

Project Details



Project Name: MTSOLAR_7A87K401B0KB-Alan-3MW- **Date:** Wed Sep 18 2024

4x6

Number of Modules: 24

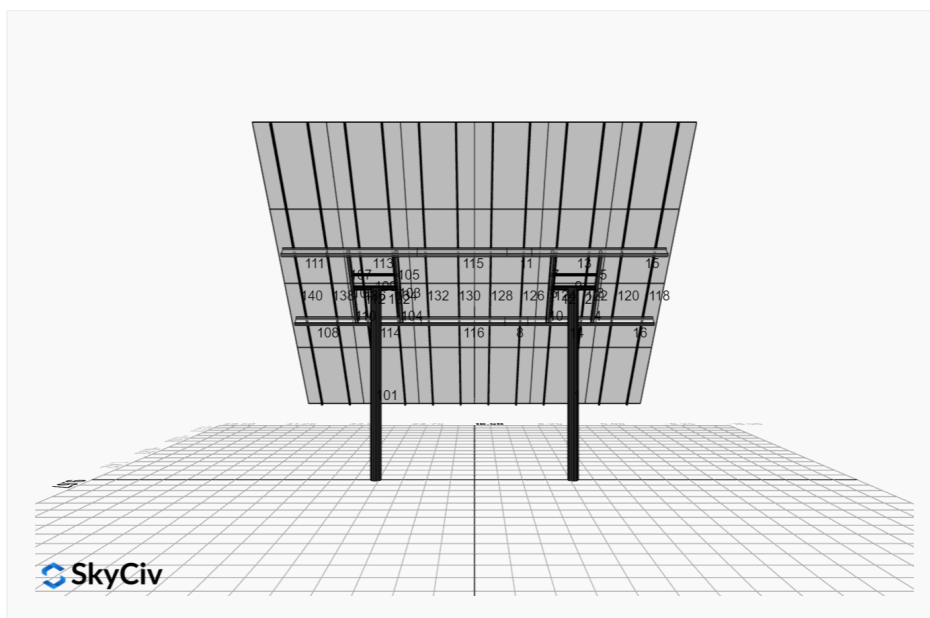
Location: Johnstown, PA 15901, USA

Number of Poles: 2

Unique ID: 2P-17-10TOP-XD-45-L-4Hx6W-C0GB

Date Sold:

Dealer: _____



Array Dimensions N/S	30.08 ft
Array Dimensions E/W	33.00 ft
Winter Tilt Angle	50
Front Edge Clearance	5 ft

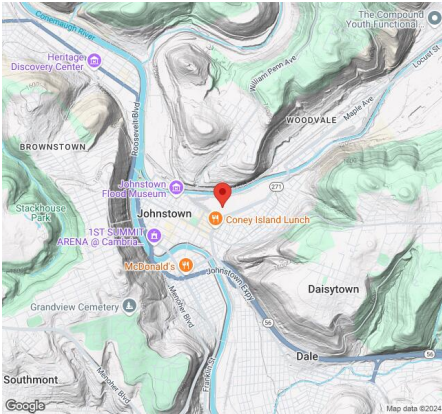
MT Solar Bill of Materials (2P-17-10TOP-XD-45-L-4Hx6W-C0GB)

Part	Short Description	BOM Qty
MTS-PC-10	10IN Pole Cap Assembly	2
MTS-HF-XD	H-Frame Assembly-XD	2
MTS-XD-Wing-45	45IN XD Wing	4
MTS-XD-Splice-57	57IN XD Splice	4
MTS-CLAMP-HOOK-4PK	Hook Clamp	6

Rail Bill of Materials

Part	Qty
Rails (359in)	12
Rail Attachment	24
Module Mid Clamp	36
Module End Clamp	24
Ground Lug	6

Site Details:



Site Address: Johnstown, PA 15901, USA

Array Specification

Duty Classification:	XD
Module Width:	89.73 in
Module Length:	65.00in
Number of Rows:	4
Number of Columns:	6
Total Number of Modules:	24
Winter Tilt Angle:	50
Front Edge Clearance:	5
Total Array Height at Tilt:	28.04 ft
Total Frame Length:	32.00 ft
Frame Weight:	4456 lbs
Array Dimensions N/S:	30.08 ft
Array Dimensions E/W:	33.00 ft
Rail Length:	360.92 in
Rail Spacing:	2.75 ft

Support Specifications

Pole Size:	10in Pipe Sch 80
Pole Length above Grade:	16.52 ft
Number of Poles:	2
Pole Spacing:	17 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 10.00 ft Pile 2: 10.00 ft
Foundation Volume:	11.852 y ³

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Johnstown, PA 15901, USA
Wind Speed:	115 mph
Snow Load:	45 psf

Design Disclaimer

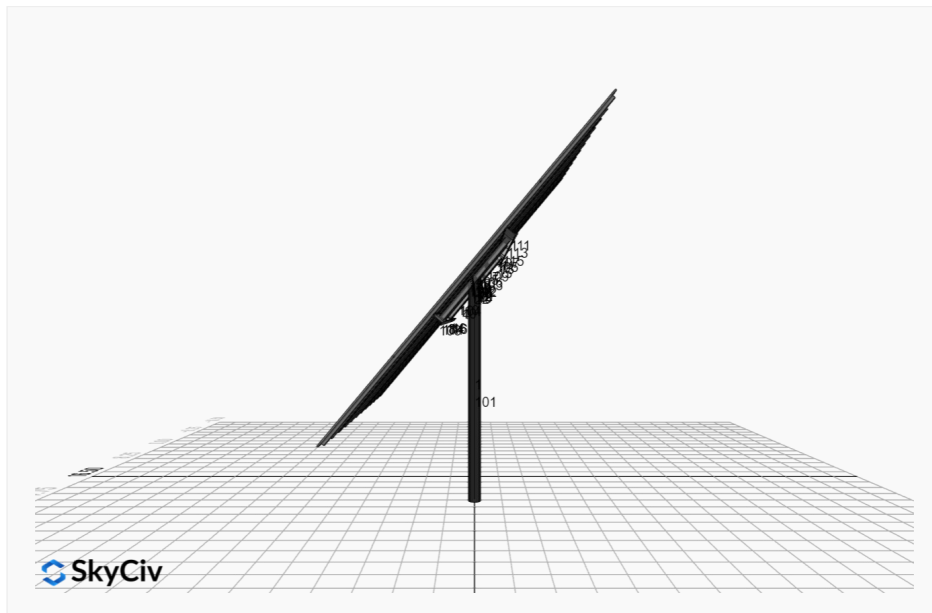
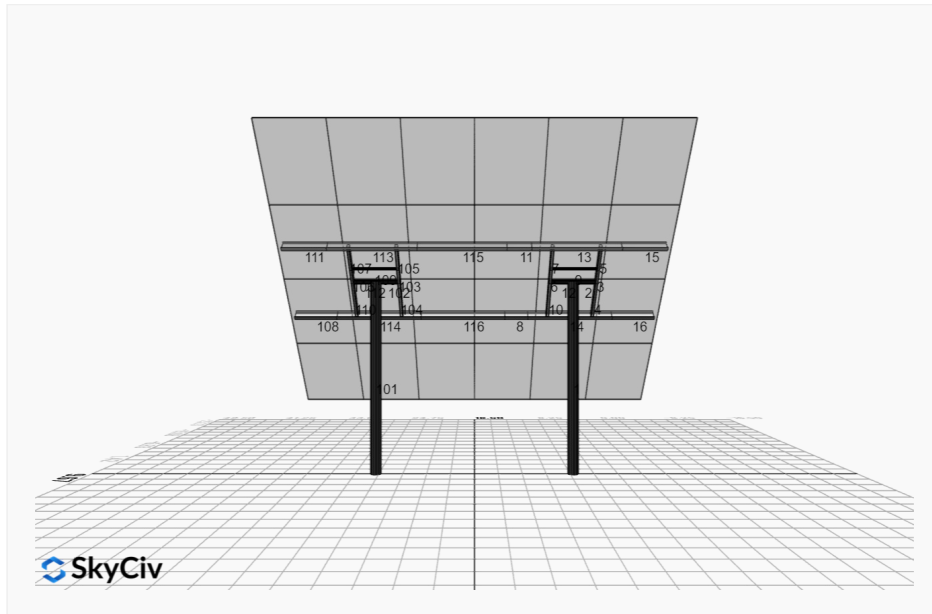
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

