

Your Project Calculations



Project Name: BucknerResidence 3x3 8in

S3D Model Link:

https://platform.skyciv.com/structural?preload_name=BucknerResidence%203x3%208in&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/8_2023

Public Model Link:

https://platform.skyciv.com/structural-viewer?project_id=dij5PebDA6AgRusfIPQWwbB7ykxd0iEXY00F8CnoZnY2HPcpXT8MGcrVRklr6KYc

Array Specification

Product:	Beam
Unique ID:	1P-0-8TOP-HD-57-L-3Hx3W-LFGB
Duty Classification:	HD
Module Width:	40.80 in
Module Length:	69.40in
Number of Rows:	3
Number of Columns:	3
Total Number of Modules:	9
Desired Tilt Angle:	33.5
Front Edge Clearance:	5
Total Array Height at Tilt:	10.66 ft
Total Frame Length:	17.00 ft
Frame Weight:	779 lbs
Array Dimensions N/S:	10.32 ft
Array Dimensions E/W:	17.60 ft
Rail Length:	123.90 in
Rail Spacing:	2.93 ft
Rail Check:	PASS (76% utilized)

Support Specifications

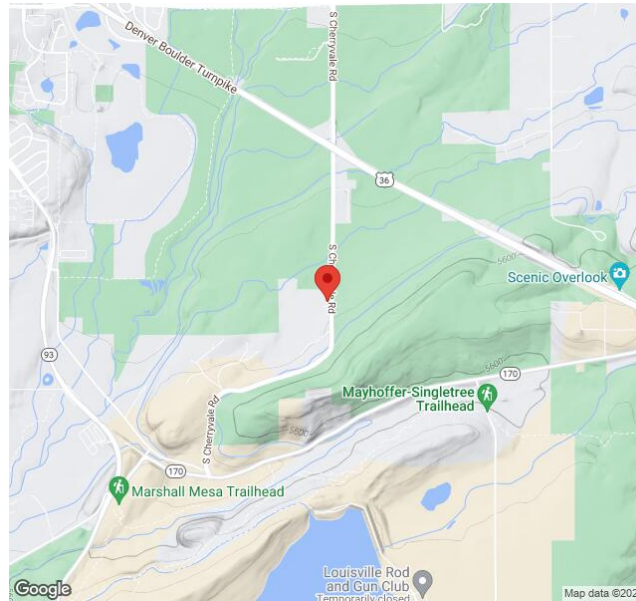
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	7.85 ft
Number of Poles:	1
Pole Spacing:	0

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 6.50 ft
Foundation Volume:	3.852 y ³
Foundation Result:	PASSED
Mount Twist:	0.000004 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	1077 S Cherryvale Rd, Boulder, CO 80303, USA
Wind Speed:	150 mph
Snow Load:	42 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.016857 ksf



Design Disclaimer

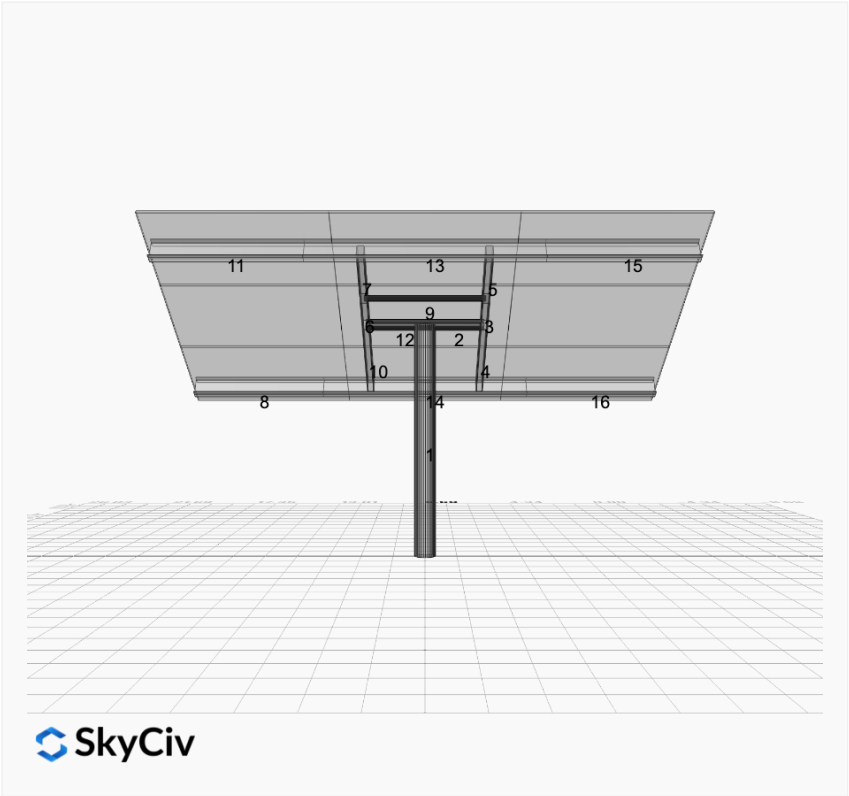
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

