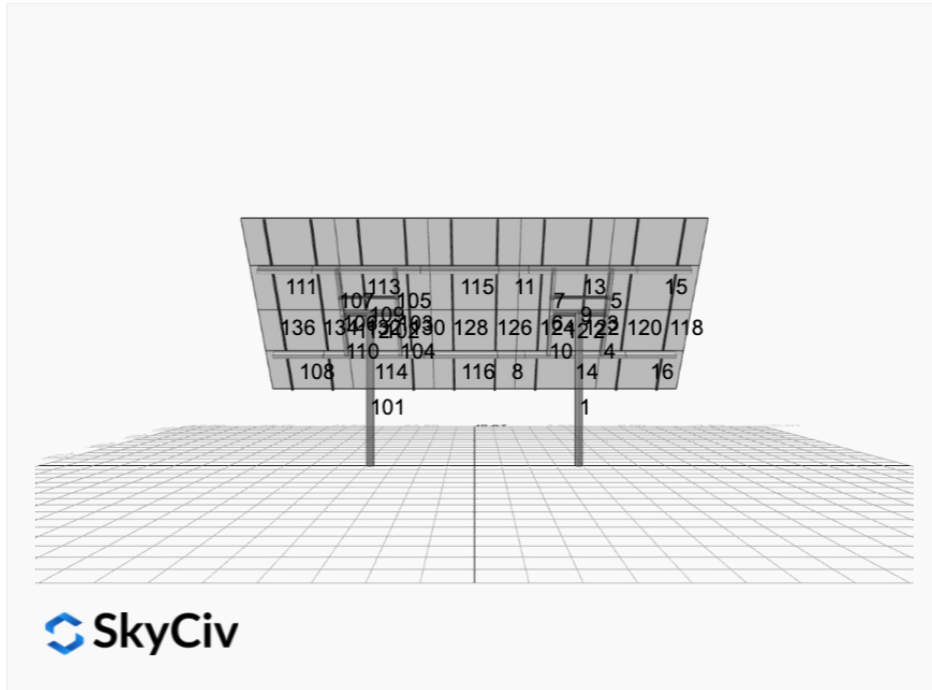


Project Details



Project Name: Grant Harvey-V2 5ft frnt clear
Location: 6410 Co Rd 250, Durango, CO 81301, USA
Unique ID: 2P-15-6TOP-SD-45-L-4Hx5W-HC18
Dealer: _____

Date: Tue Jun 24 2025
Number of Modules: 20
Number of Poles: 2
Date Sold: _____



Array Dimensions N/S	15.04 ft
Array Dimensions E/W	31.33 ft
Winter Tilt Angle	52
Front Edge Clearance	5 ft

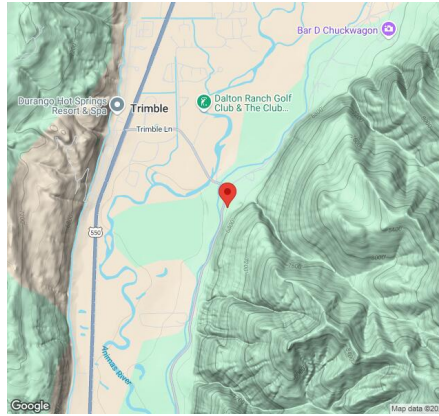
MT Solar Bill of Materials (2P-15-6TOP-SD-45-L-4Hx5W-HC18)

Part	Short Description	BOM Qty
MTS-PC-6	6IN Pole Cap Assembly	2
MTS-HF-SD	H-Frame Assembly-SD	2
MTS-SD-Wing-45	45IN SD Wing	4
MTS-SD-Splice-90	90IN SD Splice	2
MTS-CLAMP-HOOK-4PK	Hook Clamp	5

Rail Bill of Materials

Part	Qty
Rails (181in)	10
Rail Attachment	20
Module Mid Clamp	30
Module End Clamp	20
Ground Lug	5

Site Details:



Site Address: 6410 Co Rd 250, Durango, CO 81301, USA

Array Specification

Duty Classification:	SD
Module Width:	44.63 in
Module Length:	74.20in
Number of Rows:	4
Number of Columns:	5
Total Number of Modules:	20
Winter Tilt Angle:	52
Front Edge Clearance:	5
Total Array Height at Tilt:	16.85 ft
Total Frame Length:	30.00 ft
Module Info/Notes:	seg 485
Array Dimensions N/S:	15.04 ft
Array Dimensions E/W:	31.33 ft
Rail Length:	180.50 in
Rail Spacing:	3.13 ft

Support Specifications

Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	10.93 ft
Number of Poles:	2
Pole Spacing:	15 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 5.50 ft Pile 2: 5.50 ft
Foundation Volume:	6.519 y ³

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	6410 Co Rd 250, Durango, CO 81301, USA
Wind Speed:	90 mph
Snow Load:	60 psf

