

Project Details



Project Name: Sean Johnson - V1Jb

Date: Mon Aug 12 2024

Location: Battle Lake, MN 56515, USA

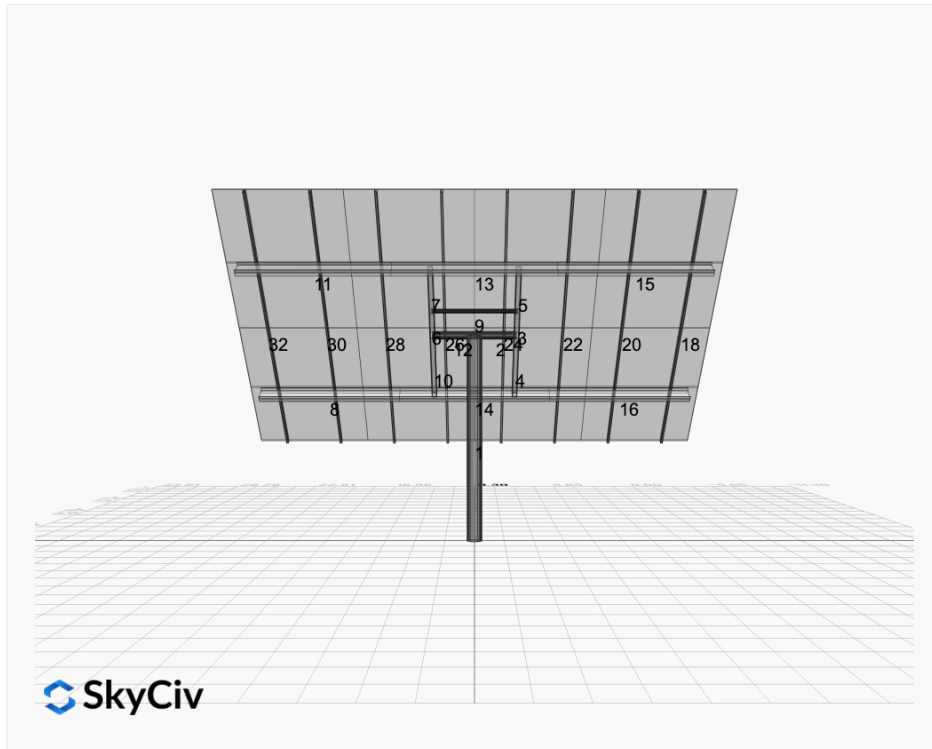
Number of Modules: 16

Unique ID: 1P-0-8TOP-HD-84-L-4Hx4W-6HG1

Number of Poles: 1

Dealer: _____

Date Sold: _____



Array Dimensions N/S	15.06 ft
Array Dimensions E/W	22.94 ft
Winter Tilt Angle	50
Front Edge Clearance	4 ft

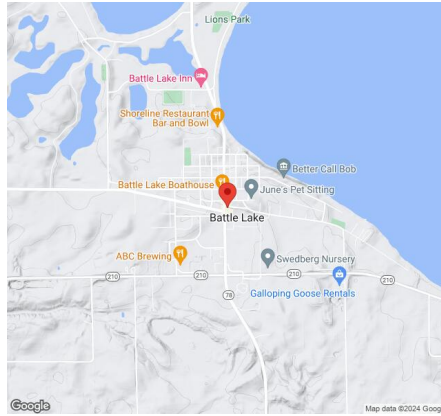
MT Solar Bill of Materials (1P-0-8TOP-HD-84-L-4Hx4W-6HG1)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	1
MTS-HF-HD	H-Frame Assembly-HD	1
MTS-HD-Wing-84	84IN HD Wing	4
MTS-CLAMP-HOOK-4PK	Hook Clamp	4

Rail Bill of Materials

Part	Qty
Rails (179in)	8
Rail Attachment	16
Module Mid Clamp	24
Module End Clamp	16
Ground Lug	4

Site Details:



Site Address: Battle Lake, MN 56515, USA

Array Specification

Duty Classification:	HD
Module Width:	44.69 in
Module Length:	67.83in
Number of Rows:	4
Number of Columns:	4
Total Number of Modules:	16
Winter Tilt Angle:	50
Front Edge Clearance:	4
Total Array Height at Tilt:	15.48 ft
Total Frame Length:	21.50 ft
Frame Weight:	1260 lbs
Array Dimensions N/S:	15.06 ft
Array Dimensions E/W:	22.94 ft
Rail Length:	180.76 in
Rail Spacing:	2.83 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	9.77 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: 7.00 ft
Foundation Volume:	4.148 y ³

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Battle Lake, MN 56515, USA
Wind Speed:	110 mph
Snow Load:	30 psf

