Your Project Calculations

Project Name: TOP15-74x41-105|5

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=TOP15-74x41-105|5&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/3_2024

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=6ZvyQqnbLZobolrnUlHngBlJZHkll77NqtBCYHoNgZIB1jsDAayH80g55HuK4ZoX

Array Specification

Product:	Beam
Unique ID:	1P-0-6TOP-SD-57-L-5Hx3W-F01D
Duty Classification:	SD
Module Width:	41.00 in
Module Length:	74.00in
Number of Rows:	5
Number of Columns:	3
Total Number of Modules:	15
Desired Tilt Angle:	15
Front Edge Clearance:	5
Total Array Height at Tilt:	9.45 ft
Total Frame Length:	17.00 ft
Frame Weight:	596 lbs
Array Dimensions N/S:	17.29 ft
Array Dimensions E/W:	18.75 ft
Rail Length:	207.50 in
Rail Spacing:	3.08 ft
Rail Check:	Not Checked

Support Specifications

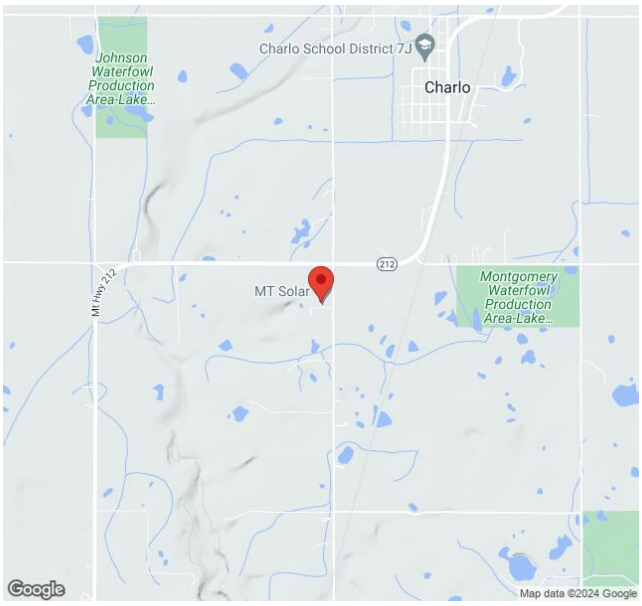
Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	7.24 ft
Number of Poles:	1
Pole Spacing:	0

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 5.50 ft
Foundation Volume:	3.259 y^3
Foundation Result:	PASSED
Mount Twist:	0.000000 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	54179 Herak Rd, Charlo, MT 59824, USA
Wind Speed:	105 mph
Snow Load:	5 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.003024 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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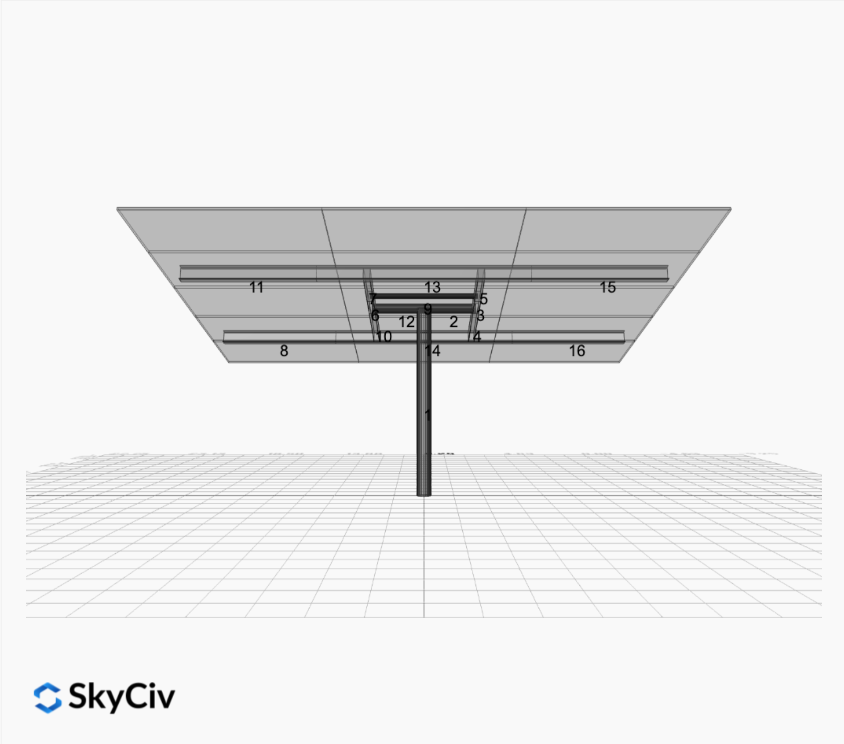
Design Notes:

- 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
- 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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4
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14
16
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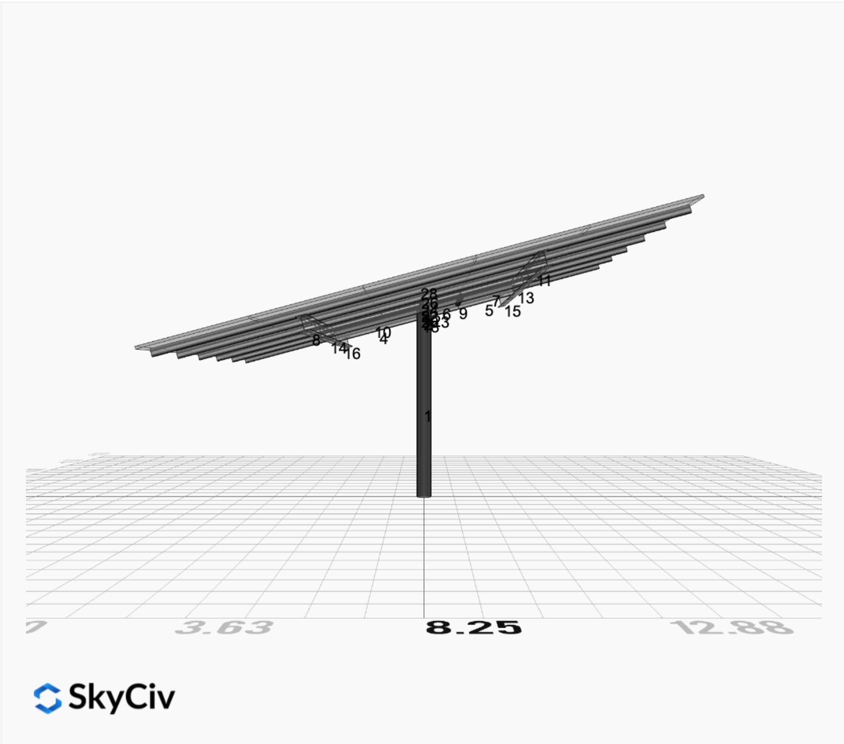
SkyCiv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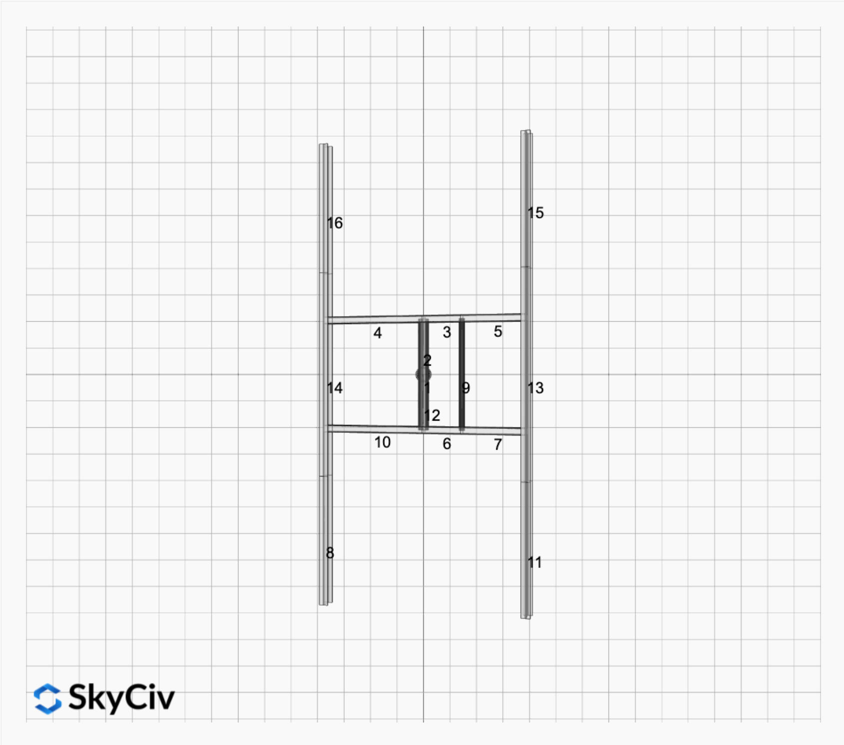
8.25
12.88