Design Disclaimer

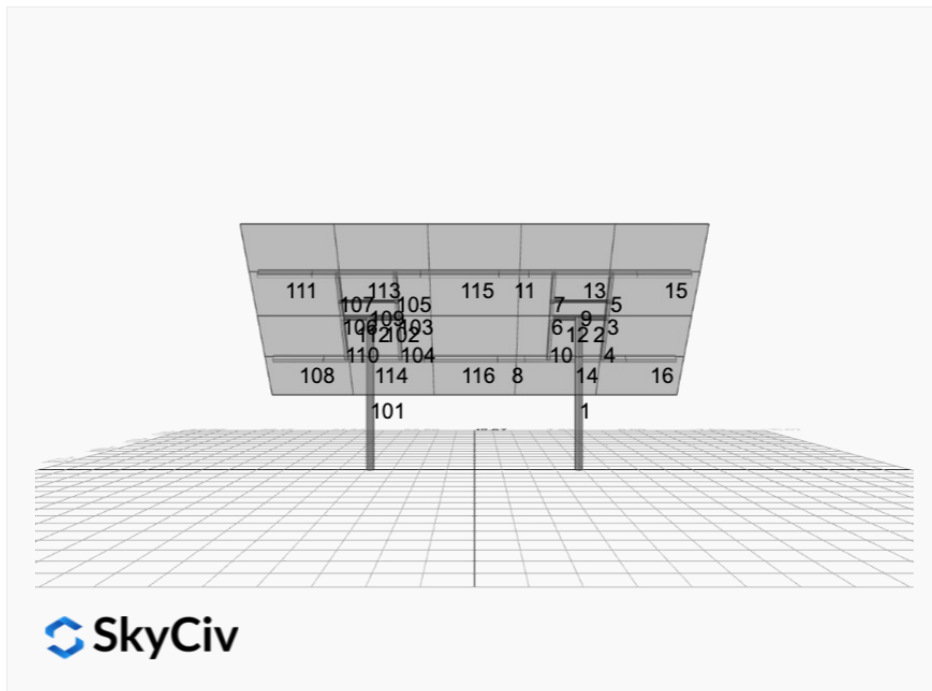
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

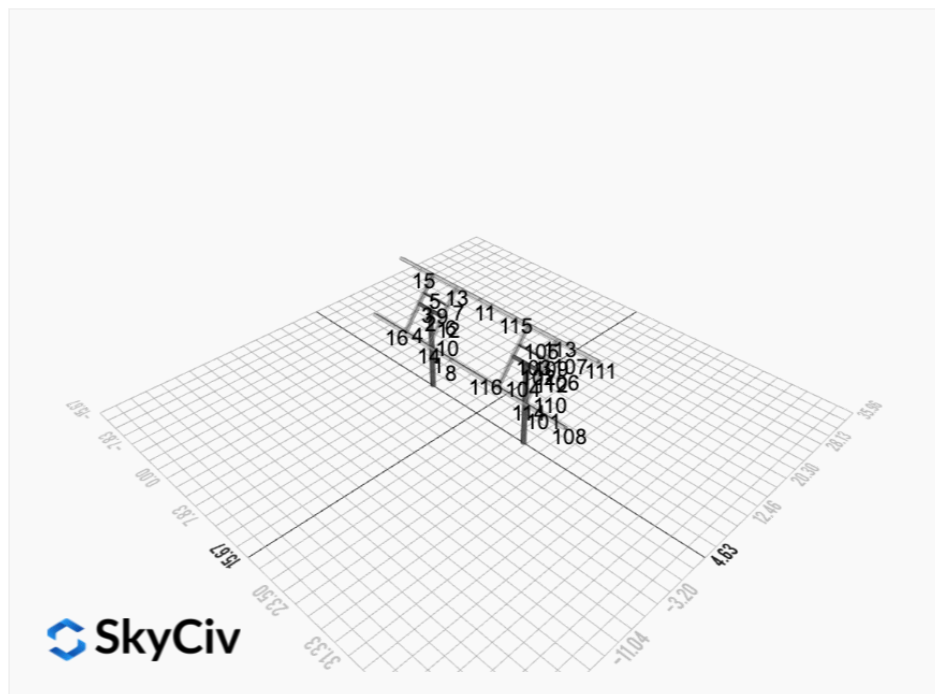
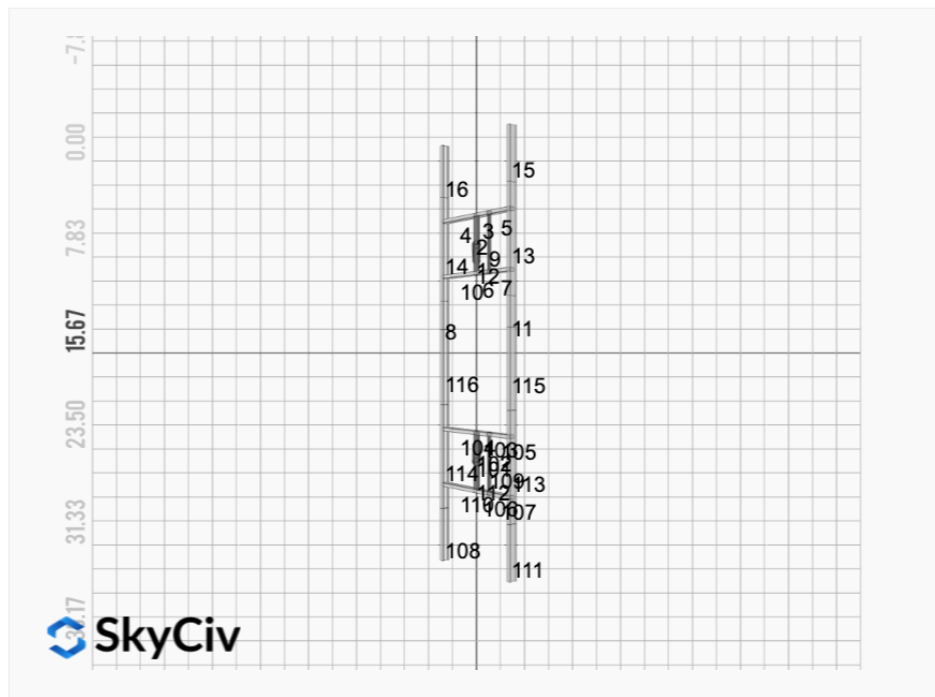
AutoDesigner Input