Design Disclaimer

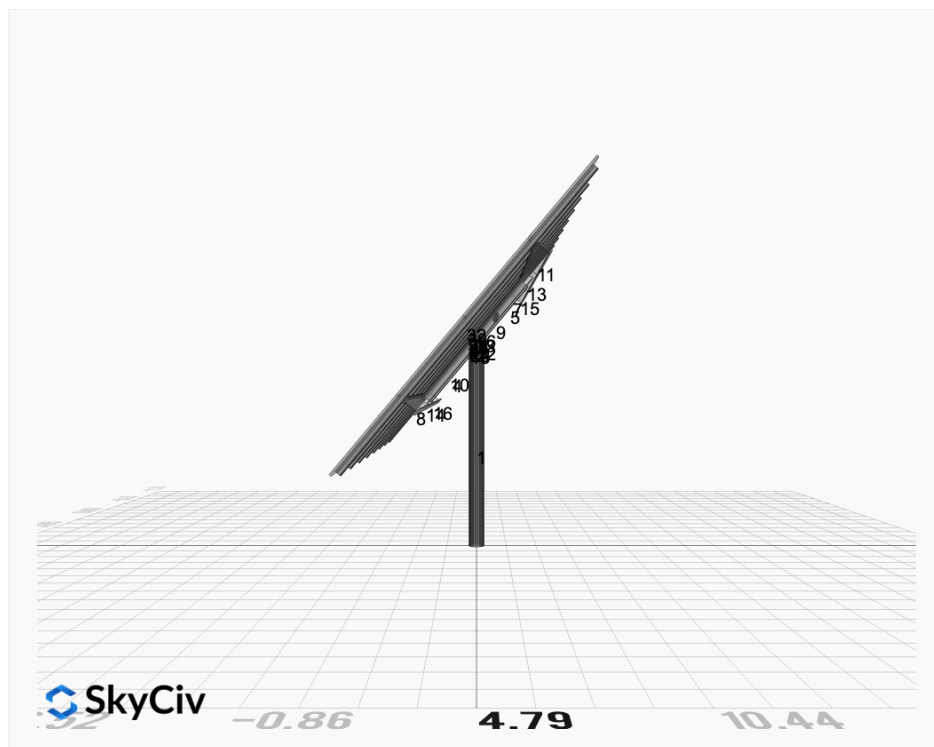
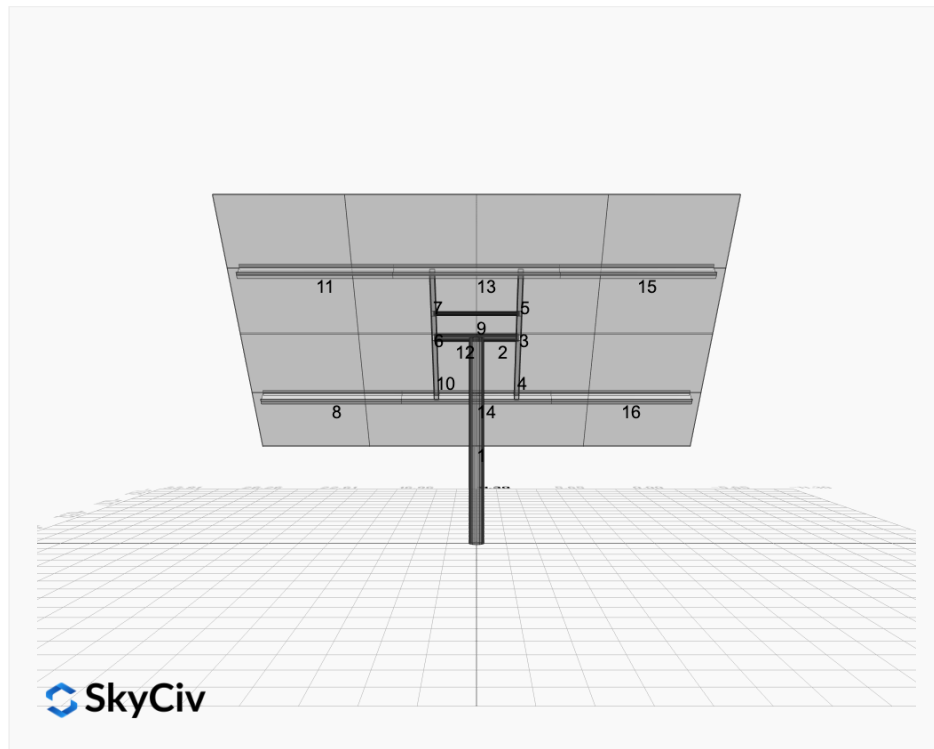
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

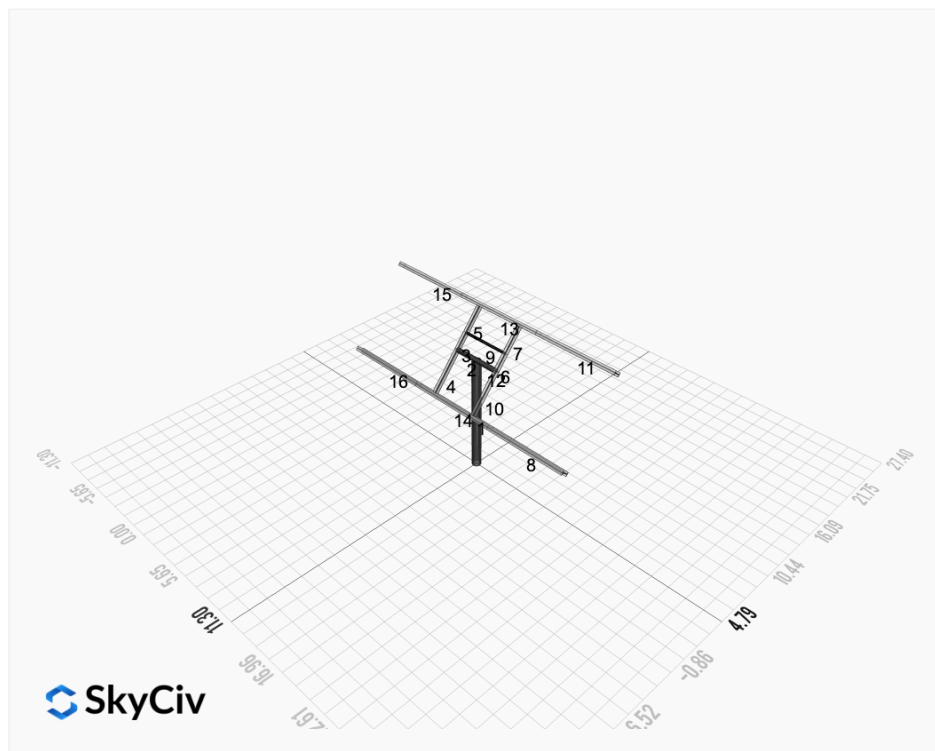
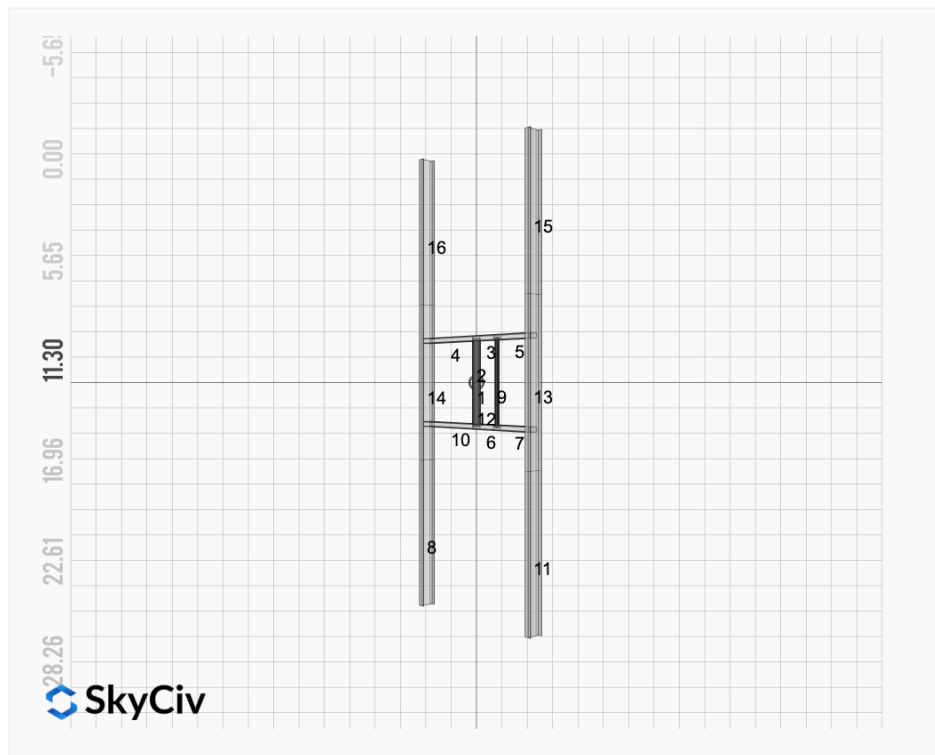
AutoDesigner Input