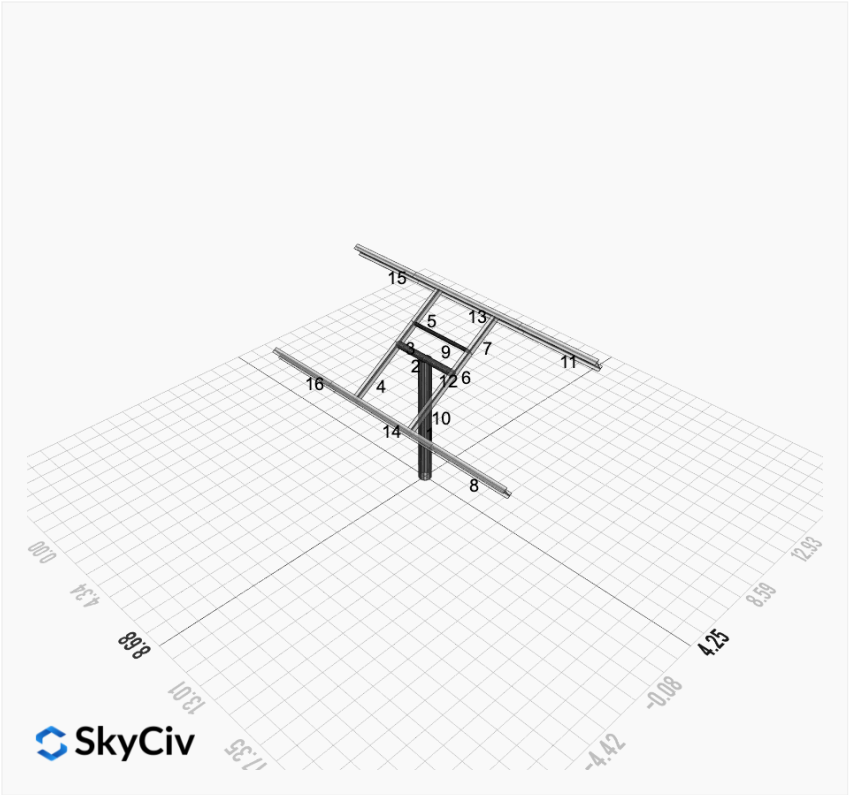
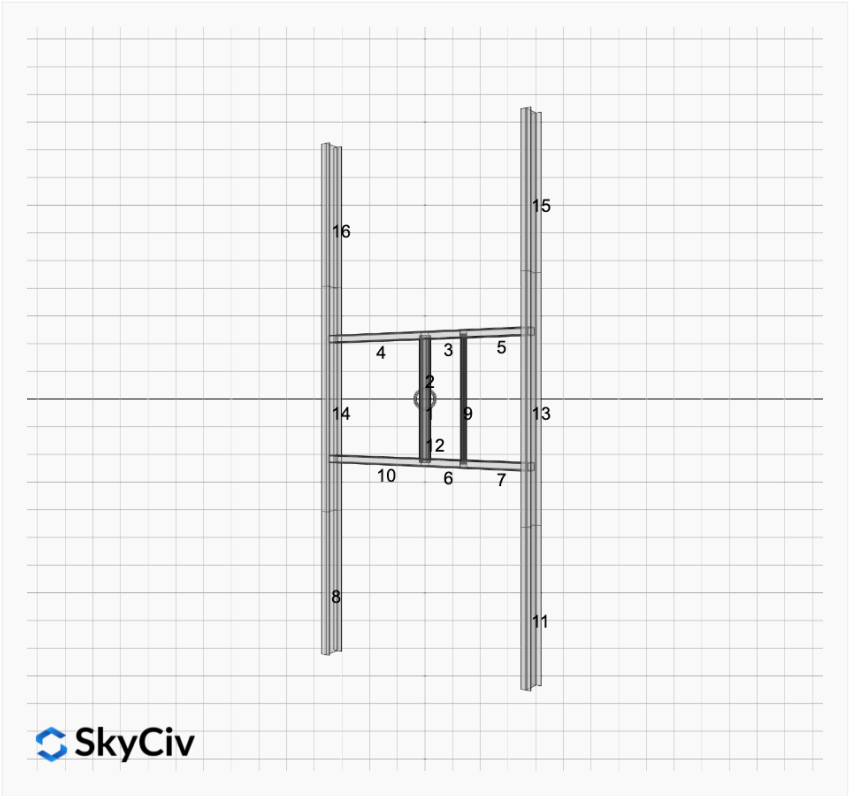
AutoDesigner Input

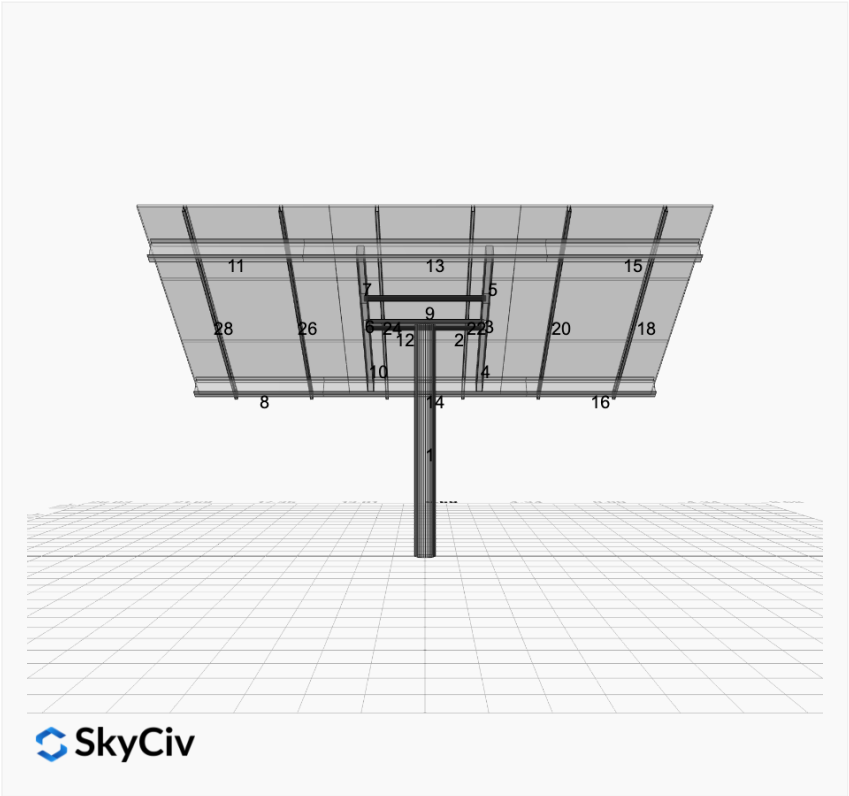
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Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles