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Design Notes:

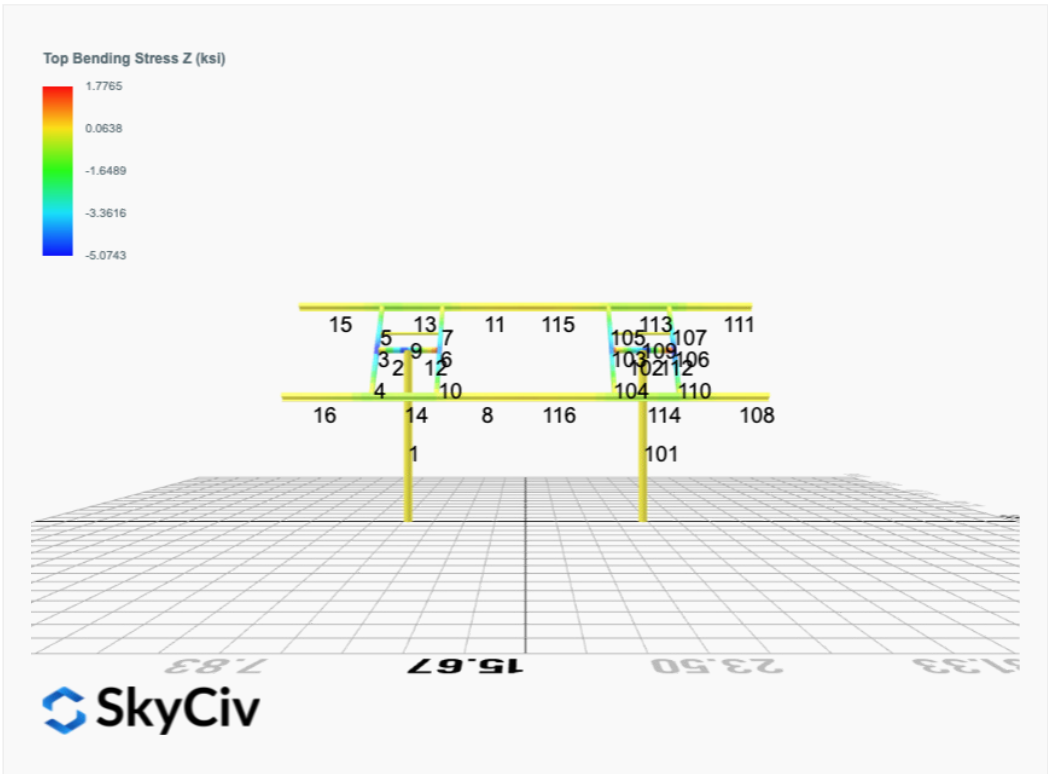
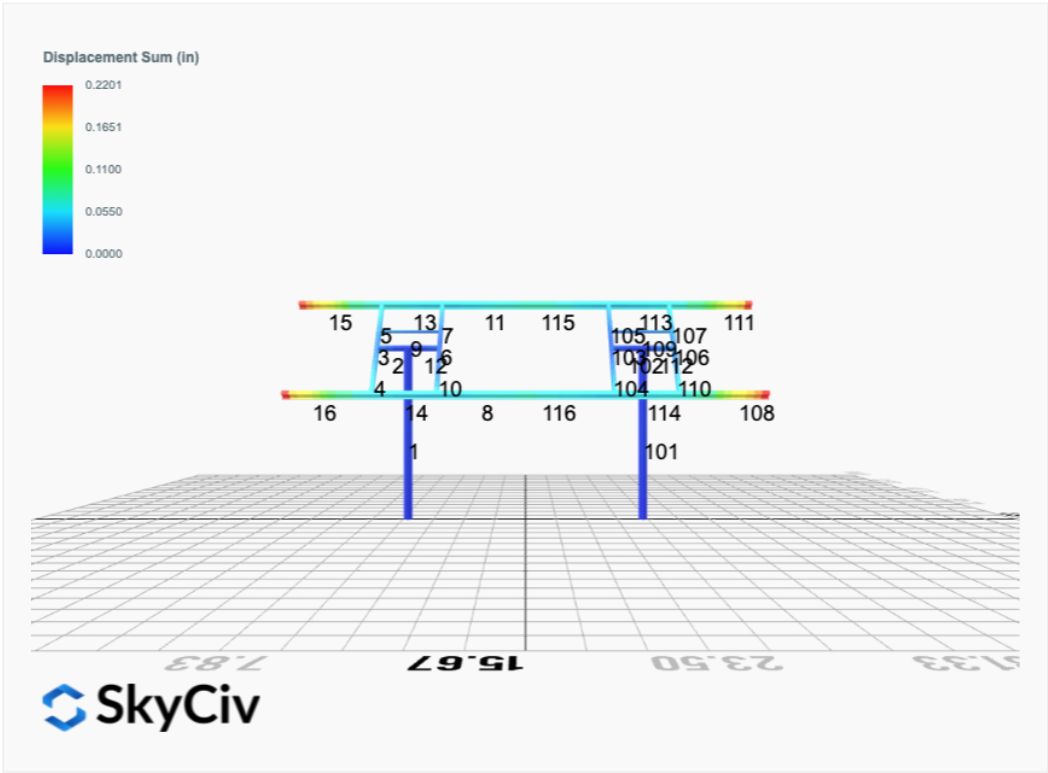
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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