SkyCiv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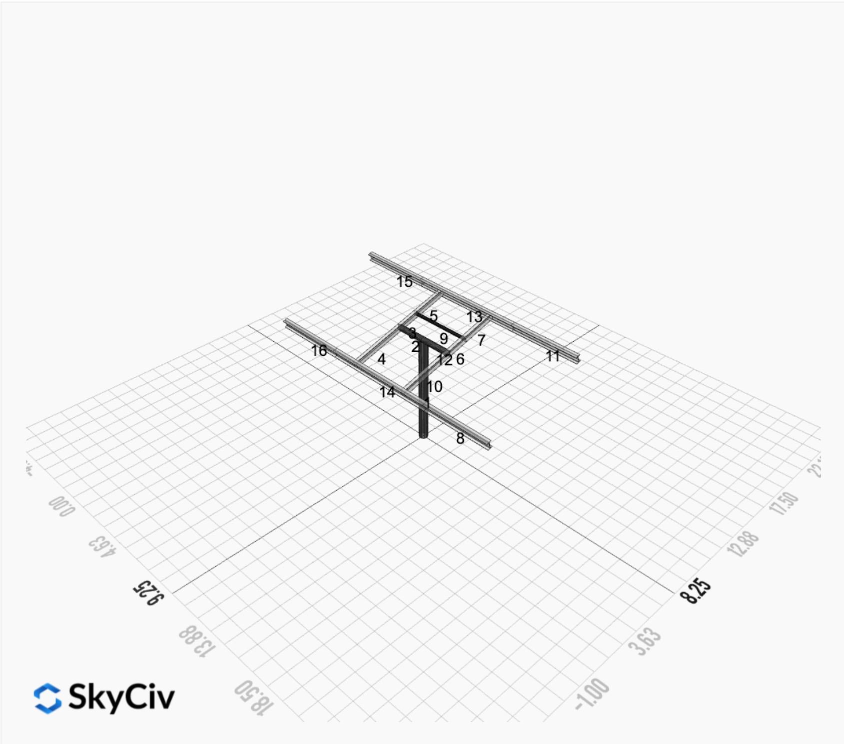
8
11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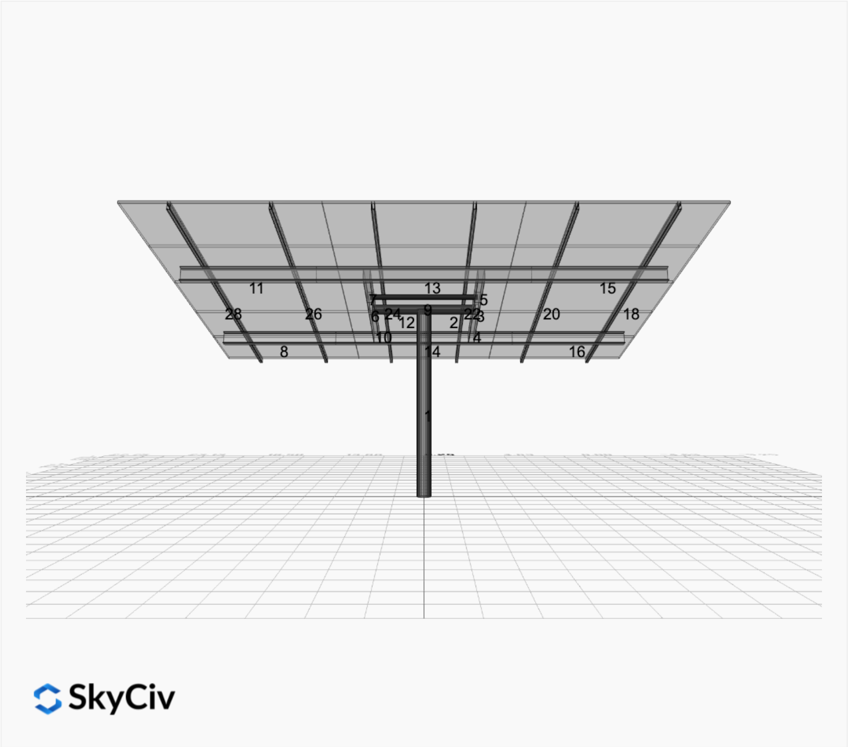
8.25
3.63
-1.00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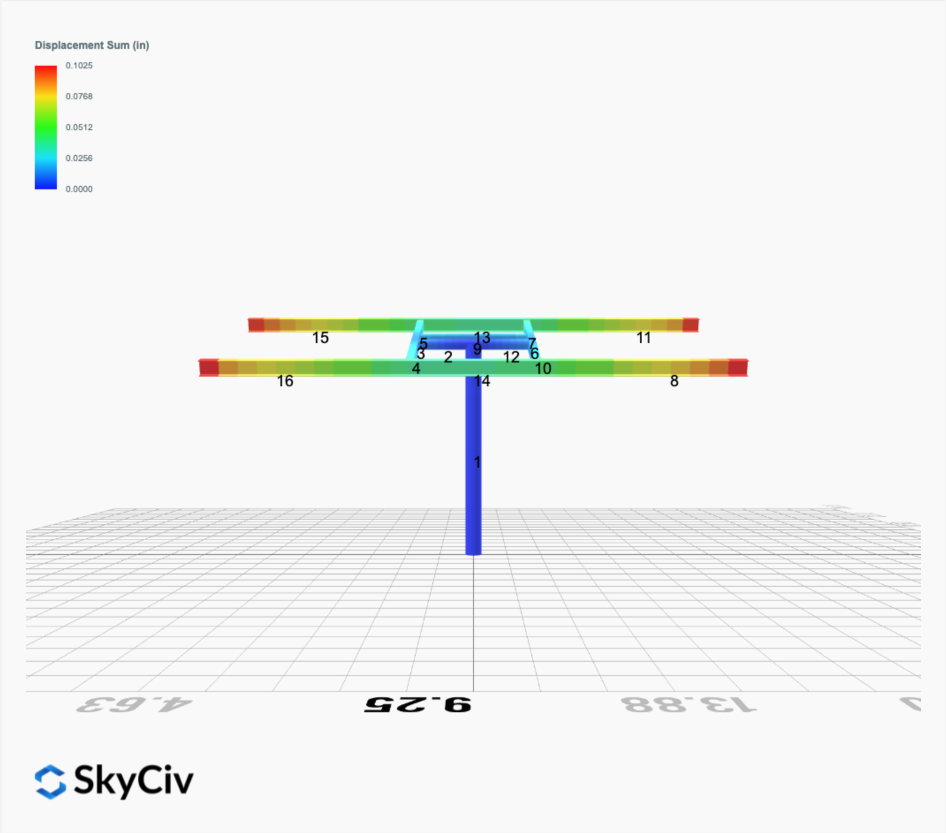
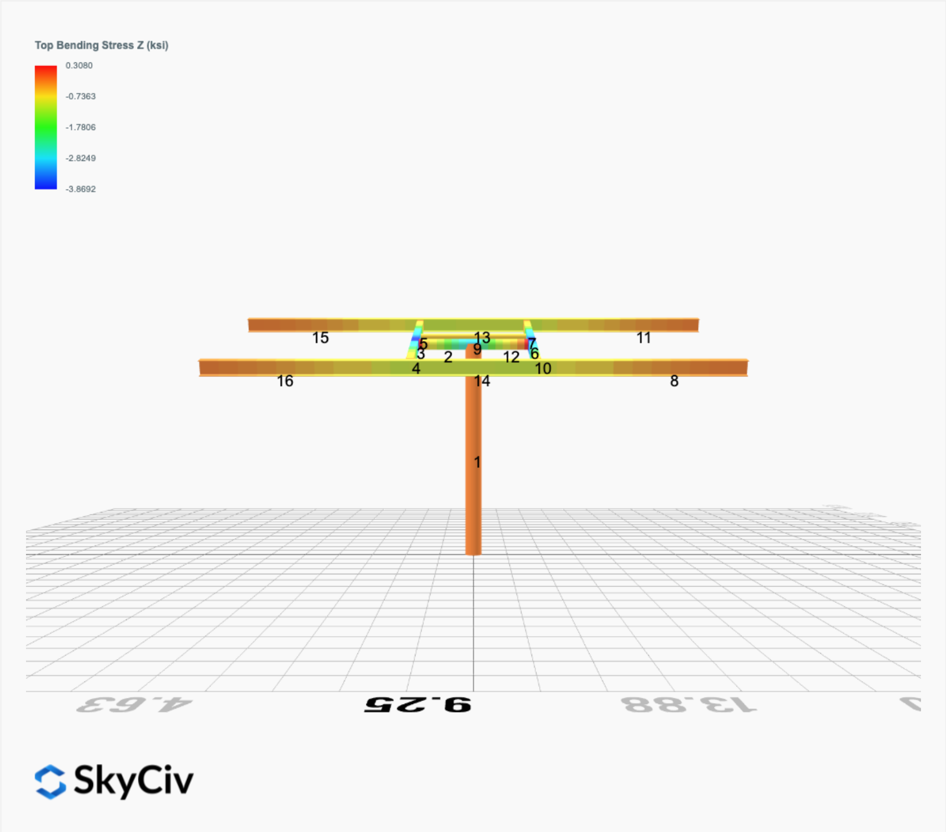
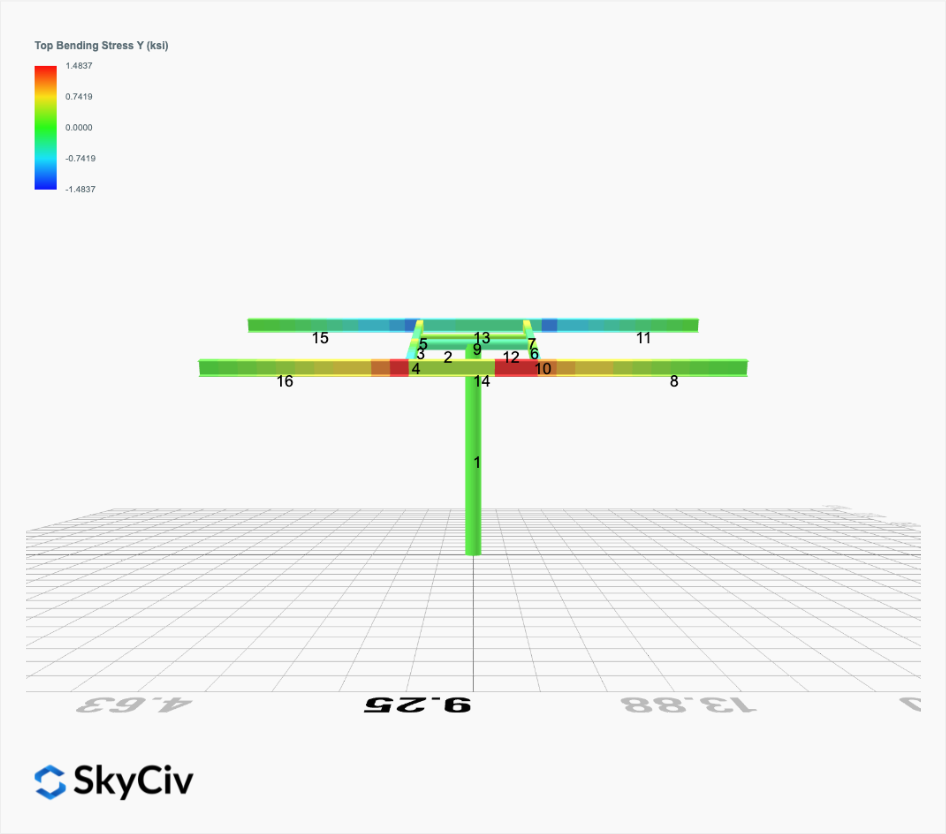
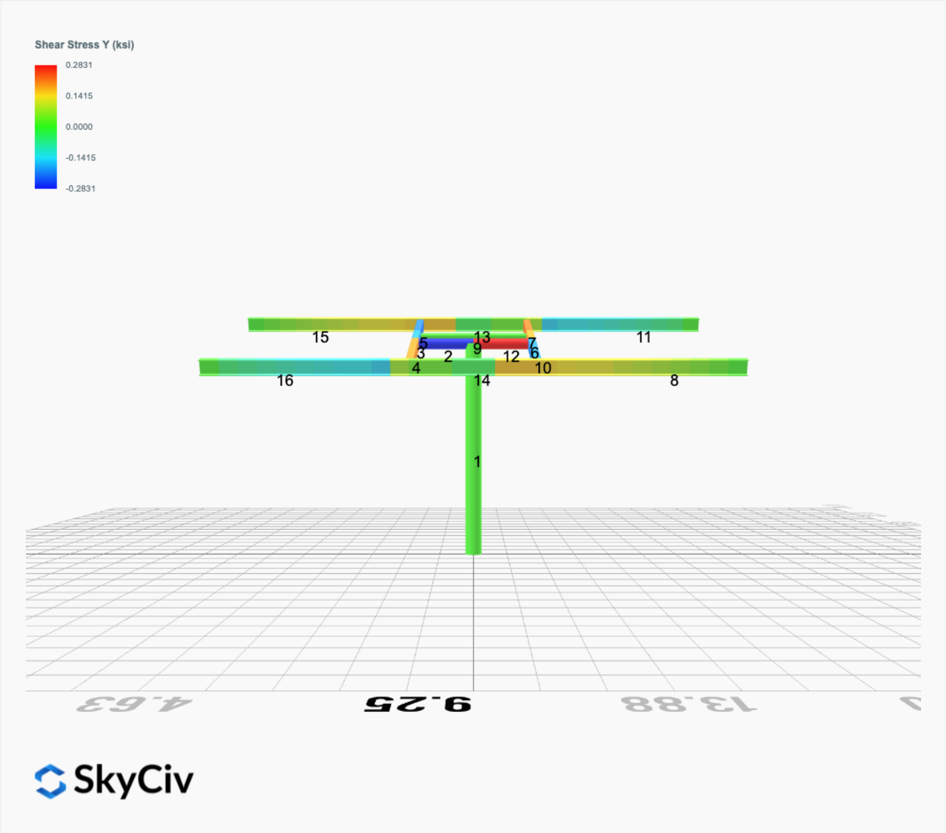
4
8
14
16
1
SkyCiv

FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
1.4837
0.7419
0.0000
-0.7419
-1.4837
15
13
11
5
7
3
9
6
2
12
4
10
16
14
8
1
SkyCiv


Shear Stress Y (ksi)
0.2831
0.1415
0.0000
-0.1415
-0.2831
15
13
11
5
7
3
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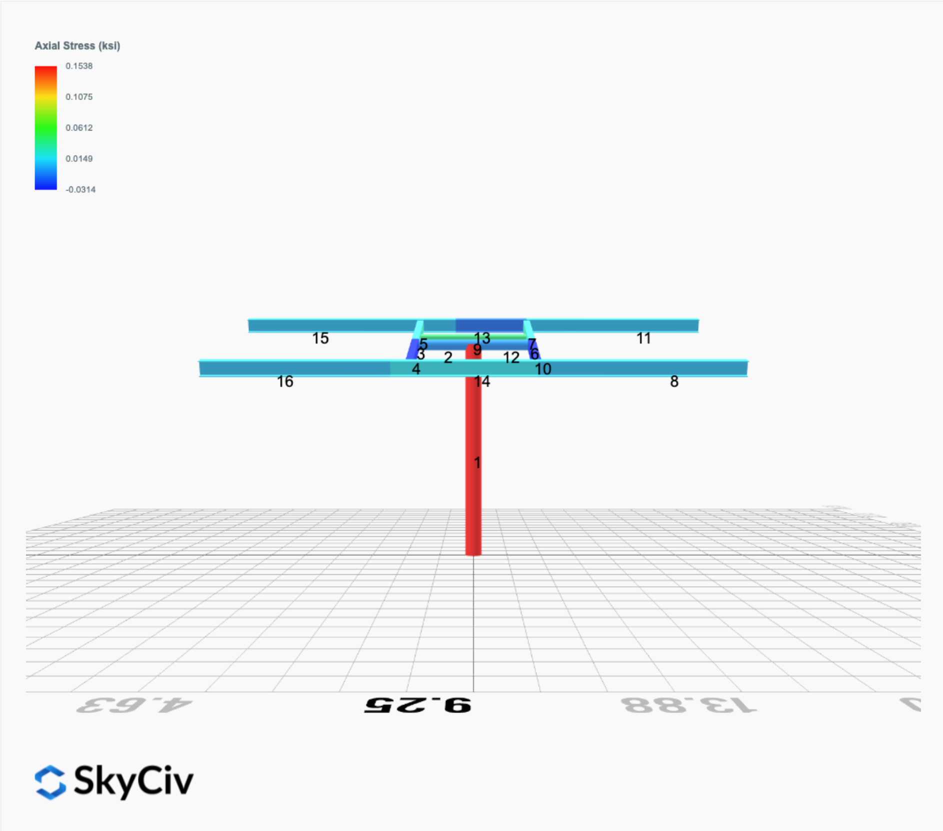
16
14
8
1
SkyCiv