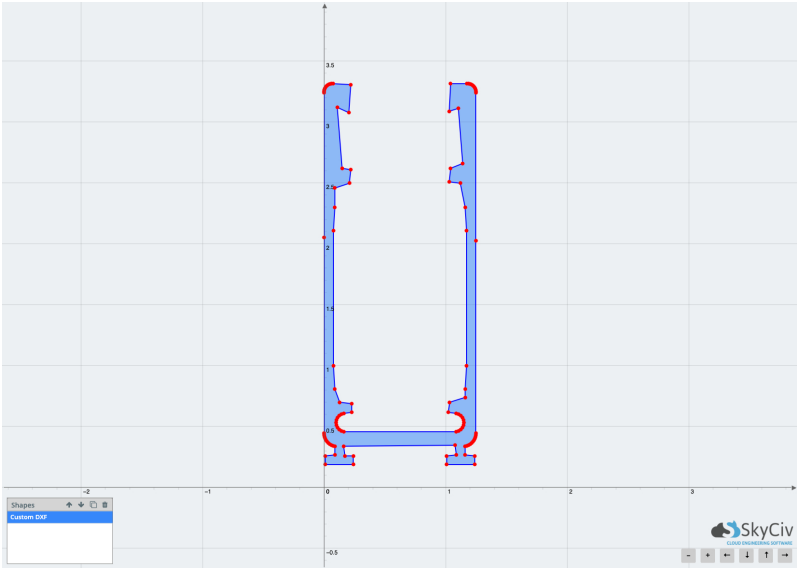




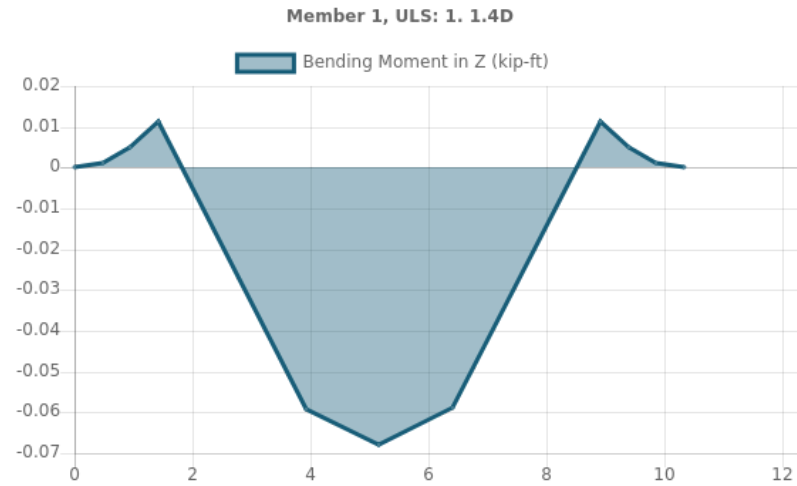


Rail Design Check

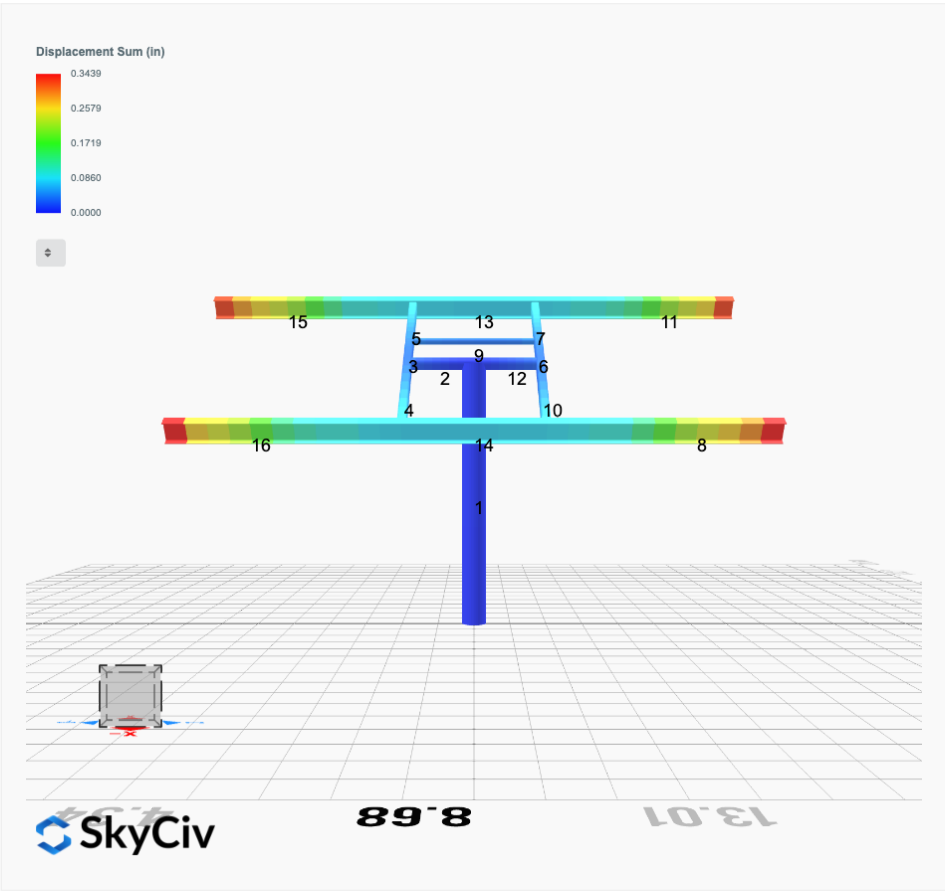
Rail Length: 10.325 ft
Additional Restraints Required: None
Tributary Width: 2.933333333333336 ft
Material: Aluminium
Density: 169 lb/ft³
Elasticity Modulus: 10000 ksi
Fy: 34.5 ksi
Fu: 37 ksi
Snow (X): 0.0412 kip/ft
Snow (Y): -0.0273 kip/ft
Wind uplift Case A: 0.1528 kip/ft
Wind uplift Case A: 0.1528 kip/ft
Wind uplift Case B (X): 0.0000 kip/ft
Wind uplift Case B (Y): 0.2083 kip/ft