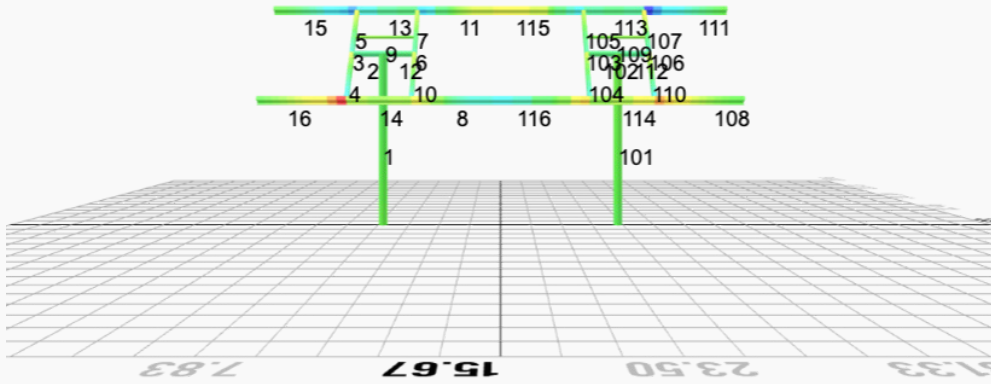




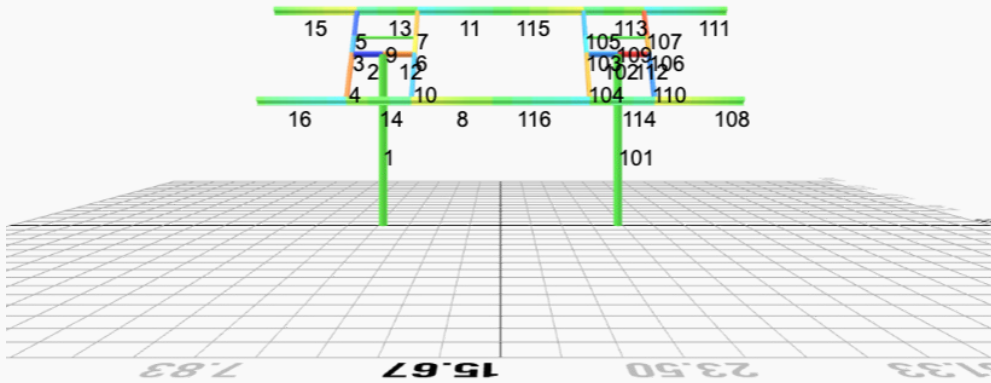
FEM Results (Envelope Worst Case for each member)

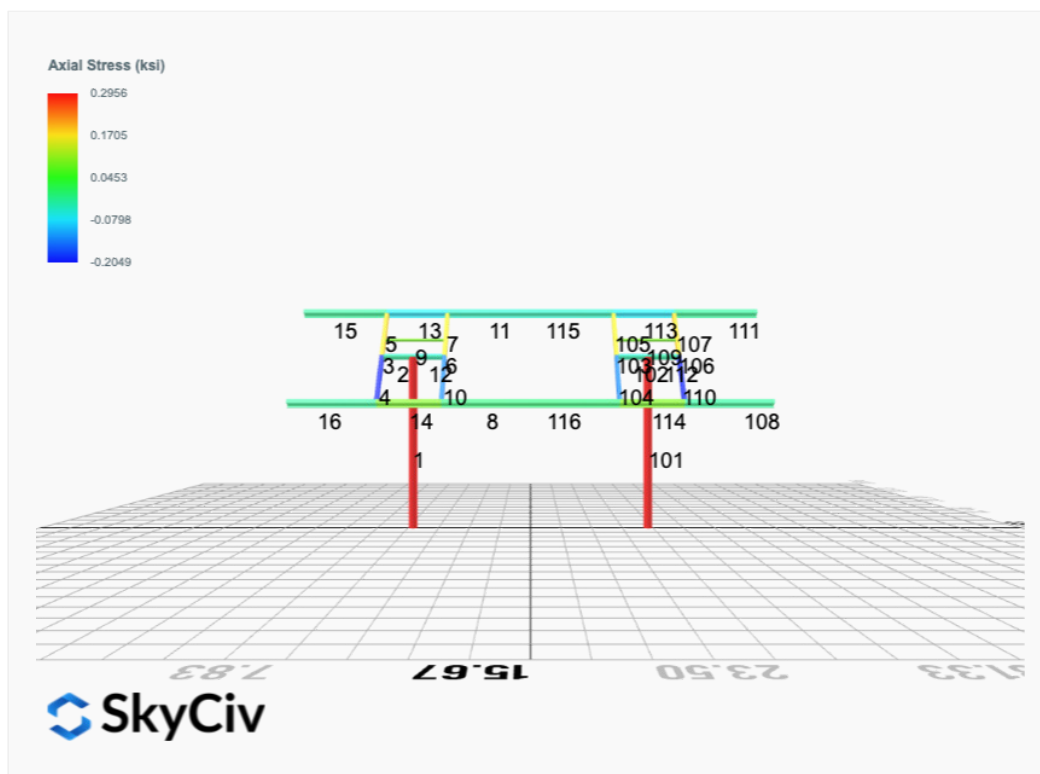


Top Bending Stress Y (ksi)