AutoDesigner Input

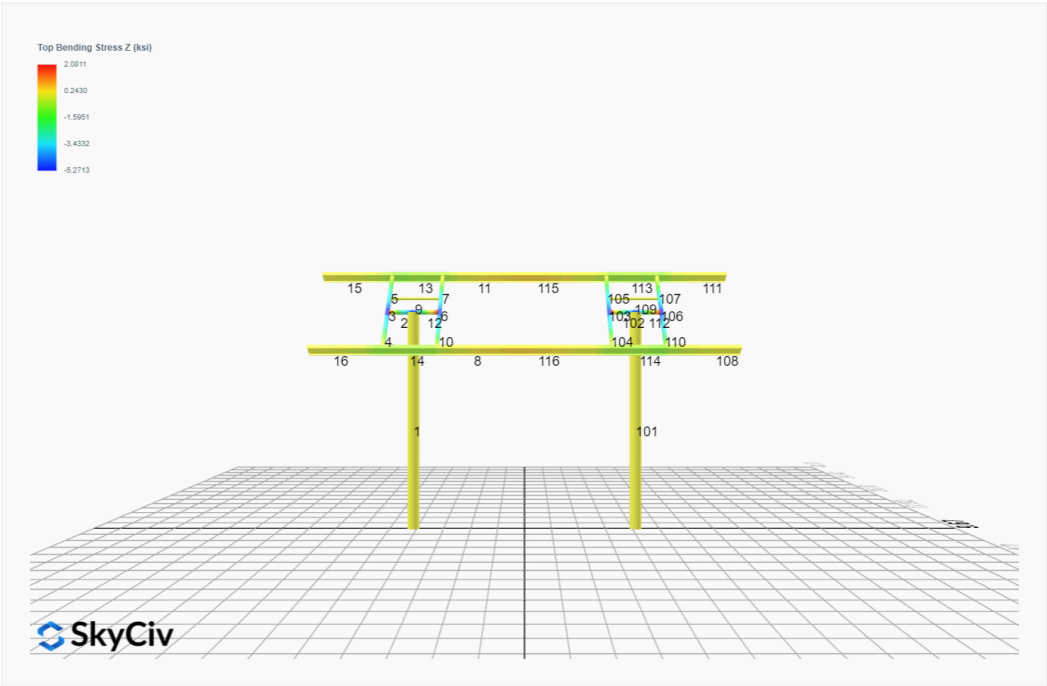
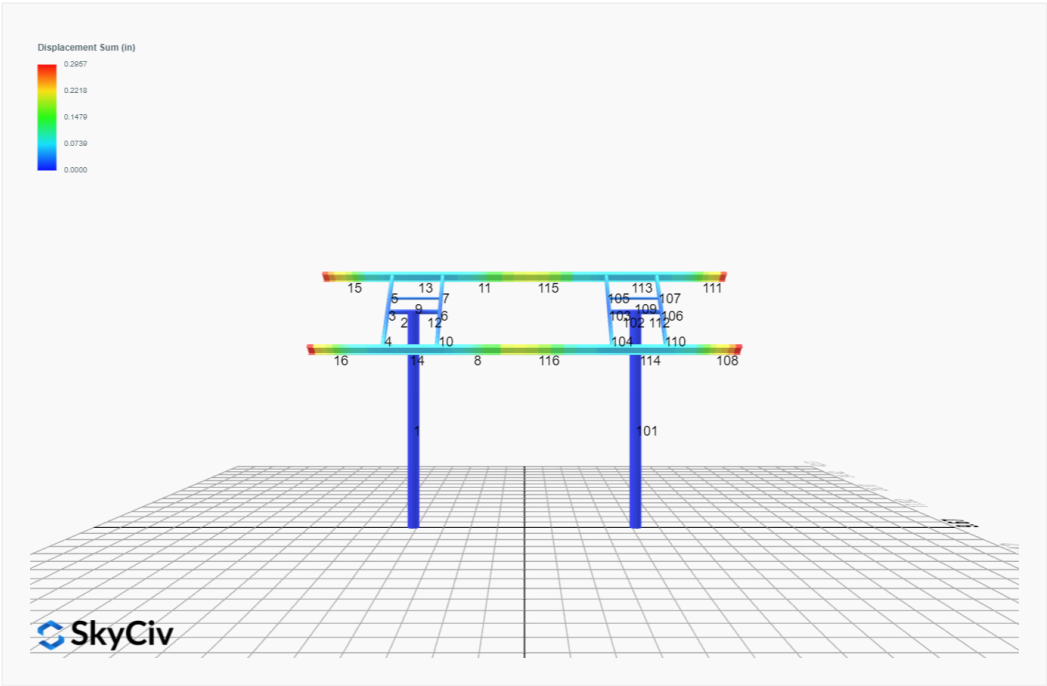
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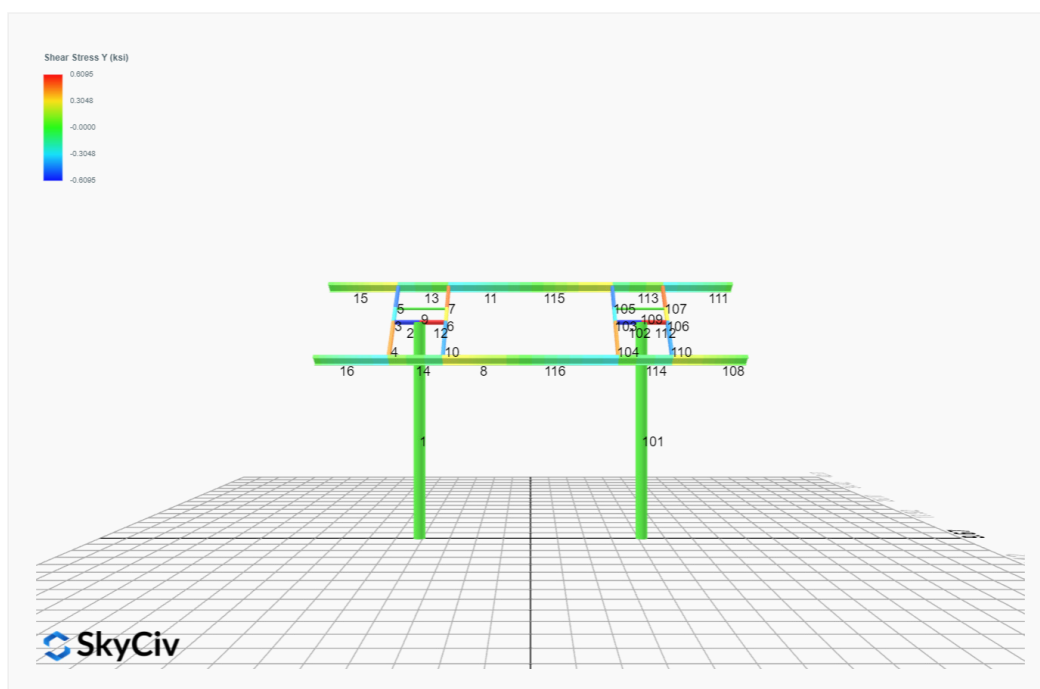
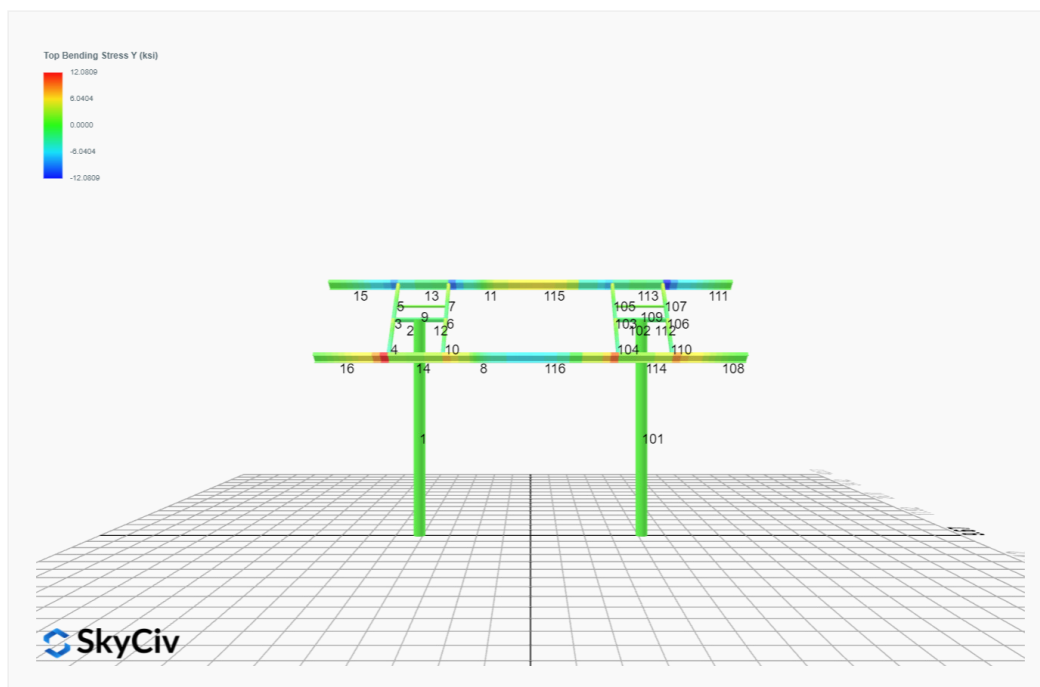
Design Notes:

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



FEM Results (Envelope Worst Case for each member)





Reaction Forces for Foundation 1 (Node ID#1), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 2. D + L	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 3. D + (S or Lr or R)	0.0000	6.9462	-0.0031	-0.0079	0.2040	0.0352
ULS: 3. D + (S or Lr or R)	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	6.1809	-0.0027	-0.0069	0.1763	0.0328
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 5b. D + 0.7E	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	6.1809	-0.0027	-0.0069	0.1763	0.0328
ULS: 8. 0.6D + 0.7E	0.0000	2.3309	-0.0009	-0.0024	0.0559	0.0154
ULS: 5a. D + 0.6W_Wind downforce Case A only	-6.2278	9.1106	-0.0339	-0.1569	0.3723	104.5954
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 5a. D + 0.6W_Wind uplift Case A only	6.2278	-1.3409	0.0309	0.1482	-0.1862	-101.2363
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.6709	10.1002	-0.0270	-0.1217	0.3856	78.4601
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	6.1809	-0.0027	-0.0069	0.1763	0.0328
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	4.6709	2.2615	0.0216	0.1072	-0.0333	-75.9137
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	6.1809	-0.0027	-0.0069	0.1763	0.0328
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.6709	7.8042	-0.0258	-0.1187	0.3025	78.4530
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	4.6709	-0.0345	0.0228	0.1102	-0.1164	-75.9208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	3.8849	-0.0015	-0.0040	0.0931	0.0257
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-6.2278	7.5567	-0.0333	-0.1554	0.3350	104.5851
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0000	2.3309	-0.0009	-0.0024	0.0559	0.0154
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	6.2278	-2.8949	0.0314	0.1498	-0.2235	-101.2466
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0000	2.3309	-0.0009	-0.0024	0.0559	0.0154

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	14.9021
Shear X	-10.3797
Shear Z	-0.0568
Moment X	-0.2627
Moment Y (Twist)	0.6334
Moment Z	176.5017

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	10.1002
Shear X	-6.2278
Shear Z	-0.0339
Moment X	-0.1569
Moment Y (Twist)	0.3856
Moment Z	104.5954

Reaction Forces for Foundation 2 (Node ID#101), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 2. D + L	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 3. D + (S or Lr or R)	-0.0000	6.9462	0.0031	0.0079	-0.2040	0.0352
ULS: 3. D + (S or Lr or R)	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	6.1809	0.0027	0.0069	-0.1762	0.0329

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 5b. D + 0.7E	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	6.1809	0.0027	0.0069	-0.1762	0.0329
ULS: 8. 0.6D + 0.7E	-0.0000	2.3309	0.0009	0.0024	-0.0559	0.0154
ULS: 5a. D + 0.6W_Wind downforce Case A only	-6.2278	9.1106	0.0339	0.1569	-0.3722	104.5954
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 5a. D + 0.6W_Wind uplift Case A only	6.2278	-1.3409	-0.0309	-0.1482	0.1862	-101.2363
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.6709	10.1002	0.0270	0.1217	-0.3856	78.4601
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	6.1809	0.0027	0.0069	-0.1762	0.0329
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	4.6709	2.2615	-0.0216	-0.1072	0.0333	-75.9137
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	6.1809	0.0027	0.0069	-0.1762	0.0329
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-4.6709	7.8042	0.0258	0.1187	-0.3025	78.4530
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	4.6709	-0.0345	-0.0228	-0.1102	0.1164	-75.9208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	3.8849	0.0015	0.0040	-0.0931	0.0257
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-6.2278	7.5567	0.0333	0.1554	-0.3350	104.5851
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0000	2.3309	0.0009	0.0024	-0.0559	0.0154
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	6.2278	-2.8949	-0.0314	-0.1498	0.2235	-101.2466
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0000	2.3309	0.0009	0.0024	-0.0559	0.0154

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	14.9021
Shear X	-10.3797
Shear Z	0.0568
Moment X	0.2628
Moment Y (Twist)	0.6337
Moment Z	176.5033

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	10.1002
Shear X	-6.2278
Shear Z	0.0339
Moment X	0.1569
Moment Y (Twist)	0.3856
Moment Z	104.5954

Project Details

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

User Name: sales@mtsolar.us
 Project Name: MTSOLAR_7A87K401B0KB-Alan-3MW-4x6
 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)					
3	2in Pipe Sch 120	2.38	0.25					
6	4in Pipe Sch 120	4.50	0.44					
12	10in Pipe Sch 80	10.75	0.59					
ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
17	HSS5x3x1/4	5.00	3.00	0.23	0.23	0.23		
ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
20	W10x12	9.87	0.19	3.96	3.96	0.21	0.21	0.30