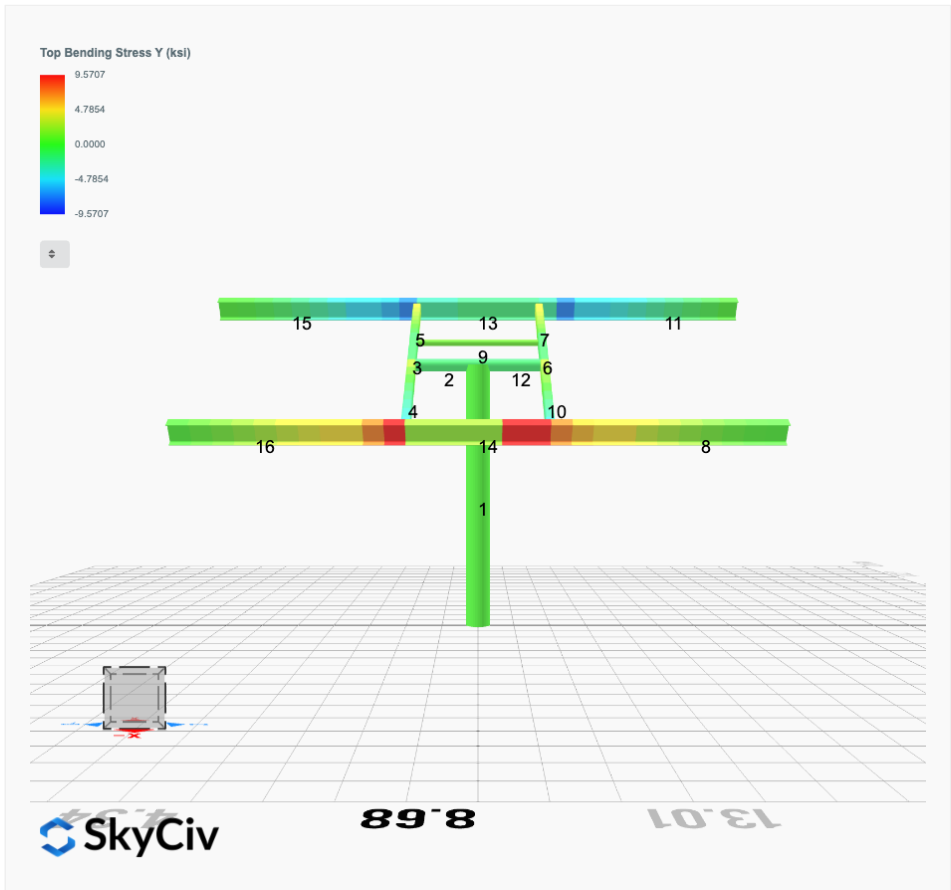
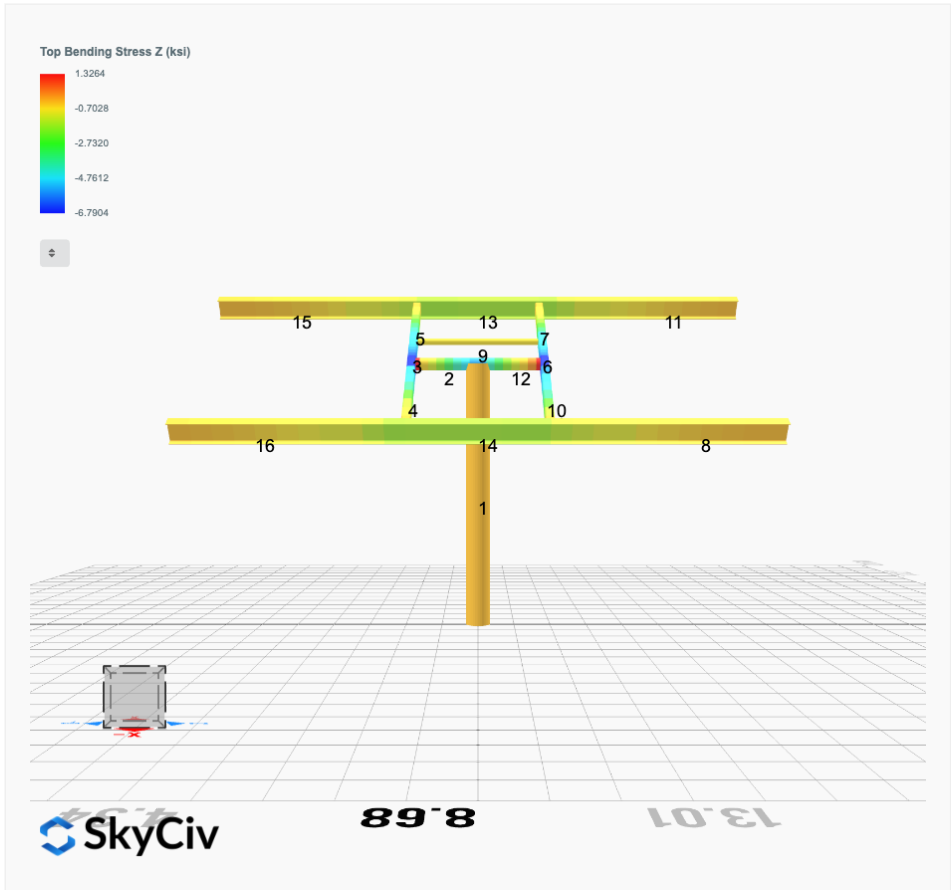