Shear Stress Y (ksi)





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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 2. D + L	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 3. D + (S or Lr or R)	-0.0001	3.3716	-0.0555	-0.1898	0.1311	0.0209
ULS: 3. D + (S or Lr or R)	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0001	2.9592	-0.0479	-0.1639	0.1132	0.0195
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 5b. D + 0.7E	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0001	2.9592	-0.0479	-0.1639	0.1132	0.0195
ULS: 8. 0.6D + 0.7E	-0.0000	1.0331	-0.0151	-0.0517	0.0357	0.0093
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.5588	2.9398	-0.0728	-0.2459	0.2336	17.2943
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5587	0.5040	0.0225	0.0734	-0.1149	-16.7775
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1691	3.8726	-0.0837	-0.2837	0.2438	12.9786
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0001	2.9592	-0.0479	-0.1639	0.1132	0.0195
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1690	2.0458	-0.0122	-0.0442	-0.0176	-12.5752
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0001	2.9592	-0.0479	-0.1639	0.1132	0.0195
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1691	2.6353	-0.0609	-0.2060	0.1901	12.9746
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1690	0.8085	0.0106	0.0335	-0.0713	-12.5793
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	1.7219	-0.0252	-0.0861	0.0595	0.0155
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.5588	2.2510	-0.0628	-0.2115	0.2098	17.2881
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0000	1.0331	-0.0151	-0.0517	0.0357	0.0093
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5587	-0.1847	0.0326	0.1078	-0.1387	-16.7837
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0000	1.0331	-0.0151	-0.0517	0.0357	0.0093

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	5.7208
Shear X	-2.5980
Shear Z	-0.1247
Moment X	-0.4220
Moment Y (Twist)	0.3963
Moment Z	29.4640

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	3.8726
Shear X	-1.5588
Shear Z	-0.0837
Moment X	-0.2837
Moment Y (Twist)	0.2438
Moment Z	17.2943

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	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 2. D + L	0.0000	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 3. D + (S or Lr or R)	0.0001	3.3715	0.0555	0.1888	-0.1323	0.0192
ULS: 3. D + (S or Lr or R)	0.0000	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0001	2.9591	0.0479	0.1630	-0.1143	0.0181

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 5b. D + 0.7E	0.0000	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0001	2.9591	0.0479	0.1630	-0.1143	0.0181
ULS: 8. 0.6D + 0.7E	0.0000	1.0331	0.0151	0.0514	-0.0361	0.0089
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.5586	2.9395	0.0728	0.2440	-0.2354	17.2920
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0000	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.5586	0.5042	-0.0225	-0.0723	0.1155	-16.7768
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0000	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1689	3.8724	0.0837	0.2817	-0.2457	12.9760
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0001	2.9591	0.0479	0.1630	-0.1143	0.0181
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1690	2.0459	0.0122	0.0445	0.0175	-12.5756
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0001	2.9591	0.0479	0.1630	-0.1143	0.0181
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.1689	2.6351	0.0609	0.2044	-0.1916	12.9727
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.1690	0.8086	-0.0106	-0.0328	0.0716	-12.5789
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	1.7219	0.0252	0.0857	-0.0601	0.0148
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.5586	2.2508	0.0628	0.2097	-0.2114	17.2861
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0000	1.0331	0.0151	0.0514	-0.0361	0.0089
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.5586	-0.1846	-0.0326	-0.1066	0.1396	-16.7827
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0000	1.0331	0.0151	0.0514	-0.0361	0.0089

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	5.7204
Shear X	-2.5977
Shear Z	0.1247
Moment X	0.4185
Moment Y (Twist)	0.3997
Moment Z	29.4606

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	3.8724
Shear X	-1.5586
Shear Z	0.0837
Moment X	0.2817
Moment Y (Twist)	0.2457
Moment Z	17.2920

Project Details

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

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



Design Input Information

Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

Section Dimensions								
ID	Name	d (in)	t_w (in)					
1	2in Pipe Sch 40	2.38	0.15					
4	4in Pipe Sch 40	4.50	0.24					
7	6in Pipe Sch 40	6.63	0.28					
ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
15	HSS5x3x1/8	5.00	3.00	0.12	0.12	0.12		
ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
18	W6x9	5.90	0.17	3.94	3.94	0.21	0.21	0.25

