Your Project Calculations

Project Name: Harhu-RevA

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Harhu-RevA&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/3_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=L48Mv3EbsTNXV8oqFDmvkn5skhiDs2FqUi5R5GkRjBZsxQOW2r31akB4sAB47zcy

Array Specification

Product:	Beam
Unique ID:	1P-0-8TOP-SD-57-L-4Hx3W-8CFL
Duty Classification:	SD
Module Width:	40.00 in
Module Length:	67.00in
Number of Rows:	4
Number of Columns:	3
Total Number of Modules:	12
Desired Tilt Angle:	85
Front Edge Clearance:	5
Total Array Height at Tilt:	18.37 ft
Total Frame Length:	17.00 ft
Frame Weight:	967 lbs
Array Dimensions N/S:	13.50 ft
Array Dimensions E/W:	17.00 ft
Rail Length:	162.00 in
Rail Spacing:	2.79 ft
Rail Check:	

Support Specifications

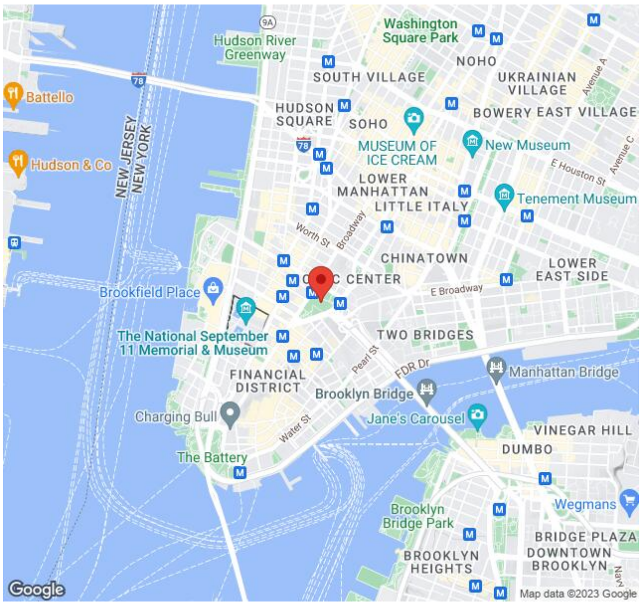
Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	11.72 ft
Number of Poles:	1
Pole Spacing:	0

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.75 ft
Foundation Volume:	4.593 y^3
Foundation Result:	PASSED

Site Info

Risk Category:	I
Exposure:	D
Soil Classification:	sand
Site Location:	254 Broadway, New York, NY 10007, USA
Wind Speed:	100 mph
Snow Load:	40 psf
Design Uplift Pressure:	0.031582 ksf
Design Downforce Pressure:	-0.031582 ksf
Design Snow Pressure:	0.000000 ksf