Section Properties								
ID	Name	A (in ²)	J (in ⁴)	I_{yD} (in ⁴)	I_{zD} (in ⁴)	I_w (in ⁶)	S_{yD} (in ³)	S_{zD} (in ³)

113	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.11	300	200	1
114	20	4.88	4.00	7.50	1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.11,1.12,1.11,1.11,1.11,1.11,1.11,1.11,1.11	300	200	1
115	20	4.84	4.84	7.45	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16	300	200	1
116	20	4.84	4.84	7.45	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16	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	851.50	319.16	229.67	229.67	255.45	255.45
2	251.01	248.88	27.16	27.16	75.30	75.30
3	151.65	150.70	20.17	14.14	54.12	28.95
4	151.65	145.15	20.17	14.14	54.12	28.95
5	151.65	149.10	20.17	14.14	54.12	28.95
6	151.65	150.70	20.17	14.14	54.12	28.95
7	151.65	149.10	20.17	14.14	54.12	28.95
8	159.30	140.46	46.90	6.46	56.26	44.91
9	75.10	66.32	4.25	4.25	22.53	22.53
10	151.65	145.15	20.17	14.14	54.12	28.95
11	159.30	140.46	46.90	6.46	56.26	44.91
12	251.01	248.88	27.16	27.16	75.30	75.30
13	159.30	97.43	33.97	6.46	56.26	44.91
14	159.30	97.43	33.93	6.46	56.26	44.91
15	159.30	55.15	46.90	6.46	56.26	44.91
16	159.30	55.15	46.90	6.46	56.26	44.91
101	851.50	319.16	229.67	229.67	255.45	255.45
102	251.01	248.88	27.16	27.16	75.30	75.30
103	151.65	150.70	20.17	14.14	54.12	28.95
104	151.65	145.15	20.17	14.14	54.12	28.95
105	151.65	149.10	20.17	14.14	54.12	28.95
106	151.65	150.70	20.17	14.14	54.12	28.95
107	151.65	149.10	20.17	14.14	54.12	28.95
108	159.30	55.15	46.90	6.46	56.26	44.91
109	75.10	66.32	4.25	4.25	22.53	22.53
110	151.65	145.15	20.17	14.14	54.12	28.95
111	159.30	55.15	46.90	6.46	56.26	44.91
112	251.01	248.88	27.16	27.16	75.30	75.30
113	159.30	97.43	33.97	6.46	56.26	44.91
114	159.30	97.43	33.92	6.46	56.26	44.91
115	159.30	97.82	35.57	6.46	56.26	44.91
116	159.30	97.82	35.57	6.46	56.26	44.91

Design Ratio

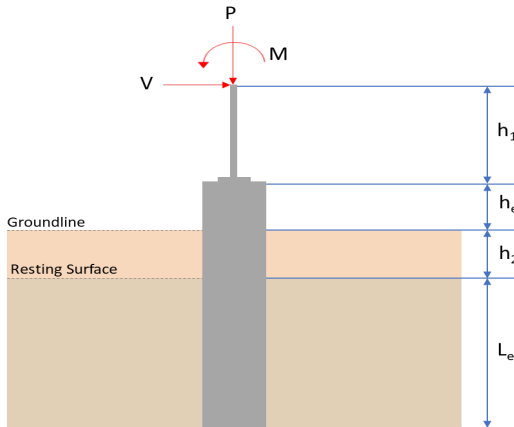
Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	δ	Status
1	0.047	0.768	0.003	0.041	0.000	0.793	#13	0.579	Not Required	Pass
2	0.002	0.422	0.370	0.092	0.071	0.793	#13	0.036	Not Required	Pass
3	0.010	0.792	0.070	0.079	0.014	0.837	#13	0.046	Not Required	Pass
4	0.010	0.780	0.153	0.078	0.023	0.847	#13	0.092	Not Required	Pass

4	0.010	0.769	0.152	0.078	0.033	0.047	#13	0.062	Not Required	Pass
5	0.010	0.492	0.154	0.078	0.038	0.511	#13	0.076	Not Required	Pass
6	0.011	0.762	0.074	0.075	0.014	0.808	#13	0.046	Not Required	Pass
7	0.011	0.474	0.148	0.075	0.038	0.496	#13	0.076	Not Required	Pass
8	0.000	0.058	0.118	0.044	0.020	0.159	#21	0.102	Not Required	Pass
9	0.010	0.055	0.068	0.001	0.000	0.125	#13	0.206	Not Required	Pass
10	0.011	0.758	0.147	0.075	0.033	0.828	#13	0.082	Not Required	Pass
11	0.000	0.058	0.116	0.044	0.020	0.157	#21	0.102	Not Required	Pass
12	0.002	0.397	0.347	0.089	0.068	0.745	#13	0.036	Not Required	Pass
13	0.007	0.251	0.446	0.060	0.028	0.611	#21	0.306	Not Required	Pass
14	0.010	0.255	0.446	0.060	0.028	0.612	#21	0.204	Not Required	Pass
15	0.000	0.077	0.207	0.034	0.016	0.263	#21	Not Required	Not Required	Pass
16	0.000	0.077	0.207	0.034	0.016	0.263	#21	Not Required	Not Required	Pass
101	0.047	0.769	0.003	0.041	0.000	0.793	#13	0.579	Not Required	Pass
102	0.002	0.397	0.347	0.089	0.068	0.745	#13	0.036	Not Required	Pass
103	0.011	0.762	0.074	0.075	0.014	0.808	#13	0.046	Not Required	Pass
104	0.011	0.758	0.147	0.075	0.033	0.828	#13	0.082	Not Required	Pass
105	0.011	0.474	0.148	0.075	0.038	0.496	#13	0.076	Not Required	Pass
106	0.010	0.792	0.070	0.079	0.014	0.837	#13	0.046	Not Required	Pass
107	0.010	0.492	0.154	0.078	0.038	0.511	#13	0.076	Not Required	Pass
108	0.000	0.077	0.207	0.034	0.016	0.263	#21	Not Required	Not Required	Pass
109	0.010	0.055	0.068	0.001	0.000	0.125	#13	0.206	Not Required	Pass
110	0.010	0.788	0.152	0.078	0.033	0.846	#13	0.082	Not Required	Pass
111	0.000	0.077	0.207	0.034	0.016	0.263	#21	Not Required	Not Required	Pass
112	0.002	0.422	0.370	0.092	0.071	0.793	#13	0.036	Not Required	Pass
113	0.007	0.251	0.446	0.060	0.028	0.611	#21	0.204	Not Required	Pass
114	0.010	0.255	0.446	0.060	0.028	0.612	#21	0.306	Not Required	Pass
115	0.000	0.128	0.223	0.044	0.020	0.315	#21	0.370	Not Required	Pass
116	0.001	0.128	0.225	0.044	0.020	0.317	#21	0.370	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/compression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis