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

1	2in Pipe Sch 40	1.07	1.33	0.67	0.67	0.00	0.76	0.76
4	4in Pipe Sch 40	3.17	14.47	7.23	7.23	0.00	4.31	4.31
7	6in Pipe Sch 40	5.58	56.28	28.14	28.14	0.00	11.28	11.28
15	HSS5x3x1/8	1.77	6.02	2.75	6.03	0.51	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties									
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1	7	22.95	22.95	10.93	-	300	200	1	
2	4	2.00	1.30	2.00	-	300	200	1	
3	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1	
4	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68	300	200	1	
5	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1	
6	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18	300	200	1	
7	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1	
8	18	1.33	1.33	2.05	2.35,2.35,2.35,2.35,2.35,2.35,2.33,2.35,2.31,2.35,2.33,2.35,2.32,2.35,2.34,2.35,2.40,2.35,2.34,2.35,2.28,2.35,2.33,2.35,2.32,2.35	300	200	1	
9	1	2.60	2.60	4.00	-	300	200	1	
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11	18	1.33	1.33	2.05	2.36,2.36,2.36,2.35,2.36,2.36,2.34,2.36,2.31,2.36,2.34,2.36,2.32,2.36,2.35,2.35,2.40,2.35,2.34,2.36,2.30,2.36,2.34,2.36,2.33,2.36	300	200	1	
12	4	1.30	1.30	2.00	-	300	200	1	
13	18	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.09,1.10,1.10,1.10,1.10	300	200	1	
14	18	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.09,1.10,1.10,1.10,1.10	300	200	1	
15	18	7.88	7.88	3.75	2.33,2.32,3,2.33,2.33,2.33,2.33,2.33	300	200	1	
16	18	7.88	7.88	3.75	2.33,2.32,3,2.33,2.33,2.33,2.33,2.33	300	200	1	
101	7	22.95	22.95	10.93	-	300	200	1	
102	4	1.30	1.30	2.00	-	300	200	1	
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18,1.18,1.16,1.18,1.18,1.18,1.17,1.18	300	200	1	
104	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68	300	200	1	
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.65,1.67,1.67,1.67,1.66,1.67	300	200	1	
106	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1	
107	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1	
108	18	7.88	7.88	3.75	2.33,2.32,3,2.33,2.33,2.33,2.33,2.33	300	200	1	
109	1	2.60	2.60	4.00	-	300	200	1	
110	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.68,1.67,1.67,1.68,1.64,1.68,1.67,1.68,1.66,1.68	300	200	1	
111	18	7.88	7.88	3.75	2.33,2.32,3,2.33,2.33,2.33,2.33,2.33	300	200	1	
112	4	2.00	1.30	2.00	-	300	200	1	

113	18	4.88	4.00	7.5 0	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.0 9,1.10,1.10,1.10,1.10,1.10	30 0	20 0	1
114	18	4.88	4.00	7.5 0	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.0 9,1.10,1.10,1.10,1.10,1.10	30 0	20 0	1
115	18	3.54	3.54	5.4 5	1.83,1.83,1.83,1.83,1.83,1.83,1.90,1.83,2.03,1.83,1.91,1.83,1.98,1.83,1.87,1.83,1.59,1.83,1.90,1.83,2.1 0,1.83,1.91,1.83,1.97,1.83	30 0	20 0	1
116	18	5.45	5.45	5.4 5	1.84,1.85,1.84,1.85,1.85,1.84,1.93,1.85,2.04,1.85,1.93,1.84,1.99,1.84,1.90,1.85,1.61,1.85,1.91,1.84,2.1 2,1.84,1.94,1.84,1.98,1.84	30 0	20 0	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	251.16	83.86	42.30	42.30	75.35	75.35
2	142.83	140.22	16.17	16.17	42.85	42.85
3	79.65	74.89	10.99	6.26	29.14	16.61
4	79.65	72.84	10.99	6.26	29.14	16.61
5	79.65	74.30	10.99	6.26	29.14	16.61
6	79.65	74.89	10.99	6.26	29.14	16.61
7	79.65	74.30	10.99	6.26	29.14	16.61
8	120.60	115.40	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.84	10.99	6.26	29.14	16.61
11	120.60	115.40	23.36	6.45	30.09	45.74
12	142.83	141.72	16.17	16.17	42.85	42.85
13	120.60	84.03	19.27	6.45	30.09	45.74
14	120.60	84.03	19.25	6.45	30.09	45.74
15	120.60	54.44	23.36	6.45	30.09	45.74
16	120.60	54.44	23.36	6.45	30.09	45.74
101	251.16	83.86	42.30	42.30	75.35	75.35
102	142.83	141.72	16.17	16.17	42.85	42.85
103	79.65	74.89	10.99	6.26	29.14	16.61
104	79.65	72.84	10.99	6.26	29.14	16.61
105	79.65	74.30	10.99	6.26	29.14	16.61
106	79.65	74.89	10.99	6.26	29.14	16.61
107	79.65	74.30	10.99	6.26	29.14	16.61
108	120.60	54.44	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.84	10.99	6.26	29.14	16.61
111	120.60	54.44	23.36	6.45	30.09	45.74
112	142.83	140.22	16.17	16.17	42.85	42.85
113	120.60	84.03	19.26	6.45	30.09	45.74
114	120.60	84.03	19.27	6.45	30.09	45.74
115	120.60	95.07	23.36	6.45	30.09	45.74
116	120.60	82.39	23.36	6.45	30.09	45.74