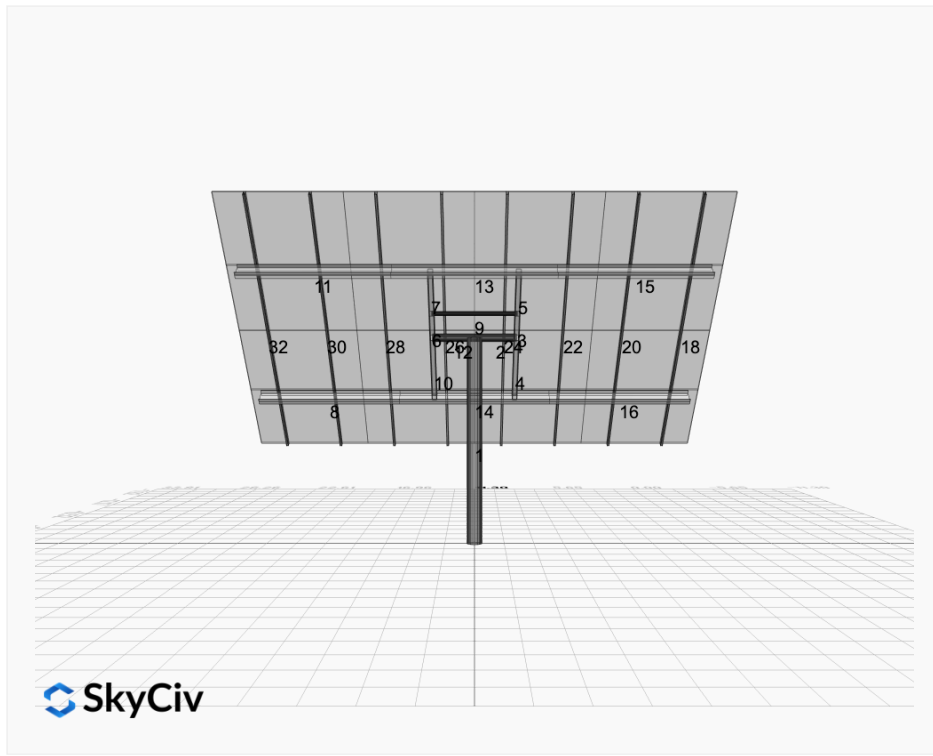
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Design Notes:

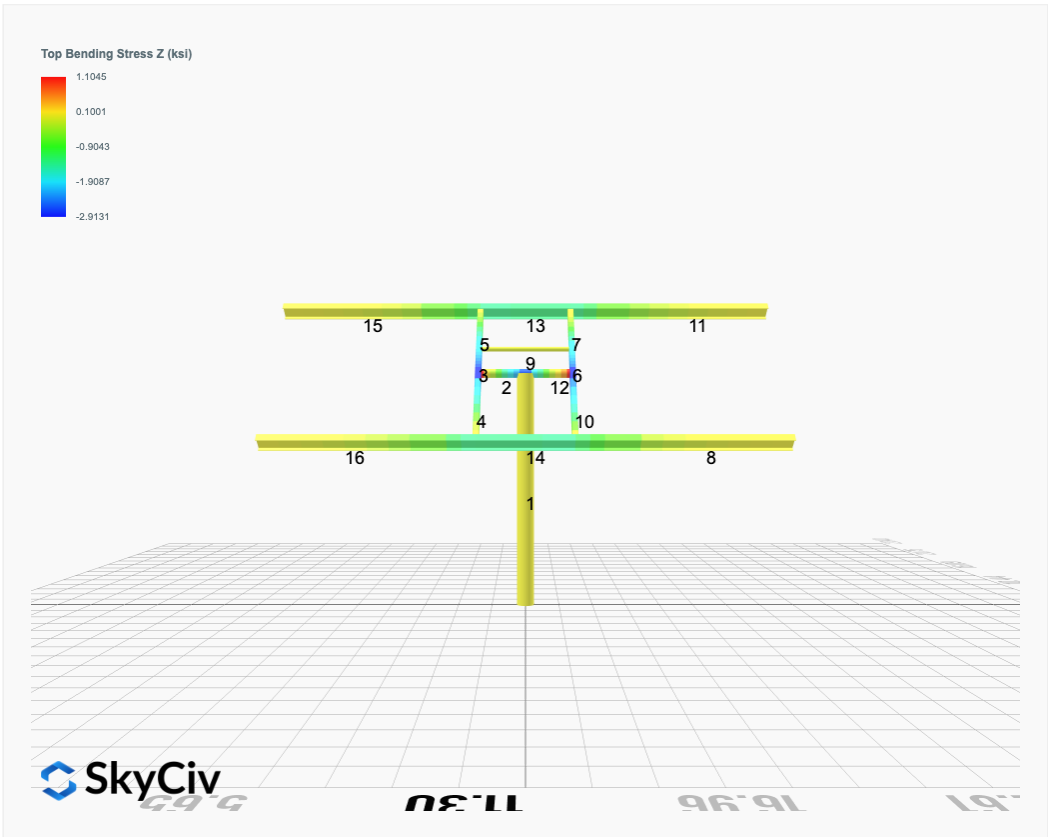
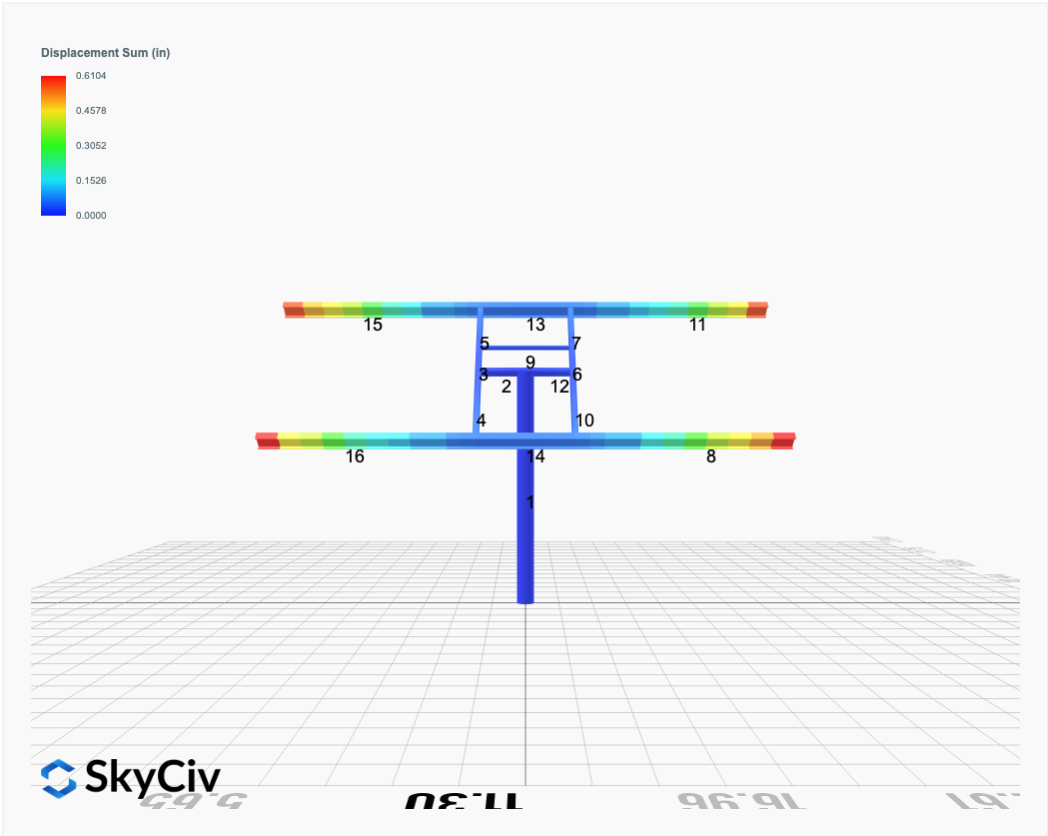
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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