V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS																											
	<div>SkyCiv Foundation Design</div> <div>Pile Foundation</div> <div>Design Information :</div> <div>Design code : IBC 2021 (International Building Code)</div> <div>Unit System : Imperial</div>																												
	<div>Pile Input</div> <div></div> <div>Geometry</div> <div>Pile shape: rectangular</div> <div>b = 48 in - Pile width</div> <div>D = 48 in - Pile depth</div> <div>L = 10 ft - Total pile length</div> <div>h1 = 0 ft - Lateral load height from the top of the pile,</div> <div>h2 = 0 ft - Depth to resisting surface</div> <div>he = 0 ft - Length of pile above the ground</div> <div>Tabulation of Soil Parameters</div> <table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa) (psf)</th><th>Allowable Lateral Pressure (R) (psf/ft)</th></tr><tr><td>1</td><td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td><td>2000.000</td><td>150.000</td></tr></table> <div>Tabulation of Loads</div> <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>10.100</td><td>14.902</td></tr><tr><td>Vx (kip)</td><td>-6.228</td><td>-10.380</td></tr><tr><td>Vz (kip)</td><td>-0.034</td><td>-0.057</td></tr><tr><td>Mx (kipft)</td><td>-0.157</td><td>-0.263</td></tr><tr><td>Mz (kipft)</td><td>104.595</td><td>176.502</td></tr></table> <div>Material Properties</div> <div>f'ck = 2.5 ksi - Concrete strength,</div>	Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	10.100	14.902	Vx (kip)	-6.228	-10.380	Vz (kip)	-0.034	-0.057	Mx (kipft)	-0.157	-0.263	Mz (kipft)	104.595	176.502	<div>Required depth to resist lateral loads (ASD)</div> <div>H - Point of application of the lateral load</div> <div>$H = h_1 + h_2 + h_e$</div> <div>$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$</div> <div>$H = 0 \text{ ft}$</div> <div>Considering x-direction:</div> <div>Ho - Lateral force per length of pile,</div> <div>$H_o = \frac{V_x}{1.57 \text{ } D}$</div> <div>$H_o = \frac{(-6.228 \text{ kip})}{1.57 \times (48 \text{ in})}$</div> <div>$H_o = -0.99172 \text{ kip/ft}$</div>	
Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)																										
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Mx (kipft)	-0.157	-0.263																											
Mz (kipft)	104.595	176.502																											

	<p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(104.59 \text{ kipft}) + ((-6.228 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 16.655 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation: $L_{e,x} = 9.2201 \text{ ft}$ - Required depth in x-direction,</p> <p>Considering z-direction:</p> <p>H_o - Lateral force per length of pile,</p> $H_o = \frac{V_z}{1.57 b}$ $H_o = \frac{(-0.034 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.005414 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_z H)}{1.57 b}$ $M_o = \frac{(0.157 \text{ kipft}) + ((-0.034 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 0.025 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation: $L_{e,z} = 1.1742 \text{ ft}$ - Required depth in z-direction,</p> <p>Minimum embedded depth required:</p> <p>$L_{e,req}$ - Depth of pile required,</p> $L_{e,req} = MAX[L_{e,x}, L_{e,z}]$ $L_{e,req} = MAX[(9.2201 \text{ ft}), (1.1742 \text{ ft})]$ $L_{e,req} = 9.22 \text{ ft}$ <p>L_e - Actual embedded length of pile,</p> $L_e = L - h_e - h_2$ $L_e = (10 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 10 \text{ ft}$ <p>Ratio - Embedded depth</p> $Ratio = \frac{L_{e,req}}{L_e}$ $Ratio = \frac{(9.22 \text{ ft})}{(10 \text{ ft})}$ $Ratio = 0.922$	<p>Status: PASS Ratio: 0.920</p>
	<p>End-bearing Capacity (ASD)</p> <p>A - Pile cross-section area</p> $A = b D$ $A = (48 \text{ in}) \times (48 \text{ in})$ $A = 16 \text{ ft}^2$ <p>q - End-bearing pressure</p>	

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

$$q = \frac{(10.1 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.63125 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$Ratio = \frac{(0.63125 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.31562$$

Status: **PASS**
Ratio: **0.320**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(10 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.5$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.99172 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 16.655 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (16.655 \text{ kipft/ft}) \times (10 \text{ ft})) + (3 \times (-0.99172 \text{ kip/ft}) \times (10 \text{ ft})^2)}{(6 \times (16.655 \text{ kipft/ft})) + (4 \times (-0.99172 \text{ kip/ft}) \times (10 \text{ ft}))}$$

$$a = 6.9035 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (16.655 \text{ kipft/ft})) + (3 \times (-0.99172 \text{ kip/ft}) \times (10 \text{ ft}))]^2}{(10 \text{ ft})^2 \times [(3 \times (16.655 \text{ kipft/ft})) + (2 \times (-0.99172 \text{ kip/ft}) \times (10 \text{ ft}))]}$$

$$p = 0.33836 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (16.655 \text{ kipft/ft})) + ((-0.99172 \text{ kip/ft}) \times (10 \text{ ft}))]}{(10 \text{ ft})^2}$$

$$s = 1.4036 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.9035 \text{ ft})}{2}$$

$$p_a = 0.51776 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

	$Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.33836 \text{ kip/ft}^2)}{(0.51776 \text{ kip/ft}^2)}$ $Ratio = 0.6535$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (10 \text{ ft})$ $p_s = 1.5 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{s}{p_s}$ $Ratio = \frac{(1.4036 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$ $Ratio = 0.93573$	<p>Status: PASS Ratio: 0.650</p> <p>Status: PASS Ratio: 0.940</p>
	<p>Considering z-direction:</p> <p>$H_o = -0.005414 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.025 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.025 \text{ kipft/ft}) \times (10 \text{ ft})) + (3 \times (-0.005414 \text{ kip/ft}) \times (10 \text{ ft})^2)}{(6 \times (0.025 \text{ kipft/ft})) + (4 \times (-0.005414 \text{ kip/ft}) \times (10 \text{ ft}))}$ $a = 7.159 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.025 \text{ kipft/ft})) + (3 \times (-0.005414 \text{ kip/ft}) \times (10 \text{ ft}))]^2}{(10 \text{ ft})^2 \times [(3 \times (0.025 \text{ kipft/ft})) + (2 \times (-0.005414 \text{ kip/ft}) \times (10 \text{ ft}))]}$ $p = -0.00087807 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.025 \text{ kipft/ft})) + ((-0.005414 \text{ kip/ft}) \times (10 \text{ ft}))]}{(10 \text{ ft})^2}$ $s = -0.00024841 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(7.159 \text{ ft})}{2}$ $p_a = 0.53692 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(-0.00087807 \text{ kip/ft}^2)}{(0.53692 \text{ kip/ft}^2)}$	

$$Ratio = -0.0016354$$

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

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (10 \text{ ft})$$

$$p_s = 1.5 \text{ kip/ft}^2$$

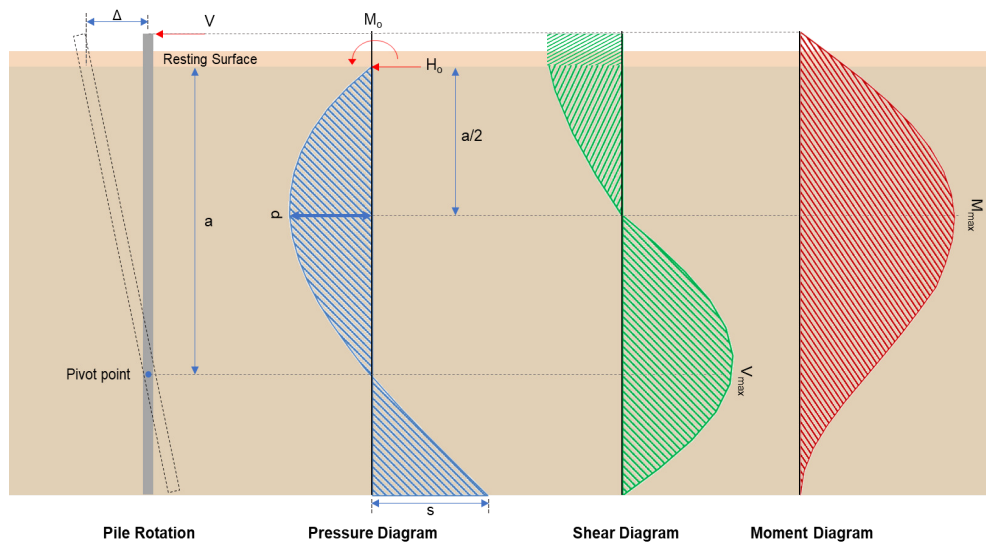
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(-0.00024841 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$$