Design Disclaimer

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

AutoDesigner Input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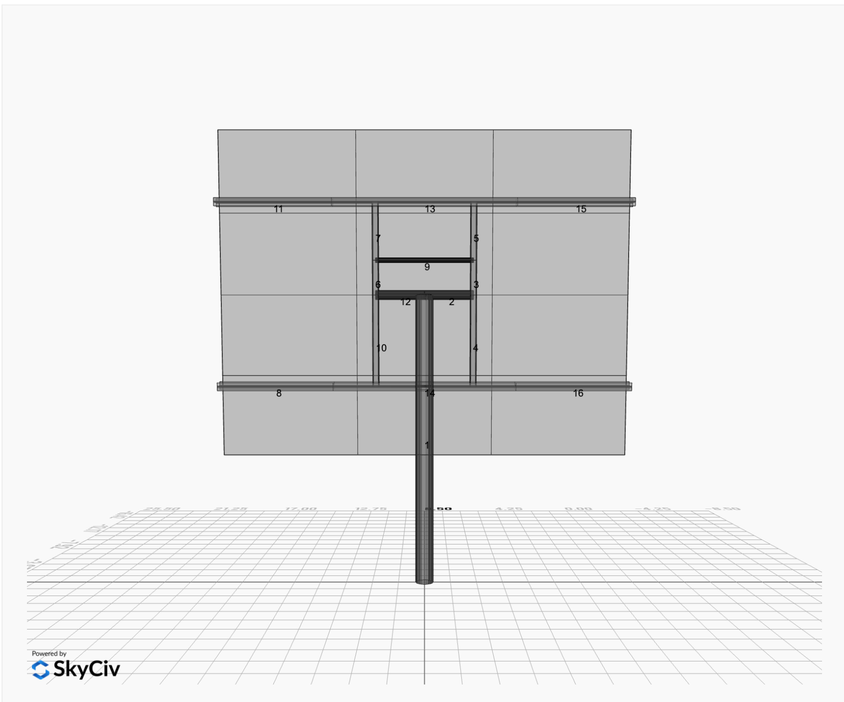
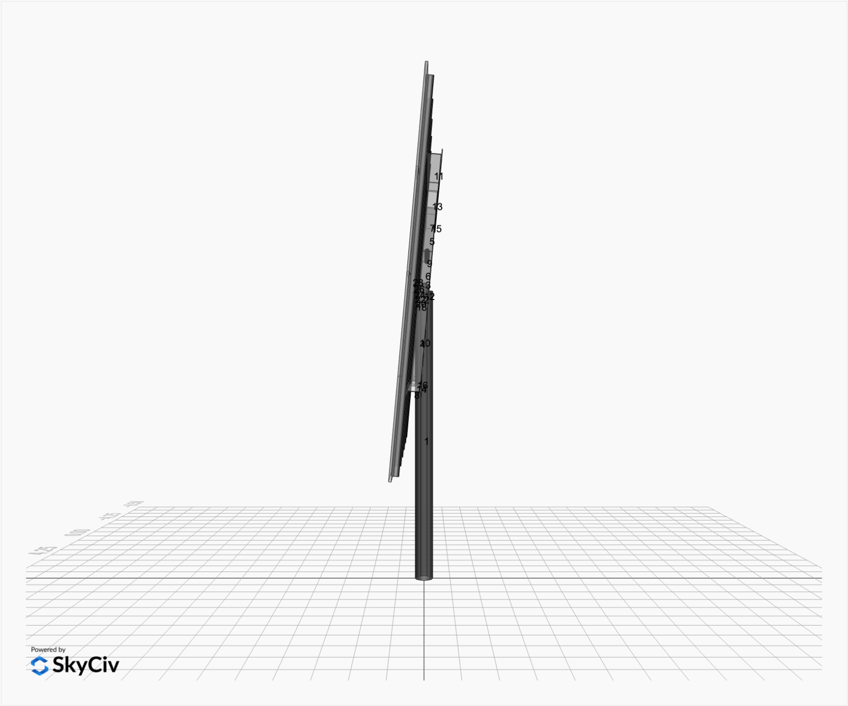
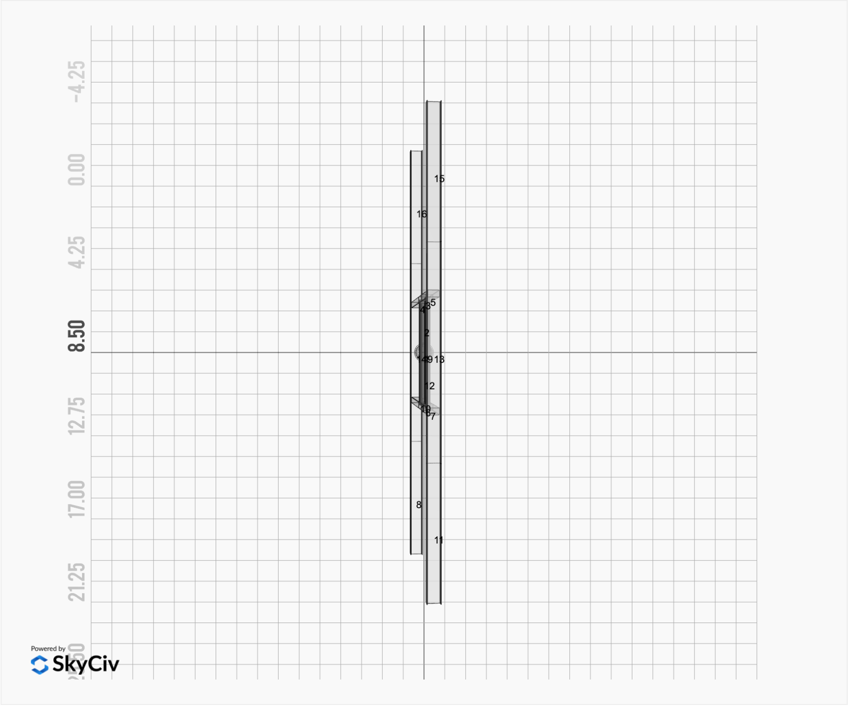
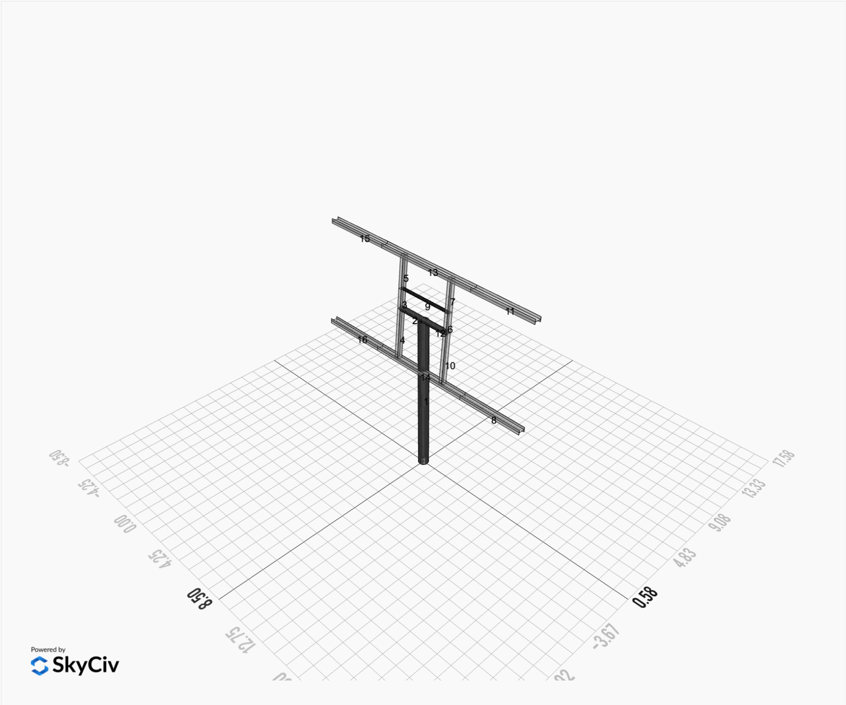
Design Notes:

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

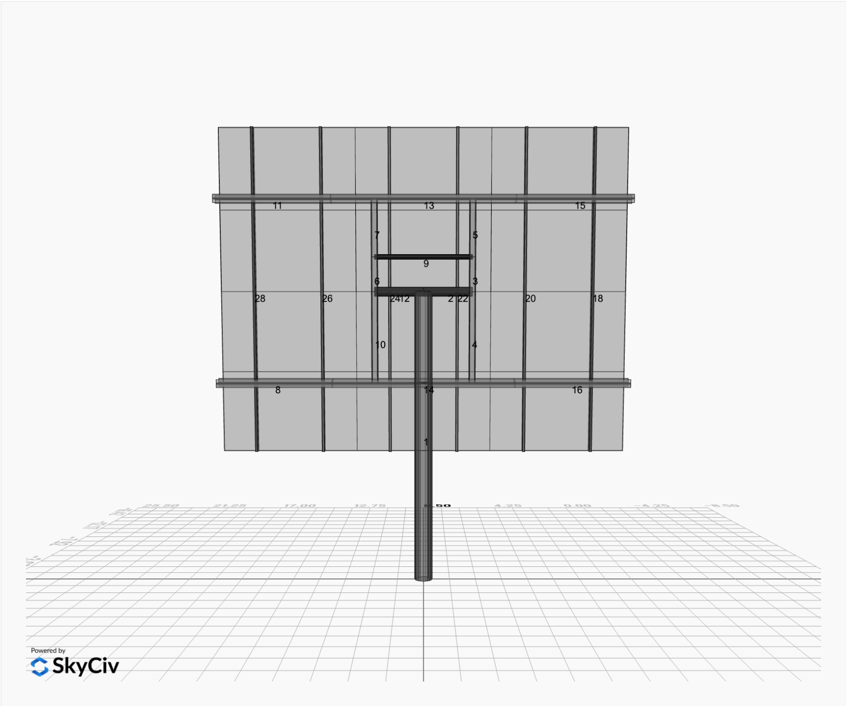





-4.25
0.00
4.25
8.50
12.75
17.00
21.25
Powered by
SkyCiv

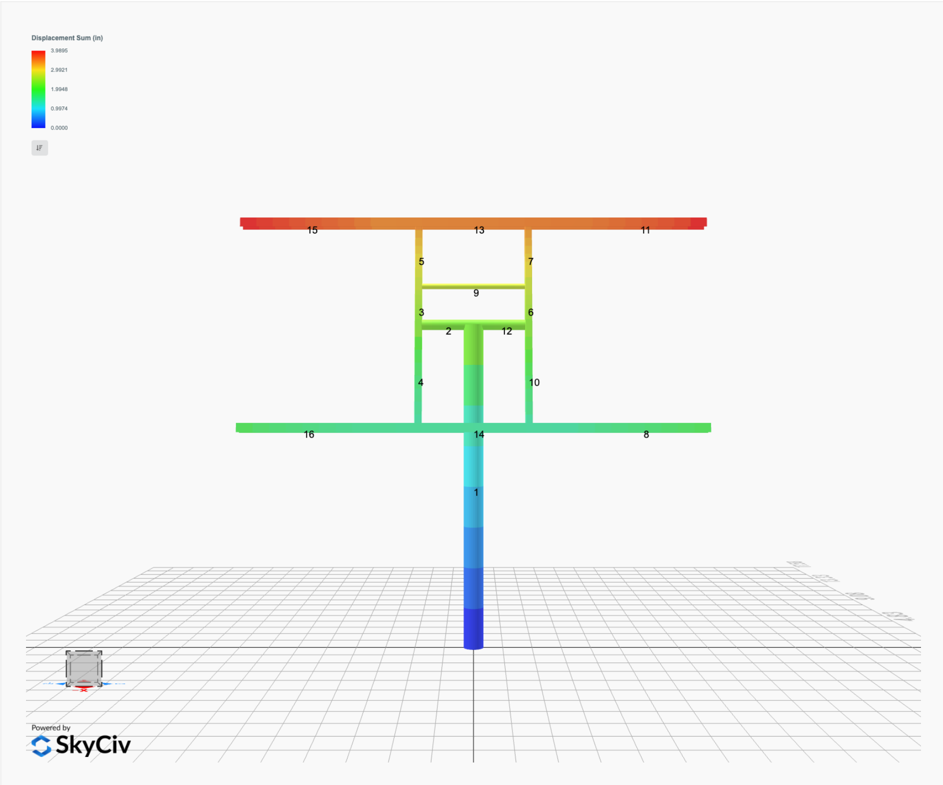


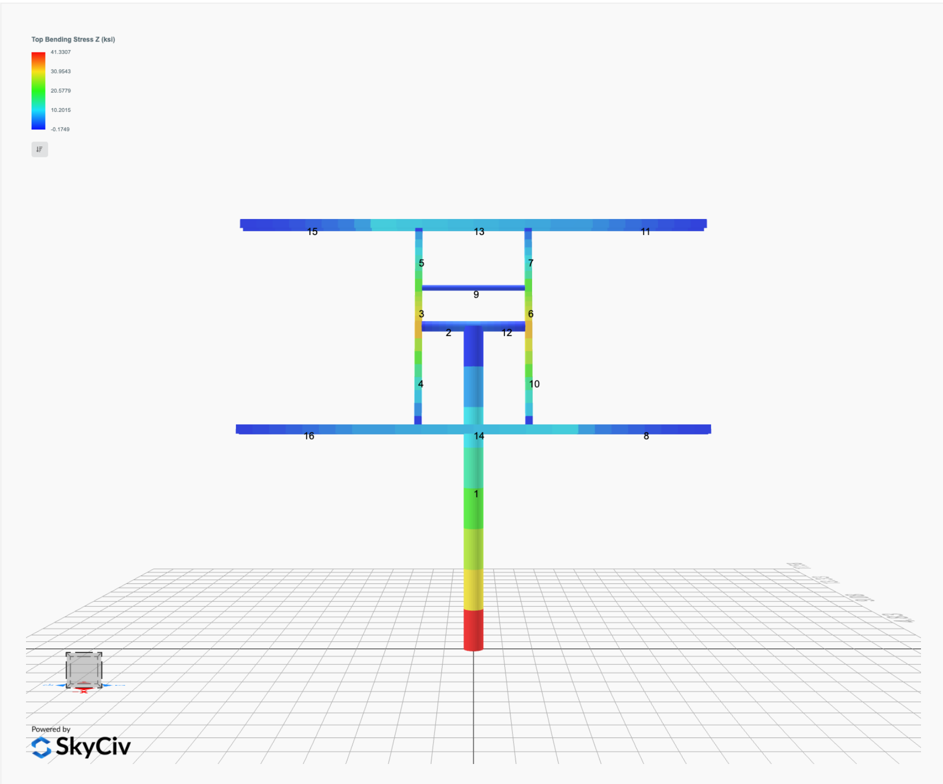
Powered by SkyCiv

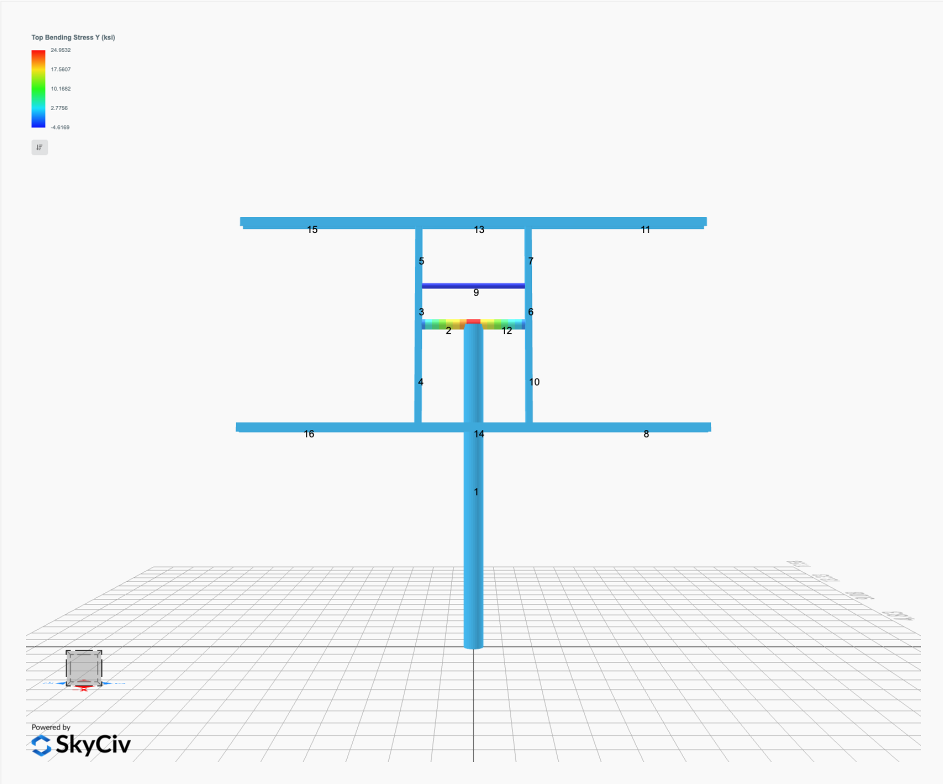


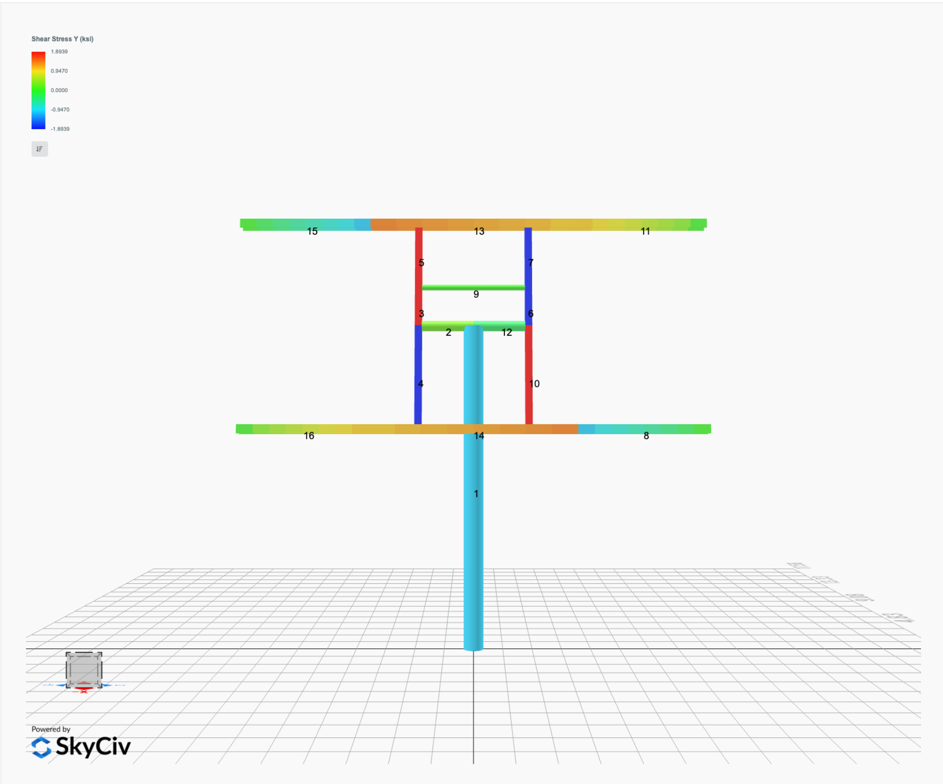
Powered by SkyCiv

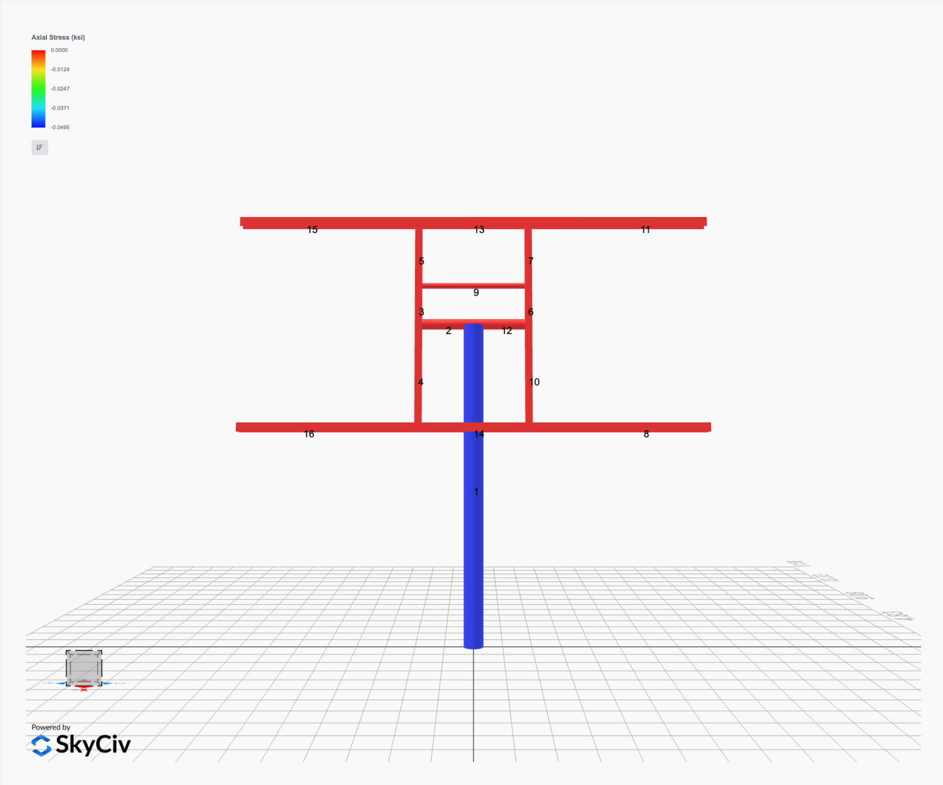
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
24.9532
17.5607
10.1682
2.7756
-4.6169
15
13
11
5
7
9
3
6
2
12
4
10
16
14
8
1
Powered by
SkyCiv


Shear Stress Y (ksi)
1.8939
0.9470
0.0000
-0.9470
-1.8939
15
13
11
5
7
9
3
6
2
12
4
10
16
14
8
1
Powered by
SkyCiv


Axial Stress (ksi)
0.0000
-0.0124
-0.0247
-0.0371
-0.0495
15
13
11
5
7
9
3
6
2
12
4
10
16
14
8
1
Powered by