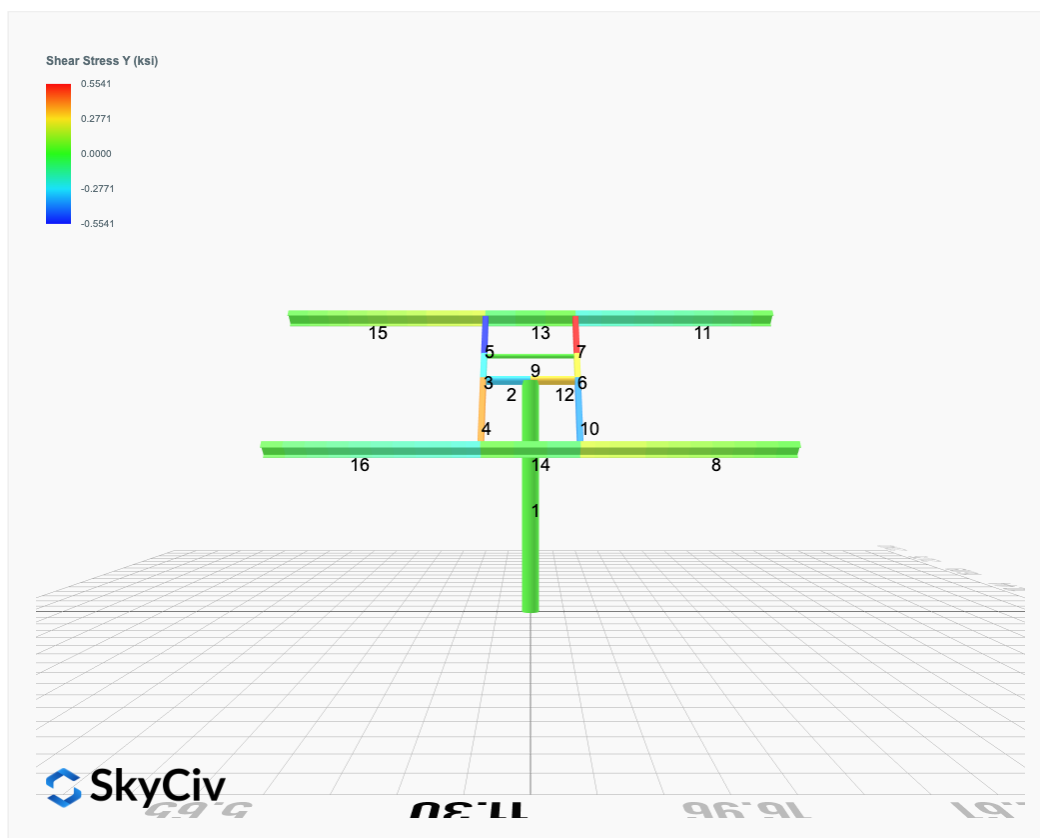
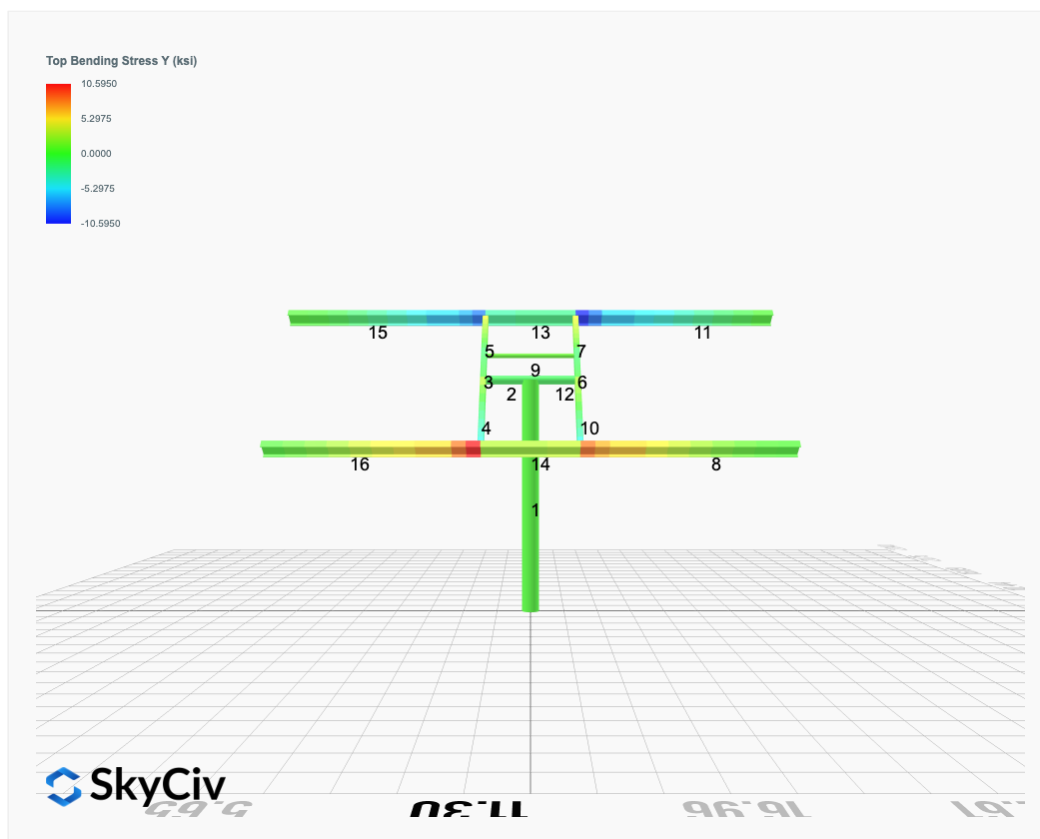


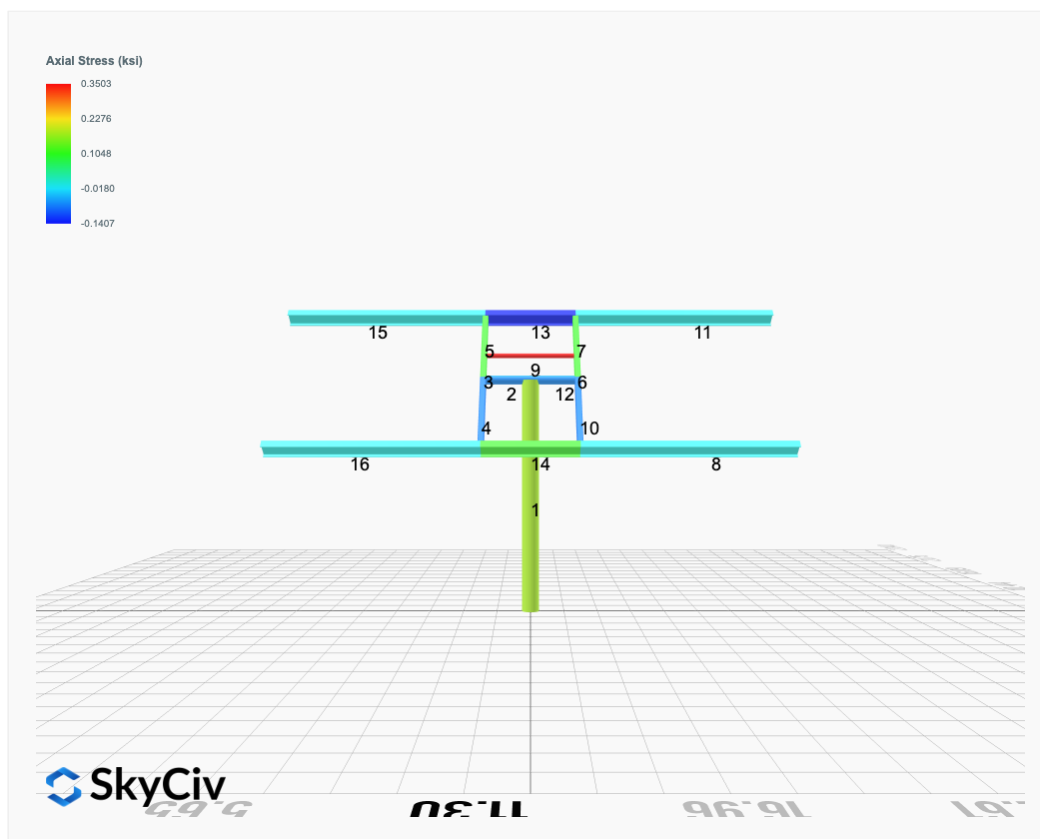




FEM Results (Envelope Worst Case for each member)