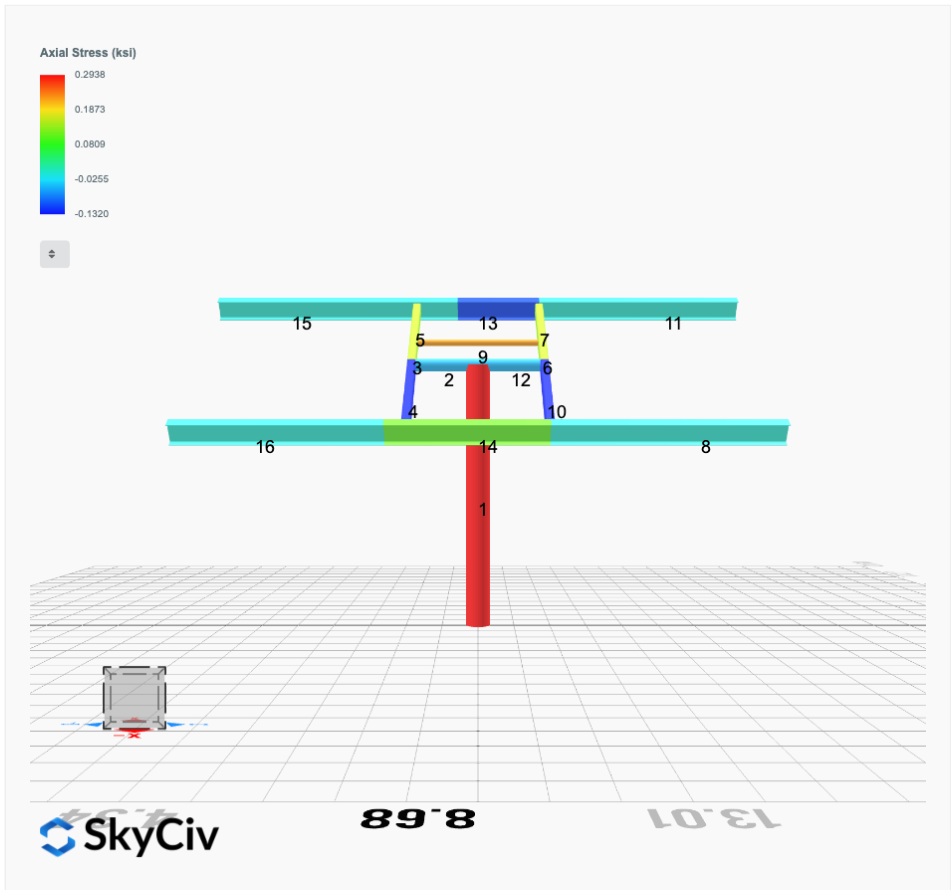
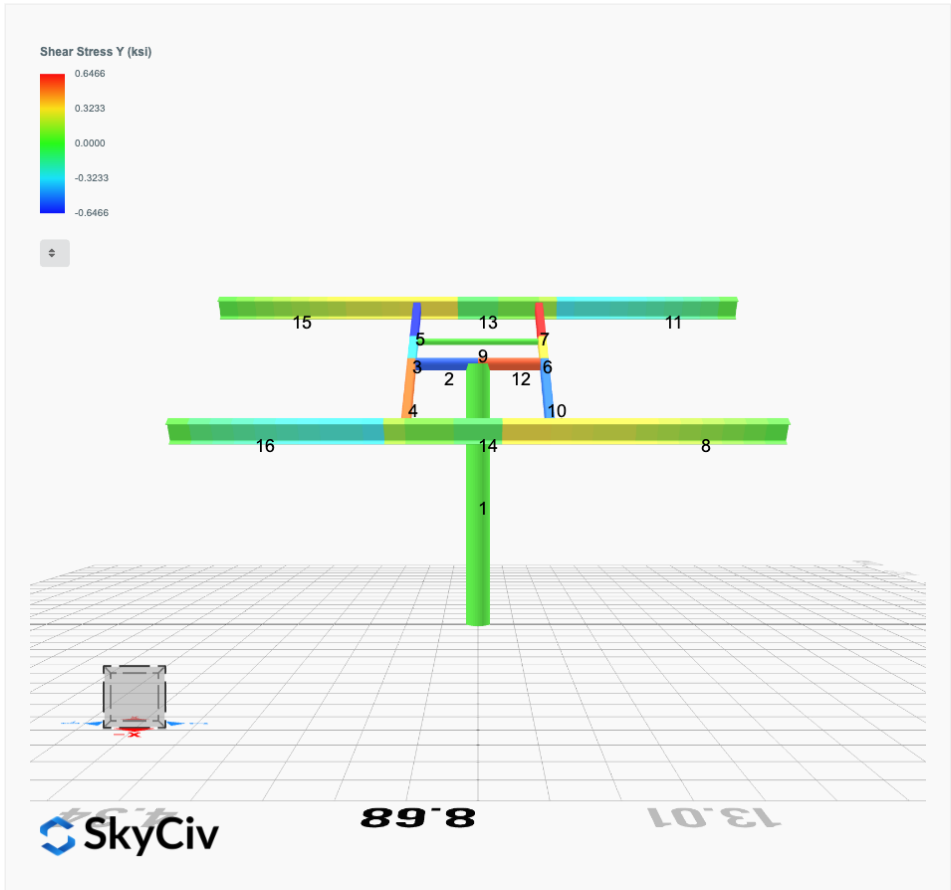
Result Check	Max Limit	Max Value	Utility	Status
Custom Stress Limit	34.5	26.15834486	0.758	PASS
Material Yield	34.5	26.15834486	0.758	PASS
Material Strength	37	26.15834486	0.707	PASS