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	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 2. D + L	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 3. D + (S or Lr or R)	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 3. D + (S or Lr or R)	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 5b. D + 0.7E	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 8. 0.6D + 0.7E	0.0000	1.2392	-0.0000	0.0000	-0.0000	0.0013
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.3323	2.4444	-0.0000	0.0000	-0.0000	50.8642
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.3323	1.6864	-0.0000	0.0000	-0.0000	-50.7217
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.2492	2.3497	-0.0000	0.0000	-0.0000	38.1487
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2492	1.7811	-0.0000	0.0000	-0.0000	-38.0407
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.2492	2.3497	-0.0000	0.0000	-0.0000	38.1487
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2492	1.7811	-0.0000	0.0000	-0.0000	-38.0407
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	2.0654	-0.0000	0.0000	-0.0000	0.0022
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.3323	1.6183	-0.0000	0.0000	-0.0000	50.8633
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0000	1.2392	-0.0000	0.0000	-0.0000	0.0013
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.3323	0.8602	-0.0000	0.0000	-0.0000	-50.7225
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0000	1.2392	-0.0000	0.0000	-0.0000	0.0013

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
Axial	3.1102
Shear X	-7.2204
Shear Z	-0.0000
Moment X	0.0000
Moment Z	85.2759

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
Axial	2.4444
Shear X	-4.3323
Shear Z	-0.0000
Moment X	0.0000
Moment Z	50.8642