$$Ratio = -0.00016561$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-10.38 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.6529 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(176.5 \text{ kipft}) + ((-10.38 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 28.105 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(28.105 \text{ kipft/ft})}{(-1.6529 \text{ kip/ft})}$$

$$E = 17.004 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (28.105 \text{ kipft/ft}) \times (10 \text{ ft})) + (3 \times (-1.6529 \text{ kip/ft}) \times (10 \text{ ft})^2)}{6 \times (28.105 \text{ kipft/ft}) + 4 \times (-1.6529 \text{ kip/ft}) \times 10 \text{ ft}}$$

$$a = \frac{(6 \times (28.105 \text{ kipft/ft})) + (4 \times (-1.6529 \text{ kip/ft}) \times (10 \text{ ft}))}{}$$

$$a = 6.9014 \text{ ft}$$

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

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

$$V_{max} = ((-1.6529 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.004 \text{ ft})}{(10 \text{ ft})} + 3 \right) \times \left(\frac{(6.9014 \text{ ft})}{(10 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (17.004 \text{ ft})}{(10 \text{ ft})} + 2 \right) \times \left(\frac{(6.9014 \text{ ft})}{(10 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 24.254 \text{ kip}$$

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

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

$$M_{max} = ((-1.6529 \text{ kip/ft}) \times (48 \text{ in}) \times (10 \text{ ft})) \times \left[\left(\frac{(17.004 \text{ ft})}{(10 \text{ ft})} + \frac{(6.9014 \text{ ft})}{2 \times (10 \text{ ft})} \right) - \left[\left(\frac{4 \times (17.004 \text{ ft})}{(10 \text{ ft})} + 3 \right) \times \left(\frac{(6.9014 \text{ ft})}{2 \times (10 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (17.004 \text{ ft})}{(10 \text{ ft})} + 2 \right) \times \left(\frac{(6.9014 \text{ ft})}{2 \times (10 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 115.27 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{1.57 b}$$

$$H_o = \frac{(-0.057 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0090764 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z H)}{1.57 b}$$

$$M_o = \frac{(0.263 \text{ kipft}) + ((-0.057 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.041879 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.041879 \text{ kipft/ft})}{(-0.0090764 \text{ kip/ft})}$$

$$E = 4.614 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.041879 \text{ kipft/ft}) \times (10 \text{ ft})) + (3 \times (-0.0090764 \text{ kip/ft}) \times (10 \text{ ft})^2)}{(6 \times (0.041879 \text{ kipft/ft})) + (4 \times (-0.0090764 \text{ kip/ft}) \times (10 \text{ ft}))}$$

$$a = 7.1591 \text{ ft}$$

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

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

$$V_{max} = ((-0.0090764 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.614 \text{ ft})}{(10 \text{ ft})} + 3 \right) \times \left(\frac{(7.1591 \text{ ft})}{(10 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.614 \text{ ft})}{(10 \text{ ft})} + 2 \right) \times \left(\frac{(7.1591 \text{ ft})}{(10 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.053861 \text{ kip}$$

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

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

$$M_{max} = ((-0.0090764 \text{ kip/ft}) \times (48 \text{ in}) \times (10 \text{ ft})) \times \left[\left(\frac{(4.614 \text{ ft})}{(10 \text{ ft})} + \frac{(7.1591 \text{ ft})}{2 \times (10 \text{ ft})} \right) - \left[\left(\frac{4 \times (4.614 \text{ ft})}{(10 \text{ ft})} + 3 \right) \times \left(\frac{(7.1591 \text{ ft})}{2 \times (10 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.614 \text{ ft})}{(10 \text{ ft})} + 2 \right) \times \left(\frac{(7.1591 \text{ ft})}{2 \times (10 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.23696 \text{ kipft}$$

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, $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = Min \left[\frac{\frac{(14.902 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.101 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max [(-84.101 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>s_{rebar} - Minimum spacing of reinforcement,</p> $s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>25.7.2.2 Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>25.7.2.1 s_{ties} - Maximum spacing of ties,</p> $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p>$Ratio$ - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(14.902 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0055705$	<p>Status: PASS Ratio: 0.010</p>
<p>22.5.2.2</p> <p>22.5.1.3</p> <p>22.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p>λ_s - size effect modification factor</p> $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

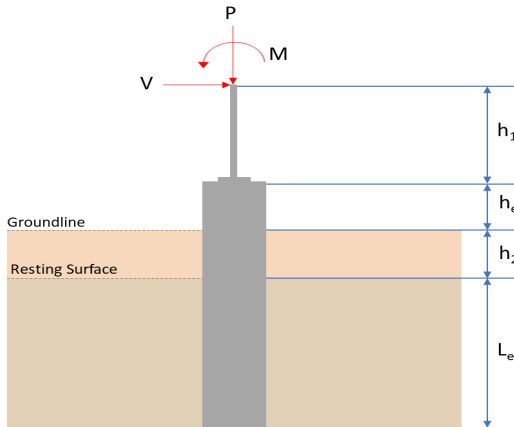
		$V_{c,max} = 296.21 \text{ kip}$	
22.5.5.1.1(a)	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 14.902 \text{ kip} \rightarrow 14902 \text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a)	$V_{c,a} = \left[2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$ $V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(14902 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,a} = 120.47 \text{ kip}$	
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	$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$ $V_c = \text{Min}[(296.21 \text{ kip}), (120.47 \text{ kip}), (348.89 \text{ kip})]$ $V_c = 120.47 \text{ kip}$	
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)	$V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$	
	V_s - Governing shear strength of steel	$V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$	
22.5.1.1	ϕV_n - Allowable shear strength	$\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.47 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.39 \text{ kip}$	
	Considering x-direction:		
	V_{max} = 24.254 kip - Maximum shear force in the x-direction, $Ratio$ - Capacity	$Ratio = \frac{V_{max}}{\phi V_n}$	

	$Ratio = \frac{(24.254 \text{ kip})}{(111.39 \text{ kip})}$ $Ratio = 0.21774$ <p>Considering z-direction:</p> <p>$V_{max} = 0.053861 \text{ kip}$ - Maximum shear force in the z-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.053861 \text{ kip})}{(111.39 \text{ kip})}$ $Ratio = 0.00048355$	<p>Status: PASS Ratio: 0.220</p> <p>Status: PASS Ratio: 0.000</p>
14.5.2.1b	<p>Flexural Strength (ACI 318-19, LRFD)</p> <p>S_m - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ <p>Considering x-direction:</p> <p>$M_{max} = 115.27 \text{ kipft}$ - Maximum moment in the x-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(115.27 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.4618$	<p>Status: PASS Ratio: 0.460</p>
	<p>Considering z-direction:</p> <p>$M_{max} = 0.23696 \text{ kipft}$ - Maximum moment in the z-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$	

$$Ratio = \frac{(0.23696 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.00094935$$