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	1.6855	0.0000	0.0000	-0.0000	0.0250
ULS: 2. D + L	-0.0000	1.6855	0.0000	0.0000	-0.0000	0.0250
ULS: 3. D + (S or Lr or R)	-0.0000	4.1528	0.0000	0.0000	-0.0000	0.0322
ULS: 3. D + (S or Lr or R)	-0.0000	1.6855	0.0000	0.0000	-0.0000	0.0250
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	3.5360	0.0000	0.0000	-0.0000	0.0304
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	1.6855	0.0000	0.0000	-0.0000	0.0250
ULS: 5b. D + 0.7E	-0.0000	1.6855	0.0000	0.0000	-0.0000	0.0250
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	3.5360	0.0000	0.0000	-0.0000	0.0304
ULS: 8. 0.6D + 0.7E	-0.0000	1.0113	0.0000	0.0000	-0.0000	0.0150
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.6990	7.2741	-0.0000	0.0000	-0.0000	29.7282
ULS: 5a. D + 0.6W_Wind downforce Case B only	-3.6990	7.2741	-0.0000	0.0000	-0.0000	29.7282
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.1357	-3.0521	-0.0000	0.0000	-0.0000	-24.3189
ULS: 5a. D + 0.6W_Wind uplift Case B only	2.6131	-2.2625	0.0000	0.0000	-0.0000	-31.4275
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7743	7.7275	-0.0000	0.0000	-0.0000	22.3078
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.7743	7.7275	-0.0000	0.0000	-0.0000	22.3078
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3518	-0.0172	-0.0000	0.0000	-0.0000	-18.2275
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.9598	0.5750	0.0000	0.0000	-0.0000	-23.5590
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7743	5.8769	-0.0000	0.0000	-0.0000	22.3024
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-2.7743	5.8769	-0.0000	0.0000	-0.0000	22.3024
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.3518	-1.8677	-0.0000	0.0000	-0.0000	-18.2329
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.9598	-1.2755	0.0000	0.0000	-0.0000	-23.5644
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.6990	6.5999	-0.0000	0.0000	-0.0000	29.7182
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-3.6990	6.5999	-0.0000	0.0000	-0.0000	29.7182
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.1357	-3.7263	-0.0000	0.0000	-0.0000	-24.3288
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	2.6131	-2.9367	0.0000	0.0000	-0.0000	-31.4375

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	12.5706
Shear X	-6.1650
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	52.6962

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	7.7275
Shear X	-3.6990
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	31.4375

Project Details

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

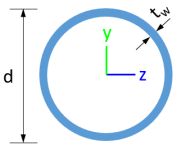
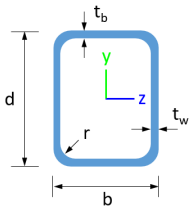
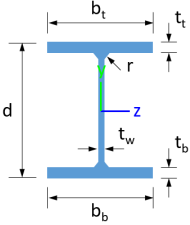
User Name: sales@mtsolar.us
 Project Name: BucknerResidence 3x3 8in
 Unit System: imperial



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

10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	32.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	104.94	23.60	6.12	40.24	43.62
14	133.20	104.94	23.14	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

Design Ratio

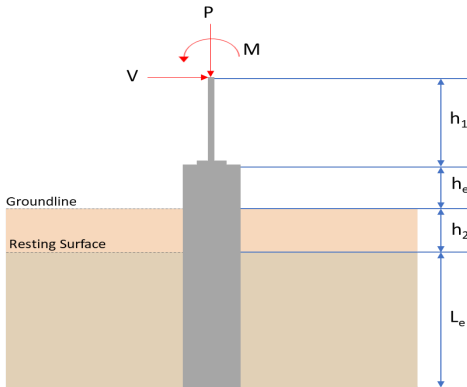
Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	δ	Status
1	0.046	0.633	0.000	0.054	0.000	0.638	#32	0.337	Not Required	Pass
2	0.003	0.492	0.273	0.103	0.052	0.765	#13	0.035	Not Required	Pass
3	0.007	0.813	0.034	0.082	0.001	0.833	#13	0.045	Not Required	Pass
4	0.007	0.796	0.128	0.080	0.026	0.838	#13	0.080	Not Required	Pass
5	0.007	0.504	0.133	0.081	0.034	0.522	#13	0.074	Not Required	Pass
6	0.007	0.813	0.034	0.082	0.001	0.833	#13	0.045	Not Required	Pass
7	0.007	0.504	0.133	0.081	0.034	0.522	#13	0.074	Not Required	Pass
8	0.000	0.135	0.163	0.046	0.010	0.265	#21	Not Required	Not Required	Pass
9	0.013	0.077	0.055	0.001	0.000	0.135	#13	0.204	Not Required	Pass
10	0.007	0.796	0.128	0.080	0.026	0.838	#13	0.080	Not Required	Pass
11	0.000	0.137	0.163	0.047	0.010	0.266	#21	Not Required	Not Required	Pass
12	0.003	0.492	0.273	0.103	0.052	0.765	#13	0.035	Not Required	Pass
13	0.006	0.375	0.305	0.064	0.013	0.573	#21	0.190	Not Required	Pass
14	0.006	0.374	0.305	0.063	0.013	0.570	#21	0.190	Not Required	Pass
15	0.000	0.137	0.163	0.047	0.010	0.266	#21	Not Required	Not Required	Pass
16	0.000	0.135	0.163	0.046	0.010	0.265	#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

