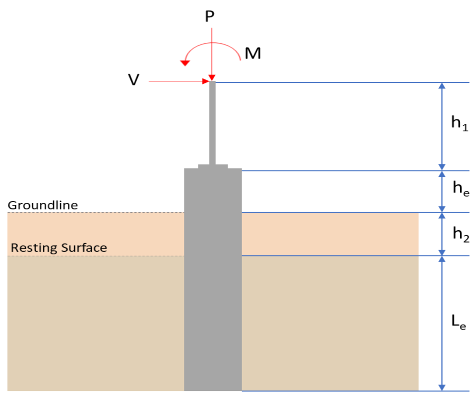
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 6\ \mathrm{ft}$ - 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)	3.438	5.299
V_x (kip)	-1.608	-2.680
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	19.644	33.395

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.608\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.25605\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(19.644 \text{ kipft}) + ((-1.608 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.128 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.4941 \text{ ft}$ - 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,

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

$$L_{e,req} = MAX[(5.4941 \text{ ft}), (0 \text{ ft})]$$

$$L_{e,req} = 5.494 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.494 \text{ ft})}{(6 \text{ ft})}$$

$$Ratio = 0.91567$$

Status: PASS
Ratio: 0.920

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(3.438 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.21488 \text{ kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.21488 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.10744$$

Status: PASS
Ratio: 0.110

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6 \text{ ft})}{(48 \text{ in})}$$

SkyCiv

$$L/D = 1.5$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.25605\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 3.128\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.128\ \mathrm{kipft/ft}) \times (6\ \mathrm{ft})) + \left(3 \times (-0.25605\ \mathrm{kip/ft}) \times (6\ \mathrm{ft})^2\right)}{(6 \times (3.128\ \mathrm{kipft/ft})) + (4 \times (-0.25605\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))}$$

$$a = 4.1233\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.128\ \mathrm{kipft/ft})) + (3 \times (-0.25605\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]^2}{(6\ \mathrm{ft})^2 \times [(3 \times (3.128\ \mathrm{kipft/ft})) + (2 \times (-0.25605\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}$$

$$p = 0.20617\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (3.128\ \mathrm{kipft/ft})) + ((-0.25605\ \mathrm{kip/ft}) \times (6\ \mathrm{ft}))]}{(6\ \mathrm{ft})^2}$$

$$s = 0.78662\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(4.1233\ \mathrm{ft})}{2}$$

$$p_a = 0.30925\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.20617\ \mathrm{kip/ft^2}\right)}{\left(0.30925\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.66669$$

Status: **PASS**
Ratio: **0.670**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (6\ \mathrm{ft})$$

$$p_s = 0.9\ \mathrm{kip/ft^2}$$

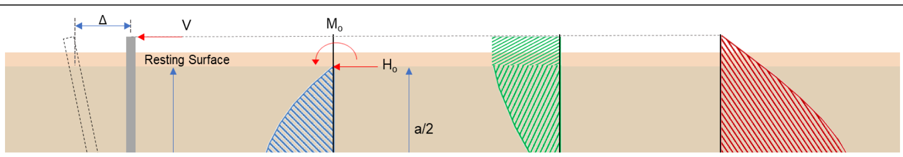
$Ratio$ - Lateral soil capacity

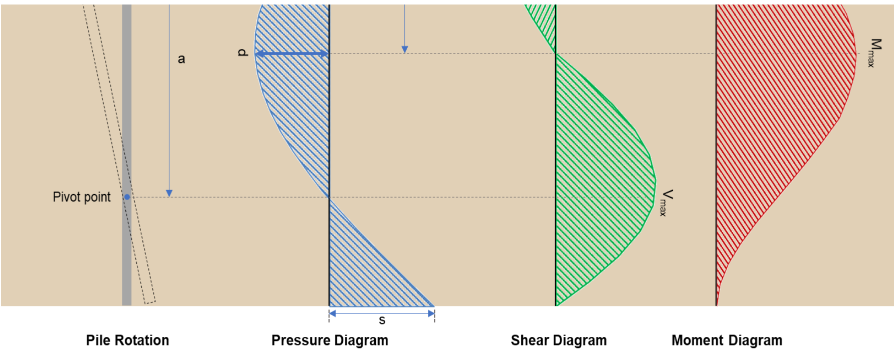
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(0.78662\ \mathrm{kip/ft^2}\right)}{\left(0.9\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.87403$$

Status: **PASS**
Ratio: **0.870**





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.68\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.42675\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(33.395\text{ kipft}) + ((-2.68\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 5.3177\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(5.3177\text{ kipft/ft})}{(-0.42675\text{ kip/ft})}$$

$$E = 12.461\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.3177\text{ kipft/ft}) \times (6\text{ ft})) + \left(3 \times (-0.42675\text{ kip/ft}) \times (6\text{ ft})^2\right)}{(6 \times (5.3177\text{ kipft/ft})) + (4 \times (-0.42675\text{ kip/ft}) \times (6\text{ ft}))}$$

$$a = 4.1215\text{ ft}$$

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

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

$$V_{max} = ((-0.42675\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.461\text{ ft})}{(6\text{ ft})} + 3\right) \times \left(\frac{(4.1215\text{ ft})}{(6\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (12.461\text{ ft})}{(6\text{ ft})} + 2\right) \times \left(\frac{(4.1215\text{ ft})}{(6\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 7.4005\text{ kip}$$

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

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

$$M_{max} = ((-0.42675\text{ kip/ft}) \times (48\text{ in}) \times (6\text{ ft})) \times \left[\left(\frac{(12.461\text{ ft})}{(6\text{ ft})} + \frac{(4.1215\text{ ft})}{2 \times (6\text{ ft})}\right) - \left[\left(\frac{4 \times (12.461\text{ ft})}{(6\text{ ft})} + 3\right) \times \left(\frac{(4.1215\text{ ft})}{2 \times (6\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (12.461\text{ ft})}{(6\text{ ft})} + 2\right) \times \left(\frac{(4.1215\text{ ft})}{2 \times (6\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 21.269 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(5.299 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.42 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.42 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

22.4.2.2	**Axial Compression Strength (ACI 318-19, LRFD)** ϕP_N - Allowable axial compressive strength $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, \left[A_g - A_{st}\right]\right) + \left(f_{yk}\, A_{st}\right)\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(2304\ \mathrm{in}^2\right) - \left(4.2951\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(4.2951\ \mathrm{in}^2\right)\right)\right]$$ $$\phi P_N = 2675.2\ \mathrm{kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(5.299\ \mathrm{kip})}{(2675.2\ \mathrm{kip})}$$ $$Ratio = 0.0019808$$	Status: **PASS** Ratio: **0.000**

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

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

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

22.5.5.1.3 λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 5.299\ \mathrm{kip} \rightarrow 5299\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(5299\ \mathrm{lbf})}{6 \times (2304\ \mathrm{in}^2)}\right] \times (48\ \mathrm{in}) \times (38.4\ \mathrm{in})$$

$$V_{c,a} = 119.19\ \mathrm{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \mathrm{kip}), (119.19\ \mathrm{kip}), (348.89\ \mathrm{kip})\right]$$

$$V_c = 119.19\ \mathrm{kip}$$

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

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

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

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

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

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)

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.19\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 110.56\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 7.4005\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(7.4005\ \mathrm{kip})}{(110.56\ \mathrm{kip})}$$

$$Ratio = 0.066939$$

Status: **PASS**
Ratio: **0.070**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001 in^3$$

$$\phi M_{n,1} = 249.600 kipft$$

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 21.269\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(21.269\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.085214$$

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