Design Ratio

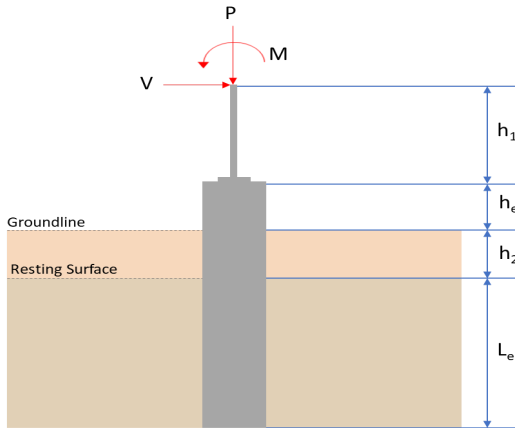
Member ID	P	M_z	M_y	V_y	V_z	(P, M_z , M_y)	Worst LC	KL/r	δ	Status
1	0.068	0.697	0.022	0.034	0.002	0.736	#13	0.613	Not Required	Pass
2	0.001	0.284	0.181	0.069	0.032	0.442	#13	0.079	Not Required	Pass
3	0.012	0.448	0.114	0.045	0.024	0.520	#13	0.044	Not Required	Pass
4	0.012	0.446	0.176	0.045	0.030	0.517	#21	0.078	Not Required	Pass

5	0.013	0.277	0.182	0.044	0.034	0.299	#13	0.073	Not Required	Pass
6	0.011	0.392	0.081	0.039	0.014	0.441	#13	0.044	Not Required	Pass
7	0.011	0.244	0.124	0.039	0.024	0.261	#13	0.073	Not Required	Pass
8	0.001	0.029	0.075	0.020	0.009	0.084	#21	0.088	Not Required	Pass
9	0.004	0.030	0.051	0.001	0.001	0.081	#13	0.198	Not Required	Pass
10	0.010	0.390	0.135	0.039	0.025	0.469	#13	0.078	Not Required	Pass
11	0.001	0.029	0.075	0.020	0.009	0.085	#21	0.059	Not Required	Pass
12	0.001	0.229	0.156	0.058	0.029	0.360	#13	0.034	Not Required	Pass
13	0.005	0.129	0.264	0.029	0.014	0.375	#21	0.177	Not Required	Pass
14	0.006	0.132	0.264	0.029	0.014	0.375	#21	0.177	Not Required	Pass
15	0.000	0.048	0.123	0.020	0.009	0.166	#21	Not Required	Not Required	Pass
16	0.000	0.048	0.123	0.020	0.009	0.166	#21	Not Required	Not Required	Pass
101	0.068	0.696	0.022	0.034	0.002	0.736	#13	0.613	Not Required	Pass
102	0.001	0.229	0.156	0.058	0.029	0.359	#13	0.034	Not Required	Pass
103	0.011	0.392	0.081	0.039	0.014	0.442	#13	0.044	Not Required	Pass
104	0.010	0.390	0.135	0.039	0.025	0.469	#13	0.078	Not Required	Pass
105	0.011	0.244	0.124	0.039	0.024	0.261	#13	0.073	Not Required	Pass
106	0.012	0.448	0.114	0.045	0.024	0.520	#13	0.044	Not Required	Pass
107	0.013	0.277	0.182	0.044	0.034	0.299	#13	0.073	Not Required	Pass
108	0.000	0.048	0.123	0.020	0.009	0.166	#21	Not Required	Not Required	Pass
109	0.004	0.030	0.051	0.001	0.001	0.081	#13	0.198	Not Required	Pass
110	0.012	0.446	0.176	0.045	0.030	0.517	#21	0.078	Not Required	Pass
111	0.000	0.048	0.123	0.020	0.009	0.166	#21	Not Required	Not Required	Pass
112	0.001	0.284	0.181	0.069	0.032	0.442	#13	0.079	Not Required	Pass
113	0.005	0.129	0.264	0.029	0.014	0.375	#21	0.177	Not Required	Pass
114	0.006	0.131	0.264	0.029	0.014	0.375	#21	0.265	Not Required	Pass
115	0.001	0.029	0.099	0.020	0.009	0.116	#21	0.156	Not Required	Pass
116	0.002	0.029	0.098	0.020	0.009	0.115	#21	0.361	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																											
	SkyCiv Foundation Design Pile Foundation Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial																												
	Pile Input  Geometry Pile shape: rectangular b = 48 in - Pile width D = 48 in - Pile depth L = 5.5 ft - Total pile length h1 = 0 ft - Lateral load height from the top of the pile, h2 = 0 ft - Depth to resisting surface he = 0 ft - Length of pile above the ground Tabulation of Soil Parameters <table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa) (psf)</th><th>Allowable Lateral Pressure (R) (psf/ft)</th></tr><tr><td>1</td><td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td><td>2000.000</td><td>150.000</td></tr></table> Tabulation of Loads <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>3.873</td><td>5.721</td></tr><tr><td>Vx (kip)</td><td>-1.559</td><td>-2.598</td></tr><tr><td>Vz (kip)</td><td>-0.084</td><td>-0.125</td></tr><tr><td>Mx (kipft)</td><td>-0.284</td><td>-0.422</td></tr><tr><td>Mz (kipft)</td><td>17.294</td><td>29.464</td></tr></table> Material Properties f'ck = 2.5 ksi - Concrete strength,	Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	3.873	5.721	Vx (kip)	-1.559	-2.598	Vz (kip)	-0.084	-0.125	Mx (kipft)	-0.284	-0.422	Mz (kipft)	17.294	29.464	Required depth to resist lateral loads (ASD) H - Point of application of the lateral load $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ Considering x-direction: Ho - Lateral force per length of pile, $H_o = \frac{V_x}{1.57 \text{ } D}$ $H_o = \frac{(-1.559 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.24825 \text{ kip/ft}$	
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)	3.873	5.721																											
Vx (kip)	-1.559	-2.598																											
Vz (kip)	-0.084	-0.125																											
Mx (kipft)	-0.284	-0.422																											
Mz (kipft)	17.294	29.464																											