OK
NG

Capacity is provided
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 in - Pile width D = 48 in - Pile depth L = 6.5 ft - Total pile length h1 = 0 ft - Lateral load height from the top of the pile, h2 = 0 ft - Depth to resisting surface he = 0 ft - Length of pile above the ground Tabulation of Soil Parameters <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> Tabulation of Loads <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>7.727</td><td>12.571</td></tr><tr><td>Vx (kip)</td><td>-3.699</td><td>-6.165</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>31.438</td><td>52.696</td></tr></table> Material Properties f'ck = 2.5 ksi - Concrete strength,	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)	7.727	12.571	Vx (kip)	-3.699	-6.165	Vz (kip)	0.000	0.000	Mx (kipft)	0.000	0.000	Mz (kipft)	31.438	52.696	
Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)																									
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Vz (kip)	0.000	0.000																										
Mx (kipft)	0.000	0.000																										
Mz (kipft)	31.438	52.696																										
	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: Ho - Lateral force per length of pile, $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-3.699 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.58901 \text{ kip/ft}$ Mo - Moment per length of pile, $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

	$M_o = \frac{(31.438 \text{ kipft}) + ((-3.699 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 5.0061 \text{ kipft/ft}$ 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: $L_{e,x} = 5.8029 \text{ ft}$ - 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, $L_{e,req} = \text{MAX}[L_{e,x}, L_{e,z}]$ $L_{e,req} = \text{MAX}[(5.8029 \text{ ft}), (0 \text{ ft})]$ $L_{e,req} = 5.803 \text{ ft}$ L_e - Actual embedded length of pile, $L_e = L - h_e - h_2$ $L_e = (6.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 6.5 \text{ ft}$ <i>Ratio</i> - Embedded depth $\text{Ratio} = \frac{L_{e,req}}{L_e}$ $\text{Ratio} = \frac{(5.803 \text{ ft})}{(6.5 \text{ ft})}$ $\text{Ratio} = 0.89277$	Status: PASS Ratio: 0.890
	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 $q = \frac{P_v}{A}$ $q = \frac{(7.727 \text{ kip})}{(16 \text{ ft}^2)}$ $q = 0.48294 \text{ kip/ft}^2$ Check bearing capacity ratio: <i>Ratio</i> - Capacity $\text{Ratio} = \frac{q}{q_o}$ $\text{Ratio} = \frac{(0.48294 \text{ kip/ft}^2)}{(2000 \text{ psf})}$ $\text{Ratio} = 0.24147$	Status: PASS Ratio: 0.240
Czerniak	Lateral Soil Pressure (ASD): L/D - Length to least lateral dimension ratio, $L/D = \frac{L}{D}$ $L/D = \frac{(6.5 \text{ ft})}{(48 \text{ in})}$	

$$L/D = 1.625$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.58901$ kip/ft - Lateral force per length of pile,

$M_o = 5.0061$ kipft/ft - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.0061 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.58901 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (5.0061 \text{ kipft/ft})) + (4 \times (-0.58901 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.5162 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (5.0061 \text{ kipft/ft})) + (3 \times (-0.58901 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^3 [(3 \times (5.0061 \text{ kipft/ft})) + (2 \times (-0.58901 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.17582 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (5.0061 \text{ kipft/ft})) + ((-0.58901 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 0.87813 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.5162 \text{ ft})}{2}$$

$$p_a = 0.33872 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.17582 \text{ kip/ft}^2)}{(0.33872 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.51906$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6.5 \text{ ft})$$

$$p_s = 0.975 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

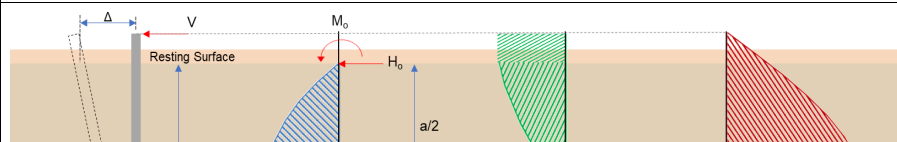
$$\text{Ratio} = \frac{s}{p_s}$$

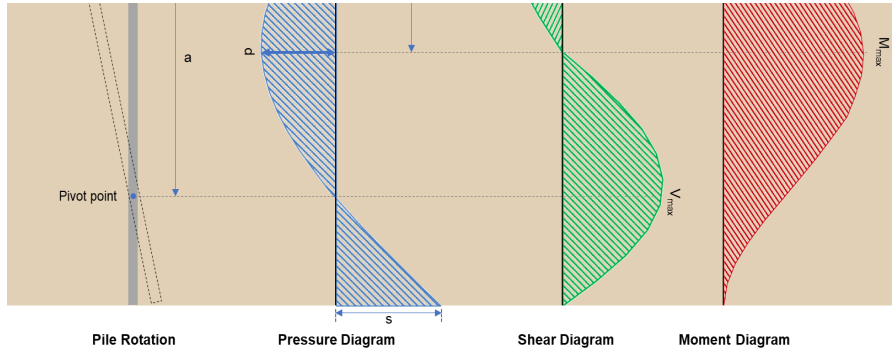
$$\text{Ratio} = \frac{(0.87813 \text{ kip/ft}^2)}{(0.975 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.90065$$