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

REFERENCES	CALCULATIONS	RESULTS																											
	<div>SkyCiv Foundation Design</div> <div>Pile Foundation</div> <div>Design Information :</div> <div>Design code : IBC 2021 (International Building Code)</div> <div>Unit System : Imperial</div>																												
	<div>Pile Input</div> <div></div> <div>Geometry</div> <div>Pile shape: rectangular</div> <div>b = 48 in - Pile width</div> <div>D = 48 in - Pile depth</div> <div>L = 10 ft - Total pile length</div> <div>h1 = 0 ft - Lateral load height from the top of the pile,</div> <div>h2 = 0 ft - Depth to resisting surface</div> <div>he = 0 ft - Length of pile above the ground</div> <div>Tabulation of Soil Parameters</div> <table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa) (psf)</th><th>Allowable Lateral Pressure (R) (psf/ft)</th></tr><tr><td>1</td><td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td><td>2000.000</td><td>150.000</td></tr></table> <div>Tabulation of Loads</div> <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>10.100</td><td>14.902</td></tr><tr><td>Vx (kip)</td><td>-6.228</td><td>-10.380</td></tr><tr><td>Vz (kip)</td><td>0.034</td><td>0.057</td></tr><tr><td>Mx (kipft)</td><td>0.157</td><td>0.263</td></tr><tr><td>Mz (kipft)</td><td>104.595</td><td>176.503</td></tr></table> <div>Material Properties</div> <div>f'ck = 2.5 ksi - Concrete strength,</div>	Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	10.100	14.902	Vx (kip)	-6.228	-10.380	Vz (kip)	0.034	0.057	Mx (kipft)	0.157	0.263	Mz (kipft)	104.595	176.503	<div>Required depth to resist lateral loads (ASD)</div> <div>H - Point of application of the lateral load</div> <div>$H = h_1 + h_2 + h_e$</div> <div>$H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$</div> <div>$H = 0 \text{ ft}$</div> <div>Considering x-direction:</div> <div>Ho - Lateral force per length of pile,</div> <div>$H_o = \frac{V_x}{1.57 \text{ } D}$</div> <div>$H_o = \frac{(-6.228 \text{ kip})}{1.57 \times (48 \text{ in})}$</div> <div>$H_o = -0.99172 \text{ kip/ft}$</div>	
Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)																										
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000																										
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Mz (kipft)	104.595	176.503																											

	<p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(104.59 \text{ kipft}) + ((-6.228 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 16.655 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation: $L_{e,x} = 9.2201 \text{ ft}$ - Required depth in x-direction,</p> <p>Considering z-direction:</p> <p>H_o - Lateral force per length of pile,</p> $H_o = \frac{V_z}{1.57 b}$ $H_o = \frac{(0.034 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = 0.005414 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_z H)}{1.57 b}$ $M_o = \frac{(0.157 \text{ kipft}) + ((0.034 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 0.025 \text{ kipft/ft}$ <p>Required depth of embedment in earth:</p> $L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ <p>Solving the cubic equation: $L_{e,z} = 1.3457 \text{ ft}$ - Required depth in z-direction,</p> <p>Minimum embedded depth required:</p> <p>$L_{e,req}$ - Depth of pile required,</p> $L_{e,req} = MAX[L_{e,x}, L_{e,z}]$ $L_{e,req} = MAX[(9.2201 \text{ ft}), (1.3457 \text{ ft})]$ $L_{e,req} = 9.22 \text{ ft}$ <p>L_e - Actual embedded length of pile,</p> $L_e = L - h_e - h_2$ $L_e = (10 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 10 \text{ ft}$ <p>Ratio - Embedded depth</p> $Ratio = \frac{L_{e,req}}{L_e}$ $Ratio = \frac{(9.22 \text{ ft})}{(10 \text{ ft})}$ $Ratio = 0.922$	<p>Status: PASS Ratio: 0.920</p>
	<p>End-bearing Capacity (ASD)</p> <p>A - Pile cross-section area</p> $A = b D$ $A = (48 \text{ in}) \times (48 \text{ in})$ $A = 16 \text{ ft}^2$ <p>q - End-bearing pressure</p>	

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

$$q = \frac{(10.1 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.63125 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$Ratio = \frac{(0.63125 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.31562$$

Status: **PASS**
Ratio: **0.320**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(10 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 2.5$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.99172 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 16.655 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (16.655 \text{ kipft/ft}) \times (10 \text{ ft})) + (3 \times (-0.99172 \text{ kip/ft}) \times (10 \text{ ft})^2)}{(6 \times (16.655 \text{ kipft/ft})) + (4 \times (-0.99172 \text{ kip/ft}) \times (10 \text{ ft}))}$$

$$a = 6.9035 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (16.655 \text{ kipft/ft})) + (3 \times (-0.99172 \text{ kip/ft}) \times (10 \text{ ft}))]^2}{(10 \text{ ft})^2 \times [(3 \times (16.655 \text{ kipft/ft})) + (2 \times (-0.99172 \text{ kip/ft}) \times (10 \text{ ft}))]}$$

$$p = 0.33836 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (16.655 \text{ kipft/ft})) + ((-0.99172 \text{ kip/ft}) \times (10 \text{ ft}))]}{(10 \text{ ft})^2}$$

$$s = 1.4036 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(6.9035 \text{ ft})}{2}$$

$$p_a = 0.51776 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

	$Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.33836 \text{ kip/ft}^2)}{(0.51776 \text{ kip/ft}^2)}$ $Ratio = 0.6535$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (10 \text{ ft})$ $p_s = 1.5 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{s}{p_s}$ $Ratio = \frac{(1.4036 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$ $Ratio = 0.93573$	<p>Status: PASS Ratio: 0.650</p> <p>Status: PASS Ratio: 0.940</p>
	<p>Considering z-direction:</p> <p>$H_o = 0.005414 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.025 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.025 \text{ kipft/ft}) \times (10 \text{ ft})) + (3 \times (0.005414 \text{ kip/ft}) \times (10 \text{ ft})^2)}{(6 \times (0.025 \text{ kipft/ft})) + (4 \times (0.005414 \text{ kip/ft}) \times (10 \text{ ft}))}$ $a = 7.159 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.025 \text{ kipft/ft})) + (3 \times (0.005414 \text{ kip/ft}) \times (10 \text{ ft}))]^2}{(10 \text{ ft})^2 \times [(3 \times (0.025 \text{ kipft/ft})) + (2 \times (0.005414 \text{ kip/ft}) \times (10 \text{ ft}))]}$ $p = 0.002818 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.025 \text{ kipft/ft})) + ((0.005414 \text{ kip/ft}) \times (10 \text{ ft}))]}{(10 \text{ ft})^2}$ $s = 0.0062484 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(7.159 \text{ ft})}{2}$ $p_a = 0.53692 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.002818 \text{ kip/ft}^2)}{(0.53692 \text{ kip/ft}^2)}$	