Project Details

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

Design Input Information

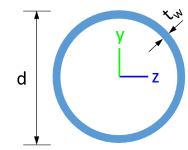
Design Factors

Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

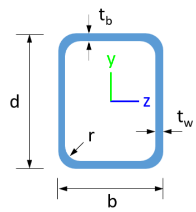
Design Materials

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

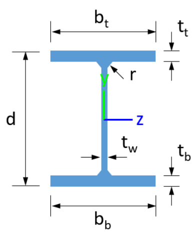
Section Dimensions



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					
10	8in Pipe Sch 80	8.63	0.50					



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

10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05
15	HSS5x3x1/8	1.77	6.02	2.75	6.03	152.35	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	10	24.62	24.62	11.72	-	300	200	1
2	4	2.00	2.00	2.00	-	300	200	1
3	15	1.42	1.42	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
4	15	3.75	3.75	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68	300	200	1
5	15	2.33	2.33	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68	300	200	1
6	15	1.42	1.42	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	300	200	1
7	15	2.33	2.33	2.33	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68	300	200	1
8	18	4.75	4.75	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	4.00	4.00	4.00	-	300	200	1
10	15	3.75	3.75	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68	300	200	1
11	18	4.75	4.75	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	2.00	2.00	2.00	-	300	200	1
13	18	1.75	1.75	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
14	18	1.75	1.75	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
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16	18	4.75	4.75	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
17	18	4.00	4.00	4.00	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07	300	200	1
18	18	1.75	1.75	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	300	200	1
19	18	4.00	4.00	4.00	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07	300	200	1
20	18	1.75	1.75	1.75	1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25,1.25	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	574.32	265.77	123.94	123.94	172.30	172.30

2	142.83	140.22	16.17	16.17	42.85	42.85
3	79.65	73.55	10.99	4.60	29.14	16.61
4	79.65	68.91	10.99	4.60	29.14	16.61
5	79.65	72.20	10.99	4.60	29.14	16.61
6	79.65	73.55	10.99	4.60	29.14	16.61
7	79.65	72.20	10.99	4.60	29.14	16.61
8	120.60	90.30	23.36	6.45	30.09	45.74
9	48.35	36.84	2.85	2.85	14.51	14.51
10	79.65	68.91	10.99	4.60	29.14	16.61
11	120.60	90.30	23.36	6.45	30.09	45.74
12	142.83	140.22	16.17	16.17	42.85	42.85
13	120.60	115.95	23.36	6.45	30.09	45.74
14	120.60	115.95	23.36	6.45	30.09	45.74
15	120.60	90.30	23.36	6.45	30.09	45.74
16	120.60	90.30	23.36	6.45	30.09	45.74
17	120.60	98.23	23.36	6.45	30.09	45.74
18	120.60	115.95	23.36	6.45	30.09	45.74
19	120.60	98.23	23.36	6.45	30.09	45.74
20	120.60	115.95	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	0.012	0.688	0.000	0.042	0.000	0.694	#13	0.513	Not Required	Pass
2	0.002	0.105	0.416	0.029	0.084	0.523	#13	0.053	Not Required	Pass
3	0.007	0.636	0.062	0.064	0.004	0.692	#13	0.068	Not Required	Pass
4	0.007	0.634	0.186	0.064	0.023	0.741	#13	0.120	Not Required	Pass
5	0.007	0.396	0.194	0.064	0.029	0.438	#13	0.112	Not Required	Pass
6	0.007	0.636	0.062	0.064	0.004	0.692	#13	0.068	Not Required	Pass
7	0.007	0.396	0.194	0.063	0.029	0.438	#13	0.112	Not Required	Pass
8	0.000	0.105	0.101	0.034	0.006	0.192	#13	Not Required	Not Required	Pass
9	0.011	0.014	0.078	0.001	0.000	0.092	#15	0.305	Not Required	Pass
10	0.007	0.634	0.186	0.064	0.023	0.741	#13	0.120	Not Required	Pass
11	0.000	0.105	0.101	0.034	0.006	0.192	#13	Not Required	Not Required	Pass
12	0.002	0.105	0.416	0.029	0.084	0.523	#13	0.053	Not Required	Pass
13	0.000	0.197	0.189	0.047	0.008	0.359	#13	Not Required	Not Required	Pass
14	0.000	0.197	0.189	0.047	0.008	0.359	#13	Not Required	Not Required	Pass
15	0.000	0.105	0.101	0.034	0.006	0.192	#13	Not Required	Not Required	Pass
16	0.000	0.105	0.101	0.034	0.006	0.192	#13	Not Required	Not Required	Pass
17	0.004	0.202	0.051	0.014	0.003	0.247	#13	0.177	Not Required	Pass
18	0.000	0.197	0.189	0.047	0.008	0.359	#13	Not Required	Not Required	Pass
19	0.004	0.205	0.057	0.014	0.003	0.256	#13	0.265	Not Required	Pass
20	0.000	0.197	0.189	0.047	0.008	0.359	#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

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

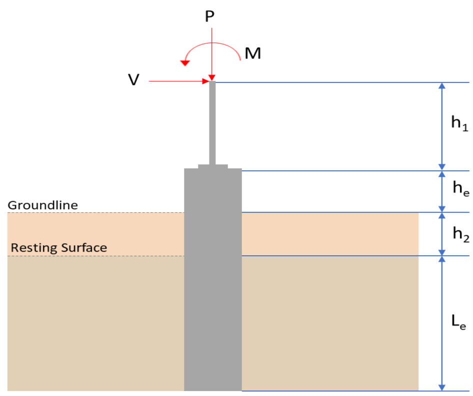
SkyCiv Foundation Design

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
$L = 7.75\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	2.444	3.110
V_x (kip)	-4.332	-7.220
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	0.000
M_z (kipft)	50.864	85.276