Axial Stress (ksi)
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0.0612
0.0149
-0.0314
15
13
11
5
9
7
3
2
12
6
4
10
16
14
8
1
4.63
9.25
13.88
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	2.0726	-0.0000	0.0000	-0.0000	0.0222
ULS: 2. D + L	0.0000	2.0726	-0.0000	0.0000	-0.0000	0.0222
ULS: 3. D + (S or Lr or R)	0.0000	2.9312	-0.0000	0.0000	-0.0000	0.0228
ULS: 3. D + (S or Lr or R)	0.0000	2.0726	-0.0000	0.0000	-0.0000	0.0222
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.7165	-0.0000	0.0000	-0.0000	0.0227
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.0726	-0.0000	0.0000	-0.0000	0.0222
ULS: 5b. D + 0.7E	0.0000	2.0726	-0.0000	0.0000	-0.0000	0.0222
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	2.7165	-0.0000	0.0000	-0.0000	0.0227
ULS: 8. 0.6D + 0.7E	0.0000	1.2435	-0.0000	0.0000	-0.0000	0.0133
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.1369	6.3154	-0.0000	0.0000	-0.0000	10.1958
ULS: 5a. D + 0.6W_Wind downforce Case B only	-1.1369	6.3154	-0.0000	0.0000	-0.0000	10.1958
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.8625	-1.1461	0.0000	0.0000	-0.0000	-3.9020
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.7448	-0.7072	0.0000	0.0000	-0.0000	-15.8581
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.8527	5.8987	-0.0000	0.0000	-0.0000	7.6529
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.8527	5.8987	-0.0000	0.0000	-0.0000	7.6529
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.6468	0.3025	0.0000	0.0000	-0.0000	-2.9205
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.5586	0.6317	-0.0000	0.0000	-0.0000	-11.8875
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.8527	5.2547	-0.0000	0.0000	-0.0000	7.6524
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.8527	5.2547	-0.0000	0.0000	-0.0000	7.6524
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.6468	-0.3415	0.0000	0.0000	-0.0000	-2.9210
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.5586	-0.0123	-0.0000	0.0000	-0.0000	-11.8880
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.1369	5.4864	-0.0000	0.0000	-0.0000	10.1869
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-1.1369	5.4864	-0.0000	0.0000	-0.0000	10.1869
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.8625	-1.9752	0.0000	0.0000	-0.0000	-3.9109
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.7448	-1.5363	0.0000	0.0000	-0.0000	-15.8670