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

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





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.165 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.98169 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_e + (V_e H)}{1.57 D}$$

$$M_o = \frac{(52.696 \text{ kipft}) + ((-6.165 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.3911 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(8.3911 \text{ kipft/ft})}{(-0.98169 \text{ kip/ft})}$$

$$E = 8.5476 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.3911 \text{ kipft/ft}) \times (6.5 \text{ ft})) + (3 \times (-0.98169 \text{ kip/ft}) \times (6.5 \text{ ft})^2)}{(6 \times (8.3911 \text{ kipft/ft})) + (4 \times (-0.98169 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.5156 \text{ ft}$$

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

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

$$V_{max} = ((-0.98169 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (8.5476 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.5156 \text{ ft})}{(6.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (8.5476 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.5156 \text{ ft})}{(6.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 11.727 \text{ kip}$$

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

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

$$M_{max} = ((-0.98169 \text{ kip/ft}) \times (48 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(8.5476 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.5156 \text{ ft})}{2 \times (6.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (8.5476 \text{ ft})}{(6.5 \text{ ft})} + 3 \right) \times \left(\frac{(4.5156 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (8.5476 \text{ ft})}{(6.5 \text{ ft})} + 2 \right) \times \left(\frac{(4.5156 \text{ ft})}{2 \times (6.5 \text{ ft})} \right)^4 \right] \right]$$

		$M_{max} = 35.803 \text{ kipft}$	
		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, $\alpha = 0.8$ - 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 $A_{st,required} = \text{Min} \left[\frac{\frac{P}{\phi \alpha} - (0.85 f'_{ck} A_g)}{f_{yk} - (0.85 f'_{ck})}, (0.08 A_g) \right]$ $A_{st,required} = \text{Min} \left[\frac{\frac{(12.571 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$ $A_{st,required} = -84.178 \text{ in}^2$ A_{min} - Governing minimum reinforcement area, $A_{min} = \text{Max} [A_{st,required}, (0.0018 A_g)]$ $A_{min} = \text{Max} [(-84.178 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$ $A_{min} = 4.1472 \text{ in}^2$ n_{rebar} - Required number of reinforcement, $n_{rebar} = \frac{A_{min}}{A_{rebar}}$ $n_{rebar} = \frac{(4.1472 \text{ in}^2)}{(0.3068 \text{ in}^2)}$ $n_{rebar} = 14$ A_{st} - Actual total reinforcement area, $A_{st} = n_{rebar} \frac{\pi d_{bar}^2}{4}$ $A_{st} = (14) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$ $A_{st} = 4.2951 \text{ in}^2$ Ratio - Capacity $\text{Ratio} = \frac{A_{min}}{A_{st}}$ $\text{Ratio} = \frac{(4.1472 \text{ in}^2)}{(4.2951 \text{ in}^2)}$ $\text{Ratio} = 0.96556$ 25.2.3 s_{rebar} - Minimum spacing of reinforcement, $s_{rebar} = \text{Max} [1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max} [1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ Ties: 25.7.2.2 Since longitudinal reinforcement is $\leq \text{No. } 10\phi$: Use #3(0.375 in) 25.7.2.1 s_{ties} - Maximum spacing of ties, $s_{ties} = \text{Min} [(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min} [(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ Summary: Main reinforcement: 14 - #5 (0.625 in)	Status: PASS Ratio: 0.970

	Ties: #3(0.375 in) - 10 in	
22.4.2.2	Axial Compression Strength (ACI 318-19, LRFD) ϕP_N - Allowable axial compressive strength $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ Ratio - Capacity $\text{Ratio} = \frac{P}{\phi P_N}$ $\text{Ratio} = \frac{(12.571 \text{ kip})}{(2675.2 \text{ kip})}$ $\text{Ratio} = 0.0046991$	Status: PASS Ratio: 0.000
22.5.2.2	Shear Strength (ACI 318-19, LRFD) Parameters: $b_w = 48 \text{ in}$ - Effective width, d - Effective depth $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$	
22.5.5.1.3	λ_s - size effect modification factor $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$	
22.5.5.1.1	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $V_{c,max}$ - Max shear strength of concrete $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,max} = 296.21 \text{ kip}$	
22.5.5.1.1(a)	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 12.571 \text{ kip} \rightarrow 12571 \text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a) $V_{c,a} = \left[2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$ $V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(12571 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,a} = 120.16 \text{ kip}$	
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 $V_c = \text{Min} [V_{c,max}, V_{c,a}, V_{c,b}]$ $V_c = \text{Min} [(296.21 \text{ kip}), (120.16 \text{ kip}), (348.89 \text{ kip})]$ $V_c = 120.16 \text{ kip}$	

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 $V_s = MIN[V_{s,a}, V_{s,b}]$ $V_s = MIN[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ 22.5.1.1 ϕV_n - Allowable shear strength $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.16 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.19 \text{ kip}$ Considering x-direction: $V_{max} = 11.727 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(11.727 \text{ kip})}{(111.19 \text{ kip})}$ $Ratio = 0.10547$	Status: PASS Ratio: 0.110
14.5.2.1b	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: $\phi M_{n,1}$ $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kip ft}$ $\phi M_{n,2}$	

	$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ 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: $M_{max} = 35.803 \text{ kipft}$ - Maximum moment in the x-direction, <i>Ratio</i> - Capacity $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(35.803 \text{ kipft})}{(249.6 \text{ kipft})}$ $\text{Ratio} = 0.14344$	
		Status: PASS Ratio: 0.140