Material Properties

$f'_{ck} = 3\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.332\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.68981\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(50.864\ \text{kipft}) + ((-4.332\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 8.0994\ \text{kipft/ft}$$

Required depth of embedment in earth:

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

Solving the cubic equation:
$L_{e,x} = 7.0801\ \text{ft}$ - 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,

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

$$L_{e,req} = MAX[(7.0801\ \text{ft}), (0\ \text{ft})]$$

$$L_{e,req} = 7.08\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.75\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.75\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.08\ \text{ft})}{(7.75\ \text{ft})}$$

$$Ratio = 0.91355$$

Status: PASS
Ratio: 0.910

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

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

$$q = \frac{(2.444\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.15275\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.15275\ \text{kip/ft}^2)}{(2000\ \text{psf})}$$

$$Ratio = 0.076375$$

Status: PASS
Ratio: 0.080

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.75\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.9375$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.68981 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 8.0994 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.0994 \text{ kipft/ft}) \times (7.75 \text{ ft})) + \left(3 \times (-0.68981 \text{ kip/ft}) \times (7.75 \text{ ft})^2\right)}{(6 \times (8.0994 \text{ kipft/ft})) + (4 \times (-0.68981 \text{ kip/ft}) \times (7.75 \text{ ft}))}$$

$$a = 5.364 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.0994 \text{ kipft/ft})) + (3 \times (-0.68981 \text{ kip/ft}) \times (7.75 \text{ ft}))]^{\,2}}{(7.75 \text{ ft})^2 \times [(3 \times (8.0994 \text{ kipft/ft})) + (2 \times (-0.68981 \text{ kip/ft}) \times (7.75 \text{ ft}))]}$$

$$p = 0.24562 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.0994 \text{ kipft/ft})) + ((-0.68981 \text{ kip/ft}) \times (7.75 \text{ ft}))]}{(7.75 \text{ ft})^2}$$

$$s = 1.0841 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.364 \text{ ft})}{2}$$

$$p_a = 0.4023 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.24562 \text{ kip/ft}^2\right)}{\left(0.4023 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.61053$$

Status: **PASS**
Ratio: **0.610**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.75 \text{ ft})$$

$$p_s = 1.1625 \text{ kip/ft}^2$$

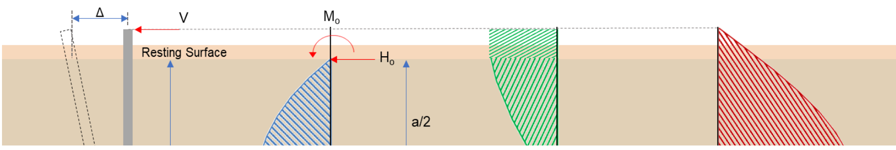
$Ratio$ - Lateral soil capacity

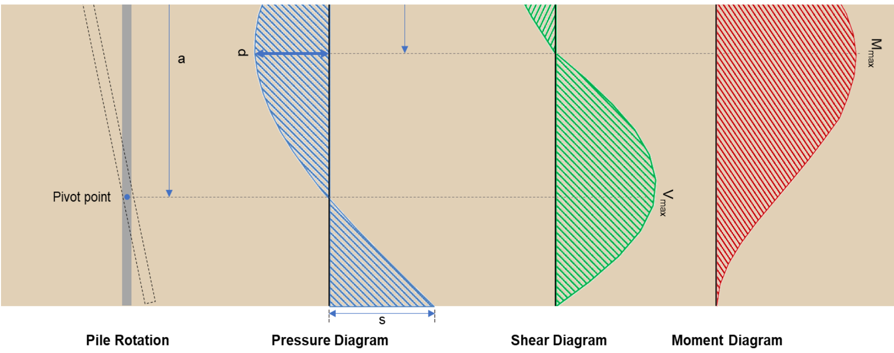
$$Ratio = \frac{s}{p_s}$$

$$Ratio = \frac{\left(1.0841 \text{ kip/ft}^2\right)}{\left(1.1625 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.93259$$

Status: **PASS**
Ratio: **0.930**





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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-7.22\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -1.1497\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(85.276\text{ kipft}) + ((-7.22\text{ kip}) \times (0\text{ ft}))}{1.57 \times (48\text{ in})}$$

$$M_o = 13.579\text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(13.579\text{ kipft/ft})}{(-1.1497\text{ kip/ft})}$$

$$E = 11.811\text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.579\text{ kipft/ft}) \times (7.75\text{ ft})) + \left(3 \times (-1.1497\text{ kip/ft}) \times (7.75\text{ ft})^2\right)}{(6 \times (13.579\text{ kipft/ft})) + (4 \times (-1.1497\text{ kip/ft}) \times (7.75\text{ ft}))}$$

$$a = 5.3632\text{ ft}$$

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

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

$$V_{max} = ((-1.1497\text{ kip/ft}) \times (48\text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.811\text{ ft})}{(7.75\text{ ft})} + 3\right) \times \left(\frac{(5.3632\text{ ft})}{(7.75\text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (11.811\text{ ft})}{(7.75\text{ ft})} + 2\right) \times \left(\frac{(5.3632\text{ ft})}{(7.75\text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 15.434\text{ kip}$$