$$Ratio = 0.0052484$$

Status: **PASS**
Ratio: **0.010**

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (10 \text{ ft})$$

$$p_s = 1.5 \text{ kip/ft}^2$$

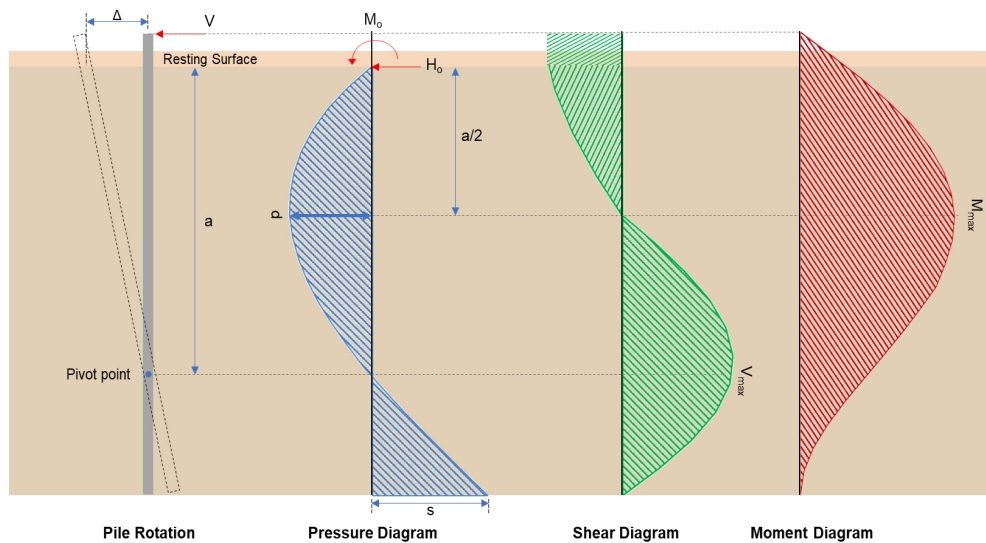
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.0062484 \text{ kip/ft}^2)}{(1.5 \text{ kip/ft}^2)}$$

$$Ratio = 0.0041656$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-10.38 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -1.6529 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(176.5 \text{ kipft}) + ((-10.38 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 28.106 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(28.106 \text{ kipft/ft})}{(-1.6529 \text{ kip/ft})}$$

$$E = 17.004 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (28.106 \text{ kipft/ft}) \times (10 \text{ ft})) + (3 \times (-1.6529 \text{ kip/ft}) \times (10 \text{ ft})^2)}{(6 \times (28.106 \text{ kipft/ft})) + (4 \times (-1.6529 \text{ kip/ft}) \times (10 \text{ ft}))}$$

$$a = \frac{(-1.6529 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (28.106 \text{ kip/ft})) + (4 \times (-1.6529 \text{ kip/ft}) \times (10 \text{ ft}))}$$

$$a = 6.9014 \text{ ft}$$

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

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

$$V_{max} = ((-1.6529 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (17.004 \text{ ft})}{(10 \text{ ft})} + 3 \right) \times \left(\frac{(6.9014 \text{ ft})}{(10 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (17.004 \text{ ft})}{(10 \text{ ft})} + 2 \right) \times \left(\frac{(6.9014 \text{ ft})}{(10 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 24.254 \text{ kip}$$

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

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

$$M_{max} = ((-1.6529 \text{ kip/ft}) \times (48 \text{ in}) \times (10 \text{ ft})) \times \left[\left(\frac{(17.004 \text{ ft})}{(10 \text{ ft})} + \frac{(6.9014 \text{ ft})}{2 \times (10 \text{ ft})} \right) - \left[\left(\frac{4 \times (17.004 \text{ ft})}{(10 \text{ ft})} + 3 \right) \times \left(\frac{(6.9014 \text{ ft})}{2 \times (10 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (17.004 \text{ ft})}{(10 \text{ ft})} + 2 \right) \times \left(\frac{(6.9014 \text{ ft})}{2 \times (10 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 115.27 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{1.57 b}$$

$$H_o = \frac{(0.057 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0090764 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z H)}{1.57 b}$$

$$M_o = \frac{(0.263 \text{ kipft}) + ((0.057 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.041879 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.041879 \text{ kipft/ft})}{(0.0090764 \text{ kip/ft})}$$

$$E = 4.614 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.041879 \text{ kipft/ft}) \times (10 \text{ ft})) + (3 \times (0.0090764 \text{ kip/ft}) \times (10 \text{ ft})^2)}{(6 \times (0.041879 \text{ kipft/ft})) + (4 \times (0.0090764 \text{ kip/ft}) \times (10 \text{ ft}))}$$

$$a = 7.1591 \text{ ft}$$

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

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

$$V_{max} = ((0.0090764 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.614 \text{ ft})}{(10 \text{ ft})} + 3 \right) \times \left(\frac{(7.1591 \text{ ft})}{(10 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (4.614 \text{ ft})}{(10 \text{ ft})} + 2 \right) \times \left(\frac{(7.1591 \text{ ft})}{(10 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.053861 \text{ kip}$$

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

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

$$M_{max} = ((0.0090764 \text{ kip/ft}) \times (48 \text{ in}) \times (10 \text{ ft})) \times \left[\left(\frac{(4.614 \text{ ft})}{(10 \text{ ft})} + \frac{(7.1591 \text{ ft})}{2 \times (10 \text{ ft})} \right) - \left[\left(\frac{4 \times (4.614 \text{ ft})}{(10 \text{ ft})} + 3 \right) \times \left(\frac{(7.1591 \text{ ft})}{2 \times (10 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (4.614 \text{ ft})}{(10 \text{ ft})} + 2 \right) \times \left(\frac{(7.1591 \text{ ft})}{2 \times (10 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.23696 \text{ kipft}$$

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, $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = Min \left[\frac{\frac{(14.902 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.101 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max [(-84.101 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p>	<p>$s_{rebar} = 0.96556$</p> <p>s_{rebar} - Minimum spacing of reinforcement,</p> $s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>25.7.2.2 Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>25.7.2.1 s_{ties} - Maximum spacing of ties,</p> $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p>Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p>$Ratio$ - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(14.902 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0055705$	<p>Status: PASS Ratio: 0.010</p>
<p>22.5.2.2</p> <p>22.5.1.3</p> <p>22.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p>λ_s - size effect modification factor</p> $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

		$V_{c,max} = 296.21 \text{ kip}$	
22.5.5.1.1(a)	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 14.902 \text{ kip} \rightarrow 14902 \text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a)	$V_{c,a} = \left[2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$ $V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(14902 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,a} = 120.47 \text{ kip}$	
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	$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$ $V_c = \text{Min}[(296.21 \text{ kip}), (120.47 \text{ kip}), (348.89 \text{ kip})]$ $V_c = 120.47 \text{ kip}$	
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)	$V_{s,b} = \frac{2 A_v f_{yw} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$	
	V_s - Governing shear strength of steel	$V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(737.28 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$	
22.5.1.1	ϕV_n - Allowable shear strength	$\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((120.47 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 111.39 \text{ kip}$	
	Considering x-direction: V_{max} = 24.254 kip - Maximum shear force in the x-direction, $Ratio$ - Capacity	$Ratio = \frac{V_{max}}{\phi V_n}$	

	$Ratio = \frac{(24.254 \text{ kip})}{(111.39 \text{ kip})}$ $Ratio = 0.21774$ <p>Considering z-direction:</p> <p>$V_{max} = 0.053861 \text{ kip}$ - Maximum shear force in the z-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.053861 \text{ kip})}{(111.39 \text{ kip})}$ $Ratio = 0.00048355$	<p>Status: PASS Ratio: 0.220</p> <p>Status: PASS Ratio: 0.000</p>
14.5.2.1b	<p>Flexural Strength (ACI 318-19, LRFD)</p> <p>S_m - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ <p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ <p>Considering x-direction:</p> <p>$M_{max} = 115.27 \text{ kipft}$ - Maximum moment in the x-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(115.27 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.46181$	<p>Status: PASS Ratio: 0.460</p>
	<p>Considering z-direction:</p> <p>$M_{max} = 0.23696 \text{ kipft}$ - Maximum moment in the z-direction, <i>Ratio</i> - Capacity</p> $Ratio = \frac{M_{max}}{\phi M_n}$	

$$Ratio = \frac{(0.23696 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.00094935$$

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