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	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 2. D + L	0.0000	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 3. D + (S or Lr or R)	0.0000	3.9200	0.0000	0.0000	-0.0000	0.0244
ULS: 3. D + (S or Lr or R)	0.0000	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	3.5766	0.0000	0.0000	-0.0000	0.0238
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 5b. D + 0.7E	0.0000	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	3.5766	0.0000	0.0000	-0.0000	0.0238
ULS: 8. 0.6D + 0.7E	0.0000	1.5279	0.0000	0.0000	-0.0000	0.0132
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.0722	5.9635	0.0000	0.0000	-0.0000	40.3068
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0000	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.0722	-0.8704	0.0000	0.0000	-0.0000	-39.2751
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0000	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.0541	6.1394	0.0000	0.0000	-0.0000	30.2374
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	3.5766	0.0000	0.0000	-0.0000	0.0238
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.0541	1.0139	0.0000	0.0000	-0.0000	-29.4490
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	3.5766	0.0000	0.0000	-0.0000	0.0238
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.0541	5.1093	0.0000	0.0000	-0.0000	30.2356
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.0541	-0.0162	0.0000	0.0000	-0.0000	-29.4508
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	2.5465	0.0000	0.0000	-0.0000	0.0220
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.0722	4.9449	0.0000	0.0000	-0.0000	40.2980
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0000	1.5279	0.0000	0.0000	-0.0000	0.0132
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.0722	-1.8891	0.0000	0.0000	-0.0000	-39.2839
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0000	1.5279	0.0000	0.0000	-0.0000	0.0132

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	9.4375
Shear X	-6.7870
Shear Z	0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	67.7993

Worst Case Reactions ASD

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

Result	Value (kip, kip-ft)
Axial	6.1394
Shear X	-4.0722
Shear Z	0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	40.3068

Project Details

Design Code: AISC 360-16 LRFD
Provision: LRFD
Country: United States

User Name: sales@mtsolar.us
Project Name: Sean Johnson - V1Jb
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	HSS5x3x16	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_{y0} (in ⁴)	I_{z0} (in ⁴)	I_w (in ⁶)	S_{y0} (in ³)	S_{z0} (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	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

[illegible]

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	226.17	83.29	83.29	113.39	113.39
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	15.17	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	15.17	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	23.30	6.12	40.24	43.62

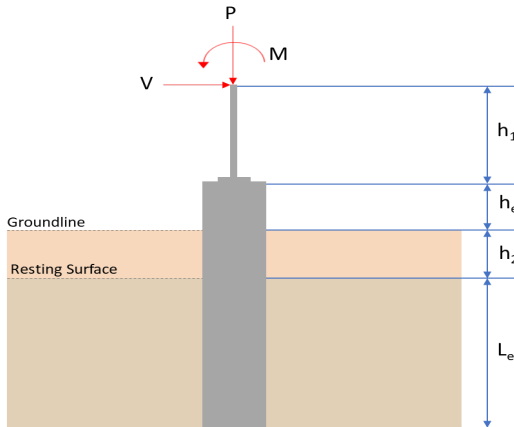
14	133.20	85.85	23.30	6.12	40.24	43.62
15	133.20	15.17	32.87	6.12	40.24	43.62
16	133.20	15.17	32.87	6.12	40.24	43.62

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	0.042	0.814	0.000	0.060	0.000	0.835	#13	0.419	Not Required	Pass
2	0.007	0.350	0.312	0.076	0.057	0.664	#13	0.035	Not Required	Pass
3	0.008	0.655	0.060	0.065	0.013	0.672	#13	0.045	Not Required	Pass
4	0.008	0.652	0.222	0.065	0.044	0.740	#13	0.080	Not Required	Pass
5	0.008	0.406	0.233	0.065	0.061	0.452	#13	0.074	Not Required	Pass
6	0.008	0.655	0.060	0.065	0.013	0.672	#13	0.045	Not Required	Pass
7	0.008	0.406	0.233	0.065	0.061	0.452	#13	0.074	Not Required	Pass
8	0.000	0.189	0.333	0.044	0.013	0.461	#21	Not Required	Not Required	Pass
9	0.029	0.050	0.071	0.001	0.000	0.131	#13	0.204	Not Required	Pass
10	0.008	0.652	0.222	0.065	0.044	0.740	#13	0.080	Not Required	Pass
11	0.000	0.189	0.333	0.044	0.013	0.461	#21	Not Required	Not Required	Pass
12	0.007	0.350	0.312	0.076	0.057	0.664	#13	0.035	Not Required	Pass
13	0.011	0.424	0.520	0.055	0.017	0.804	#21	0.190	Not Required	Pass
14	0.012	0.429	0.520	0.055	0.017	0.804	#21	0.190	Not Required	Pass
15	0.000	0.189	0.333	0.044	0.013	0.461	#21	Not Required	Not Required	Pass
16	0.000	0.189	0.333	0.044	0.013	0.461	#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/compression)
M _n	Nominal flexural strength (about Z/Y axis)
V _n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M _z	Design ratio in case of bending about Z axis
M _y	Design ratio in case of bending about Y axis
V _y	Design ratio in case of shear along Y axis
V _z	Design ratio in case of shear along Z axis
(P,M _z ,M _y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS																											
	<div>SkyCiv Foundation Design</div> <div>Pile Foundation</div> <div>Design Information :</div> <div>Design code : IBC 2021 (International Building Code)</div> <div>Unit System : Imperial</div>																												
	<div>Pile Input</div> <div></div> <div>Geometry</div> <div>Pile shape: rectangular</div> <div>b = 48 in - Pile width</div> <div>D = 48 in - Pile depth</div> <div>L = 7 ft - Total pile length</div> <div>h1 = 0 ft - Lateral load height from the top of the pile,</div> <div>h2 = 0 ft - Depth to resisting surface</div> <div>he = 0 ft - Length of pile above the ground</div> <div>Tabulation of Soil Parameters</div> <table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa) (psf)</th><th>Allowable Lateral Pressure (R) (psf/ft)</th></tr><tr><td>1</td><td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td><td>2000.000</td><td>150.000</td></tr></table> <div>Tabulation of Loads</div> <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>6.139</td><td>9.438</td></tr><tr><td>Vx (kip)</td><td>-4.072</td><td>-6.787</td></tr><tr><td>Vz (kip)</td><td>0.000</td><td>0.000</td></tr><tr><td>Mx (kipft)</td><td>0.000</td><td>0.000</td></tr><tr><td>Mz (kipft)</td><td>40.307</td><td>67.799</td></tr></table> <div>Material Properties</div> <div>f'ck = 2.5 ksi - Concrete strength,</div>	Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	6.139	9.438	Vx (kip)	-4.072	-6.787	Vz (kip)	0.000	0.000	Mx (kipft)	0.000	0.000	Mz (kipft)	40.307	67.799	<div>Required depth to resist lateral loads (ASD)</div> <div>H - Point of application of the lateral load</div> <div>$H = h_1 + h_2 + h_e$</div> <div>$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$</div> <div>$H = 0 \text{ ft}$</div> <div>Considering x-direction:</div> <div>Ho - Lateral force per length of pile,</div> <div>$H_o = \frac{V_x}{1.57 \text{ } D}$</div> <div>$H_o = \frac{(-4.072 \text{ kip})}{1.57 \times (48 \text{ in})}$</div> <div>$H_o = -0.64841 \text{ kip/ft}$</div>	
Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)																										
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000																										
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P (kip)	6.139	9.438																											
Vx (kip)	-4.072	-6.787																											
Vz (kip)	0.000	0.000																											
Mx (kipft)	0.000	0.000																											
Mz (kipft)	40.307	67.799																											