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	9.9878
Shear X	-1.8948
Shear Z	0.0000
Moment X	-0.0000
Moment Y (Twist)	0.0000
Moment Z	26.7646

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	6.3154
Shear X	-1.1369
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0000
Moment Z	15.8670

Project Details

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

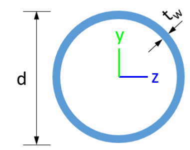
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

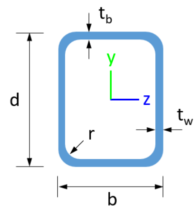
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

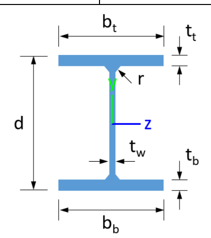
Section Dimensions



ID	Name	d (in)	t_w (in)					
1	2in Pipe Sch 40	2.38	0.15					
4	4in Pipe Sch 40	4.50	0.24					
7	6in Pipe Sch 40	6.63	0.28					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
15	HSS5x3x1/8	5.00	3.00	0.12	0.12	0.12		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
18	W6x9	5.90	0.17	3.94	3.94	0.21	0.21	0.25

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)
1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28

15	HSS5x3x1/8	1.77	6.02	2.75	6.03	0.51	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b (ft)	C_b	LST	LSC	LD
1	7	15.20	15.20	7.24	-	300	200	1
2	4	1.30	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.09,1.17,1.18,1.18,1.17,1.18	300	200	1
4	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.83,1.67,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.68	300	200	1
5	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.58,1.66,1.67,1.67,1.66,1.67	300	200	1
6	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.19,1.17,1.18,1.18,1.09,1.17,1.18,1.18,1.17,1.18	300	200	1
7	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.58,1.66,1.67,1.67,1.66,1.67	300	200	1
8	18	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
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.66,1.68,1.67,1.67,1.83,1.67,1.67,1.67,1.65,1.68,1.67,1.67,1.66,1.68	300	200	1
11	18	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
12	4	1.30	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.07,1.03,1.03,1.03,1.06,1.03,1.03,1.04,1.18,1.03,1.03,1.03,1.09,1.03,1.03,1.03,1.06	300	200	1
14	18	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.19,1.03,1.03,1.03,1.24,1.03,1.03,1.02,1.06,1.03,1.03,1.04,1.10,1.03,1.03,1.03,1.36	300	200	1
15	18	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	18	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

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	155.04	42.30	42.30	75.35	75.35
2	142.83	141.72	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	4.60	29.14	16.61
4	79.65	72.01	10.99	4.60	29.14	16.61
5	79.65	73.44	10.99	4.60	29.14	16.61
6	79.65	74.02	10.99	4.60	29.14	16.61
7	79.65	73.44	10.99	4.60	29.14	16.61
8	120.60	34.69	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	4.60	29.14	16.61

11	120.60	34.69	23.36	6.45	30.09	45.74
12	142.83	141.72	16.17	16.17	42.85	42.85
13	120.60	98.23	18.05	6.45	30.09	45.74
14	120.60	98.23	17.94	6.45	30.09	45.74
15	120.60	34.69	23.36	6.45	30.09	45.74
16	120.60	34.69	23.36	6.45	30.09	45.74