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

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

$$M_{max} = ((-1.1497\text{ kip/ft}) \times (48\text{ in}) \times (7.75\text{ ft})) \times \left[\left(\frac{(11.811\text{ ft})}{(7.75\text{ ft})} + \frac{(5.3632\text{ ft})}{2 \times (7.75\text{ ft})}\right) - \left[\left(\frac{4 \times (11.811\text{ ft})}{(7.75\text{ ft})} + 3\right) \times \left(\frac{(5.3632\text{ ft})}{2 \times (7.75\text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (11.811\text{ ft})}{(7.75\text{ ft})} + 2\right) \times \left(\frac{(5.3632\text{ ft})}{2 \times (7.75\text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 56.576 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - 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 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(3.11 \text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (3 \text{ ksi}) \times \left(2304 \text{ in}^2\right)\right)}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, \left(0.08 \times \left(2304 \text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -102.16 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-102.16 \text{ in}^2\right), \left(0.0018 \times \left(2304 \text{ in}^2\right)\right)\right]$$

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

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,

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

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

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

Ties:

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

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

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

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

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 $$\phi P_N = \phi\, 0.80\, \left[\left(0.85\, f'_{ck}\, [A_g - A_{st}]\right) + (f_{yk}\, A_{st})\right]$$ $$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (3\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$ $$\phi P_N = 3183.4\text{ kip}$$ $Ratio$ - Capacity $$Ratio = \frac{P}{\phi P_N}$$ $$Ratio = \frac{(3.11\text{ kip})}{(3183.4\text{ kip})}$$ $$Ratio = 0.00097694$$	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 $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete $$V_{c,max} = 5\, \lambda_s\, \sqrt{f'_{ck}}\, b_w\, d$$ $$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000\text{ psi})} \times (48\text{ in}) \times (38.4\text{ in})$$ $$V_{c,max} = 324.49\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,$P = 3.11\text{ kip} \rightarrow 3110\text{ lbf}$,	
22.5.5.1.1(a)	$V_{c,a}$ - Shear strength of concrete (a) $$V_{c,a} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \frac{P}{6\, A_g}\right]\, b_w\, d$$ $$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000\text{ psi})} + \frac{(3110\text{ lbf})}{6 \times \left(2304\text{ in}^2\right)}\right] \times (48\text{ in}) \times (38.4\text{ in})$$ $$V_{c,a} = 130.21\text{ kip}$$ The following variables were converted to be consistent with empirical formula $f'_{ck} = 3\text{ ksi} \rightarrow 3000\text{ psi}$,	
22.5.5.1.2	$V_{c,b}$ - Shear strength of concrete (b) $$V_{c,b} = \left[2\, \lambda_s\, \sqrt{f'_{ck}} + \left(0.05\, f'_{ck}\right)\right]\, b_w\, d$$ $$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000\text{ psi})} + (0.05 \times (3000\text{ psi}))\right] \times (48\text{ in}) \times (38.4\text{ in})$$ $$V_{c,b} = 406.27\text{ kip}$$ V_c - Governing shear strength of concrete $$V_c = Min\left[V_{c,max}, V_{c,a}, V_{c,b}\right]$$ $$V_c = Min\left[(324.49\text{ kip}), (130.21\text{ kip}), (406.27\text{ kip})\right]$$ $$V_c = 130.21\text{ kip}$$	

22.5.1.2	The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$, $V_{s,a}$ - Shear strength of steel (a) $$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$ $$V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$ $$V_{s,a} = 807.65 \text{ kip}$$ A_v - Ties rebar area, $$A_v = \frac{\pi\, d_{ties}^2}{4}$$ $$A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$$ $$A_v = 0.11045 \text{ in}^2$$	
22.5.8.5.3	$V_{s,b}$ - Shear strength of steel (b) $$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$ $$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$ $$V_{s,b} = 50.894 \text{ kip}$$ V_s - Governing shear strength of steel $$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$ $$V_s = MIN\left[(807.65 \text{ kip}), (50.894 \text{ kip})\right]$$ $$V_s = 50.894 \text{ kip}$$	
22.5.1.1	ϕV_n - Allowable shear strength $$\phi V_n = \phi\, (V_c + V_s)$$ $$\phi V_n = (0.65) \times ((130.21 \text{ kip}) + (50.894 \text{ kip}))$$ $$\phi V_n = 117.72 \text{ kip}$$ **Considering x-direction:** $V_{max} = 15.434 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(15.434 \text{ kip})}{(117.72 \text{ kip})}$$ $$Ratio = 0.13111$$	Status: **PASS** Ratio: **0.130**
	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: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(3ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 273.423kipft$$	
14.5.2.1b	$\phi M_{n,2}$ $$\phi M_{n,2} = \phi\, 0.85\, f'_c\, S_m$$	

$$\phi M_{n,2} = \phi\ 0.85\ f_{ck}\ S_m$$

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

$$\phi M_{n,2} = 2545.9 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(273.42 \text{ kipft}), (2545.9 \text{ kipft})]$$

$$\phi M_n = 273.42 \text{ kipft}$$

Considering x-direction:

$M_{max} = 56.576 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(56.576 \text{ kipft})}{(273.42 \text{ kipft})}$$

$$Ratio = 0.20692$$

Status: **PASS**
Ratio: **0.210**