	<p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(40.307 \text{ kipft}) + ((-4.072 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 6.4183 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation: $L_{e,x} = 6.4144 \text{ ft}$ - Required depth in x-direction,</p> <p>Considering z-direction: $L_{e,z} = 0 \text{ ft}$ - Required depth in z-direction,</p> <p>Minimum embedded depth required: $L_{e,req}$ - Depth of pile required,</p> $L_{e,req} = MAX[L_{e,x}, L_{e,z}]$ $L_{e,req} = MAX[(6.4144 \text{ ft}), (0 \text{ ft})]$ $L_{e,req} = 6.414 \text{ ft}$ <p>L_e - Actual embedded length of pile,</p> $L_e = L - h_e - h_2$ $L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 7 \text{ ft}$ <p>Ratio - Embedded depth</p> $Ratio = \frac{L_{e,req}}{L_e}$ $Ratio = \frac{(6.414 \text{ ft})}{(7 \text{ ft})}$ $Ratio = 0.91629$	<p>Status: PASS Ratio: 0.920</p>
	<p>End-bearing Capacity (ASD)</p> <p>A - Pile cross-section area</p> $A = b D$ $A = (48 \text{ in}) \times (48 \text{ in})$ $A = 16 \text{ ft}^2$ <p>q - End-bearing pressure</p> $q = \frac{P_v}{A}$ $q = \frac{(6.139 \text{ kip})}{(16 \text{ ft}^2)}$ $q = 0.38369 \text{ kip/ft}^2$ <p>Check bearing capacity ratio: Ratio - Capacity</p> $Ratio = \frac{q}{q_a}$ $Ratio = \frac{(0.38369 \text{ kip/ft}^2)}{(2000 \text{ psf})}$ $Ratio = 0.19184$	<p>Status: PASS Ratio: 0.190</p>
Czerniak	<p>Lateral Soil Pressure (ASD):</p> <p>L/D - Length to least lateral dimension ratio,</p>	

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

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

$$L/D = 1.75$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.64841 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 6.4183 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.4183 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.64841 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (6.4183 \text{ kipft/ft})) + (4 \times (-0.64841 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8536 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.4183 \text{ kipft/ft})) + (3 \times (-0.64841 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (6.4183 \text{ kipft/ft})) + (2 \times (-0.64841 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.21862 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (6.4183 \text{ kipft/ft})) + ((-0.64841 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 1.0161 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8536 \text{ ft})}{2}$$

$$p_a = 0.36402 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.21862 \text{ kip/ft}^2)}{(0.36402 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.60058$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

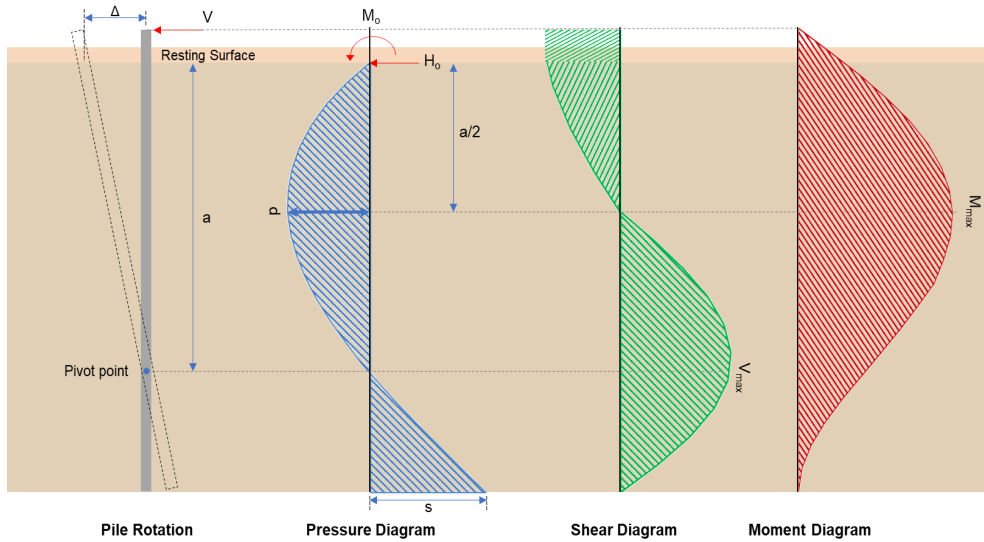
$$\text{Ratio} = \frac{s}{p_s}$$

$$\text{Ratio} = \frac{(1.0161 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

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

$$Ratio = 0.96767$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.787 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.0807 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(67.799 \text{ kipft}) + ((-6.787 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 10.796 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(10.796 \text{ kipft/ft})}{(-1.0807 \text{ kip/ft})}$$

$$E = 9.9895 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (10.796 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-1.0807 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (10.796 \text{ kipft/ft})) + (4 \times (-1.0807 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8524 \text{ ft}$$