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	0.064	0.633	0.000	0.025	0.000	0.636	#16	0.406	Not Required	Pass
2	0.001	0.557	0.122	0.115	0.022	0.679	#13	0.034	Not Required	Pass
3	0.003	0.908	0.027	0.092	0.001	0.930	#13	0.044	Not Required	Pass
4	0.003	0.777	0.086	0.079	0.010	0.819	#13	0.078	Not Required	Pass
5	0.003	0.564	0.090	0.091	0.013	0.581	#13	0.073	Not Required	Pass
6	0.003	0.908	0.027	0.092	0.001	0.930	#13	0.044	Not Required	Pass
7	0.003	0.564	0.090	0.091	0.013	0.581	#13	0.073	Not Required	Pass
8	0.000	0.129	0.047	0.042	0.003	0.163	#13	Not Required	Not Required	Pass
9	0.005	0.103	0.030	0.001	0.000	0.134	#13	0.198	Not Required	Pass
10	0.003	0.777	0.086	0.079	0.010	0.819	#13	0.078	Not Required	Pass
11	0.000	0.150	0.047	0.049	0.003	0.184	#13	Not Required	Not Required	Pass
12	0.001	0.557	0.122	0.115	0.022	0.679	#13	0.034	Not Required	Pass
13	0.002	0.369	0.088	0.067	0.004	0.426	#13	0.177	Not Required	Pass
14	0.002	0.327	0.088	0.057	0.004	0.374	#13	0.177	Not Required	Pass
15	0.000	0.150	0.047	0.049	0.003	0.184	#13	Not Required	Not Required	Pass
16	0.000	0.129	0.047	0.042	0.003	0.163	#13	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

N/C	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

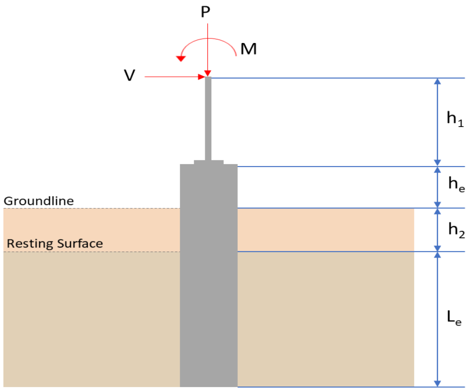
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 5.5\ \text{ft}$ - 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)	6.315	9.988
V_x (kip)	-1.137	-1.895
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	15.867	26.765

Material Properties

$f'_{ck} = 2.5\ \text{ksi}$ - 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,

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

$$H_o = \frac{(-1.137\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.18105\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

	$$M_o = \frac{(15.867\ \mathrm{kipft}) + ((-1.137\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$ $$M_o = 2.5266\ \mathrm{kipft/ft}$$ Required depth of embedment in earth: $$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R}\right) - \left(18.85 \times \frac{M_o}{R}\right) = 0$$ Solving the cubic equation: $L_{e,x} = 5.2542\ \mathrm{ft}$ - Required depth in x-direction, **Considering z-direction:** $L_{e,z} = 0\ \mathrm{ft}$ - Required depth in z-direction, **Minimum embedded depth required:** $L_{e,req}$ - Depth of pile required, $$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$ $$L_{e,req} = MAX[(5.2542\ \mathrm{ft}), (0\ \mathrm{ft})]$$ $$L_{e,req} = 5.254\ \mathrm{ft}$$ L_e - Actual embedded length of pile, $$L_e = L - h_e - h_2$$ $$L_e = (5.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$ $$L_e = 5.5\ \mathrm{ft}$$ $Ratio$ - Embedded depth $$Ratio = \frac{L_{e,req}}{L_e}$$ $$Ratio = \frac{(5.254\ \mathrm{ft})}{(5.5\ \mathrm{ft})}$$ $$Ratio = 0.95527$$	Status: **PASS** Ratio: **0.960**
	End-bearing Capacity (ASD) A - Pile cross-section area $$A = b\,D$$ $$A = (48\ \mathrm{in}) \times (48\ \mathrm{in})$$ $$A = 16\ \mathrm{ft}^2$$ q - End-bearing pressure $$q = \frac{P_v}{A}$$ $$q = \frac{(6.315\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$ $$q = 0.39469\ \mathrm{kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{(0.39469\ \mathrm{kip/ft}^2)}{(2000\ \mathrm{psf})}$$ $$Ratio = 0.19734$$	Status: **PASS** Ratio: **0.200**
Czerniak	**Lateral Soil Pressure (ASD):** L/D - Length to least lateral dimension ratio, $$L/D = \frac{L}{D}$$ $$L/D = \frac{(5.5\ \mathrm{ft})}{(48\ \mathrm{in})}$$	

$$L/D = 1.375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.18105\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 2.5266\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.5266\ \text{kipft/ft}) \times (5.5\ \text{ft})) + \left(3 \times (-0.18105\ \text{kip/ft}) \times (5.5\ \text{ft})^2\right)}{(6 \times (2.5266\ \text{kipft/ft})) + (4 \times (-0.18105\ \text{kip/ft}) \times (5.5\ \text{ft}))}$$

$$a = 3.762\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.5266\ \text{kipft/ft})) + (3 \times (-0.18105\ \text{kip/ft}) \times (5.5\ \text{ft}))]^{\ 2}}{(5.5\ \text{ft})^2 \times [(3 \times (2.5266\ \text{kipft/ft})) + (2 \times (-0.18105\ \text{kip/ft}) \times (5.5\ \text{ft}))]}$$

$$p = 0.22486\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (2.5266\ \text{kipft/ft})) + ((-0.18105\ \text{kip/ft}) \times (5.5\ \text{ft}))]}{(5.5\ \text{ft})^2}$$

$$s = 0.80477\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(3.762\ \text{ft})}{2}$$

$$p_a = 0.28215\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.22486\ \text{kip/ft}^2\right)}{\left(0.28215\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.79693$$