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

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

$$V_{max} = ((-1.0807 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.9895 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8524 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (9.9895 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8524 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

	$V_{max} = 13.104 \text{ kip}$ <p>M_{max} - Max bending moment located at depth $a/2$,</p> $M_{max} = (H_o D L_e) \left[\left(\frac{E}{L_e} + \frac{a}{2 L_e} \right) - \left[\left(\frac{4 E}{L_e} + 3 \right) \left(\frac{a}{2 L_e} \right)^3 + \left[\left(\frac{3 E}{L_e} + 2 \right) \left(\frac{a}{2 L_e} \right)^4 \right] \right] \right]$ $M_{max} = ((-1.0807 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(9.9895 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8524 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (9.9895 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8524 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (9.9895 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8524 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right] \right]$ $M_{max} = 45.443 \text{ kipft}$	
<p>Table 22.4.2.1</p> <p>22.4.2.2, 10.6.1.1</p>	<p>Minimum Reinforcement Check (LRFD)</p> <p>Parameters:</p> <p>$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength, $f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength, $\phi = 0.65$ - Reduction factor for axial strength, $\alpha = 0.8$ - Alpha factor for axial strength, $A_g = 2304 \text{ in}^2$ - Gross area of concrete,</p> <p>Longitudinal reinforcement:</p> <p>Required reinforcement due to axial load, $A_{st,required}$</p> $A_{st,required} = \text{Min} \left[\frac{\frac{P}{\phi \alpha} - (0.85 f'_{ck} A_g)}{f_{yk} - (0.85 f'_{ck})}, (0.08 A_g) \right]$ $A_{st,required} = \text{Min} \left[\frac{\frac{(9.438 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$ $A_{st,required} = -84.283 \text{ in}^2$ <p>A_{min} - Governing minimum reinforcement area,</p> $A_{min} = \text{Max} [A_{st,required}, (0.0018 A_g)]$ $A_{min} = \text{Max} [(-84.283 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$ $A_{min} = 4.1472 \text{ in}^2$ <p>n_{rebar} - Required number of reinforcement,</p> $n_{rebar} = \frac{A_{min}}{A_{rebar}}$ $n_{rebar} = \frac{(4.1472 \text{ in}^2)}{(0.3068 \text{ in}^2)}$ $n_{rebar} = 14$ <p>A_{st} - Actual total reinforcement area,</p> $A_{st} = n_{rebar} \frac{\pi d_{bar}^2}{4}$ $A_{st} = (14) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$ $A_{st} = 4.2951 \text{ in}^2$ <p>Ratio - Capacity</p> $\text{Ratio} = \frac{A_{min}}{A_{st}}$ $\text{Ratio} = \frac{(4.1472 \text{ in}^2)}{(4.2951 \text{ in}^2)}$ $\text{Ratio} = 0.96556$ <p>25.2.3 s_{rebar} - Minimum spacing of reinforcement,</p> $s_{rebar} = \text{Max} [1.5, (1.5 d_{bar})]$	<p>Status: PASS Ratio: 0.970</p>

	<div>$s_{rebar} = Max [1.5, (1.5 \times (0.625 \text{ in}))]$$s_{rebar} = 1.5 \text{ in}$<p>Ties:</p><p>25.7.2.2 Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p><p>25.7.2.1 s_{ties} - Maximum spacing of ties,</p>$s_{ties} = Min [(16 d_{bar}), (48 d_{ties}), Min (D, b)]$$s_{ties} = Min [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min ((48 \text{ in}), (48 \text{ in}))]$$s_{ties} = 10 \text{ in}$<p>Summary:</p><p>Main reinforcement: 14 - #5 (0.625 in)</p><p>Ties: #3(0.375 in) - 10 in</p></div>	
22.4.2.2	<div><p>Axial Compression Strength (ACI 318-19, LRFD)</p><p>ϕP_N - Allowable axial compressive strength</p>$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$\phi P_N = 2675.2 \text{ kip}$<p><i>Ratio</i> - Capacity</p>$Ratio = \frac{P}{\phi P_N}$$Ratio = \frac{(9.438 \text{ kip})}{(2675.2 \text{ kip})}$$Ratio = 0.003528$</div>	Status: PASS Ratio: 0.000
22.5.2.2	<div><p>Shear Strength (ACI 318-19, LRFD)</p><p>Parameters:</p><p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p>$d = 0.80 D$$d = 0.80 \times (48 \text{ in})$$d = 38.4 \text{ in}$</div>	
22.5.5.1.3	<div><p>λ_s - size effect modification factor</p>$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$$\lambda_s = 0.64282$</div>	
22.5.5.1.1	<div><p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p><p>$V_{c,max}$ - Max shear strength of concrete</p>$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$V_{c,max} = 296.21 \text{ kip}$</div>	
22.5.5.1.1(a)	<div><p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 9.438 \text{ kip} \rightarrow 9438 \text{ lbf}$,</p><p>$V_{c,a}$ - Shear strength of concrete (a)</p>$V_{c,a} = \left[2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$</div>	

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(9438 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.74 \text{ kip}$$

22.5.5.1.2 The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,
 $V_{c,b}$ - Shear strength of concrete (b)

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.74 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.74 \text{ kip}$$

22.5.1.2 The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,
 $V_{s,a}$ - Shear strength of steel (a)

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.74 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.91 \text{ kip}$$

Considering x-direction:

$V_{max} = 13.767 \text{ kip}$ - Maximum shear force in the x-direction,
 $Ratio$ - Capacity

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

$$Ratio = \frac{(13.767 \text{ kip})}{(110.91 \text{ kip})}$$

$$Ratio = 0.12412$$

Status: **PASS**
Ratio: **0.120**

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

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

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

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

$\lambda = 1$ - Concrete modification factor (Normal concrete),

Allowable flexural strength:

M_n shall be the lesser of:

$\phi M_{n,1}$

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

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

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

14.5.2.1b

$\phi M_{n,2}$

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

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 45.443 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(45.443 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.18206$$

Status: **PASS**
Ratio: **0.180**