Status: **PASS**
Ratio: **0.800**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \text{psf/ft}) \times (5.5\ \text{ft})$$

$$p_s = 0.825\ \text{kip/ft}^2$$

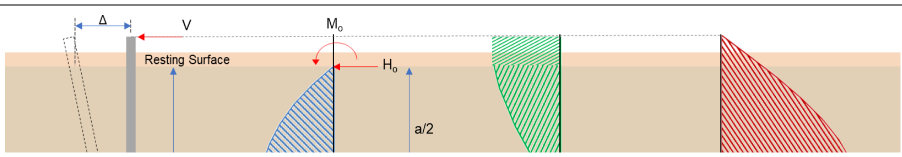
$Ratio$ - Lateral soil capacity

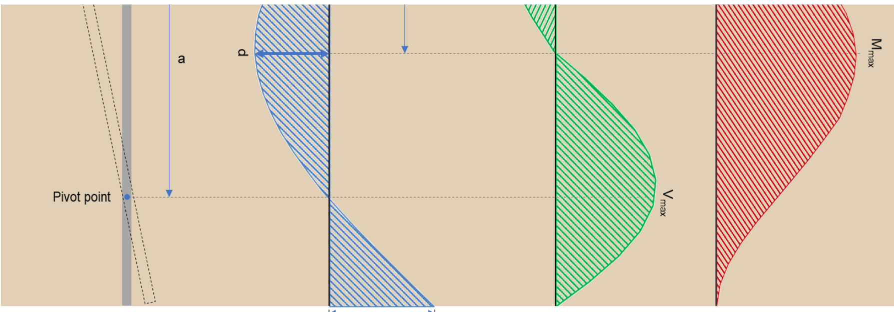
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(0.80477\ \text{kip/ft}^2\right)}{\left(0.825\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.97548$$

Status: **PASS**
Ratio: **0.980**





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-1.895\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.30175\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(26.765\text{ kipft}) + ((-1.895\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 4.2619\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.2619\text{ kipft/ft})}{(-0.30175\text{ kip/ft})}$$

$$E = 14.124\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.2619\text{ kipft/ft}) \times (5.5\text{ ft})) + \left(3 \times (-0.30175\text{ kip/ft}) \times (5.5\text{ ft})^2\right)}{(6 \times (4.2619\text{ kipft/ft})) + (4 \times (-0.30175\text{ kip/ft}) \times (5.5\text{ ft}))}$$

$$a = 3.7611\text{ ft}$$

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

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

$$V_{max} = ((-0.30175\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.124\text{ ft})}{(5.5\text{ ft})} + 3\right) \times \left(\frac{(3.7611\text{ ft})}{(5.5\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.124\text{ ft})}{(5.5\text{ ft})} + 2\right) \times \left(\frac{(3.7611\text{ ft})}{(5.5\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 6.2843\text{ kip}$$

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

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

$$M_{max} = ((-0.30175\text{ kip/ft}) \times (48\text{ in}) \times (5.5\text{ ft})) \times \left[\left(\frac{(14.124\text{ ft})}{(5.5\text{ ft})} + \frac{(3.7611\text{ ft})}{2 \times (5.5\text{ ft})}\right) - \left[\left(\frac{4 \times (14.124\text{ ft})}{(5.5\text{ ft})} + 3\right) \times \left(\frac{(3.7611\text{ ft})}{2 \times (5.5\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.124\text{ ft})}{(5.5\text{ ft})} + 2\right) \times \left(\frac{(3.7611\text{ ft})}{2 \times (5.5\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 16.676 \text{ kipft}$$

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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(9.988 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.264 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.264 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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,

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

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

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

Ties:

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

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

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

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

Summary:

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

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

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

$$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, [A_g - A_{st}]\right) + (f_{yk}\, A_{st})\right]$$

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(9.988\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0037336$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 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

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

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

$$\lambda_s = 0.64282$$

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

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

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

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

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\text{ ksi} \rightarrow 2500\text{ psi}$, $P = 9.988\text{ kip} \rightarrow 9988\text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\text{ psi})} + \frac{(9988\text{ lbf})}{6 \times (2304\text{ in}^2)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$

$$V_{c,a} = 119.82\text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\text{ kip}), (119.82\text{ kip}), (348.89\text{ kip})\right]$$

$$V_c = 119.82\text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.82\ \mathrm{kip}) + (50.894\ \mathrm{kip}))$$

$$\phi V_n = 110.96\ \mathrm{kip}$$

Considering x-direction:

$V_{max} = 6.2843\ \mathrm{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(6.2843\ \mathrm{kip})}{(110.96\ \mathrm{kip})}$$

$$Ratio = 0.056635$$

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

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:
$\phi M_{n,1}$

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

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

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

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

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

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

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

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

Therefore,
ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 16.676\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(16.676\ \text{kipft})}{(249.6\ \text{kipft})}$$

$$Ratio = 0.066811$$

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