	M_o - Moment per length of pile, $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(17.294 \text{ kipft}) + ((-1.559 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 2.7538 \text{ kipft/ft}$ Required depth of embedment in earth: $L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ Solving the cubic equation: $L_{e,x} = 5.2233 \text{ ft}$ - Required depth in x-direction, Considering z-direction: H_o - Lateral force per length of pile, $H_o = \frac{V_z}{1.57 b}$ $H_o = \frac{(-0.084 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.013376 \text{ kip/ft}$ M_o - Moment per length of pile, $M_o = \frac{M_x + (V_z H)}{1.57 b}$ $M_o = \frac{(0.284 \text{ kipft}) + ((-0.084 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 0.045223 \text{ kipft/ft}$ Required depth of embedment in earth: $L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ Solving the cubic equation: $L_{e,z} = 1.3616 \text{ ft}$ - Required depth in z-direction, Minimum embedded depth required: $L_{e,req}$ - Depth of pile required, $L_{e,req} = \text{MAX}[L_{e,x}, L_{e,z}]$ $L_{e,req} = \text{MAX}[(5.2233 \text{ ft}), (1.3616 \text{ ft})]$ $L_{e,req} = 5.223 \text{ ft}$ L_e - Actual embedded length of pile, $L_e = L - h_e - h_2$ $L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 5.5 \text{ ft}$ Ratio - Embedded depth $\text{Ratio} = \frac{L_{e,req}}{L_e}$ $\text{Ratio} = \frac{(5.223 \text{ ft})}{(5.5 \text{ ft})}$ $\text{Ratio} = 0.94964$	Status: PASS Ratio: 0.950
	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	

	$q = \frac{P_v}{A}$ $q = \frac{(3.873 \text{ kip})}{(16 \text{ ft}^2)}$ $q = 0.24206 \text{ kip/ft}^2$ Check bearing capacity ratio: Ratio - Capacity $\text{Ratio} = \frac{q}{q_a}$ $\text{Ratio} = \frac{(0.24206 \text{ kip/ft}^2)}{(2000 \text{ psf})}$ $\text{Ratio} = 0.12103$	Status: PASS Ratio: 0.120
Czerniak	Lateral Soil Pressure (ASD): L/D - Length to least lateral dimension ratio, $L/D = \frac{L}{D}$ $L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$ $L/D = 1.375$ Since $L/D \leq 10$, Pile is short. Considering x-direction: $H_o = -0.24825 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 2.7538 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (2.7538 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.7538 \text{ kipft/ft})) + (4 \times (-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.7805 \text{ ft}$ p - Earth pressure against the pile at distance $a/2$ from resting surface, $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (2.7538 \text{ kipft/ft})) + (3 \times (-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.7538 \text{ kipft/ft})) + (2 \times (-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = 0.21462 \text{ kip/ft}^2$ s - Earth pressure against the pile at distance L_e, $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (2.7538 \text{ kipft/ft})) + ((-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.82161 \text{ kip/ft}^2$ Check lateral soil pressure capacity: p_a - Allowable lateral soil pressure at depth $a/2$, $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.7805 \text{ ft})}{2}$ $p_a = 0.28354 \text{ kip/ft}^2$ Ratio - Lateral soil capacity	

	$Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.21462 \text{ kip/ft}^2)}{(0.28354 \text{ kip/ft}^2)}$ $Ratio = 0.75692$ p_s - Allowable lateral soil pressure at depth L_e, $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ Ratio - Lateral soil capacity $Ratio = \frac{s}{p_s}$ $Ratio = \frac{(0.82161 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$ $Ratio = 0.9959$	Status: PASS Ratio: 0.760 Status: PASS Ratio: 1.000
	Considering z-direction: $H_o = -0.013376 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.045223 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.045223 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.013376 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.045223 \text{ kipft/ft})) + (4 \times (-0.013376 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.9051 \text{ ft}$ p - Earth pressure against the pile at distance $a/2$ from resting surface, $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.045223 \text{ kipft/ft})) + (3 \times (-0.013376 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.045223 \text{ kipft/ft})) + (2 \times (-0.013376 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = -0.0034271 \text{ kip/ft}^2$ s - Earth pressure against the pile at distance L_e, $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.045223 \text{ kipft/ft})) + ((-0.013376 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.0033479 \text{ kip/ft}^2$ Check lateral soil pressure capacity: p_a - Allowable lateral soil pressure at depth $a/2$, $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.9051 \text{ ft})}{2}$ $p_a = 0.29288 \text{ kip/ft}^2$ Ratio - Lateral soil capacity $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(-0.0034271 \text{ kip/ft}^2)}{(0.29288 \text{ kip/ft}^2)}$	

$$Ratio = -0.011701$$

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

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

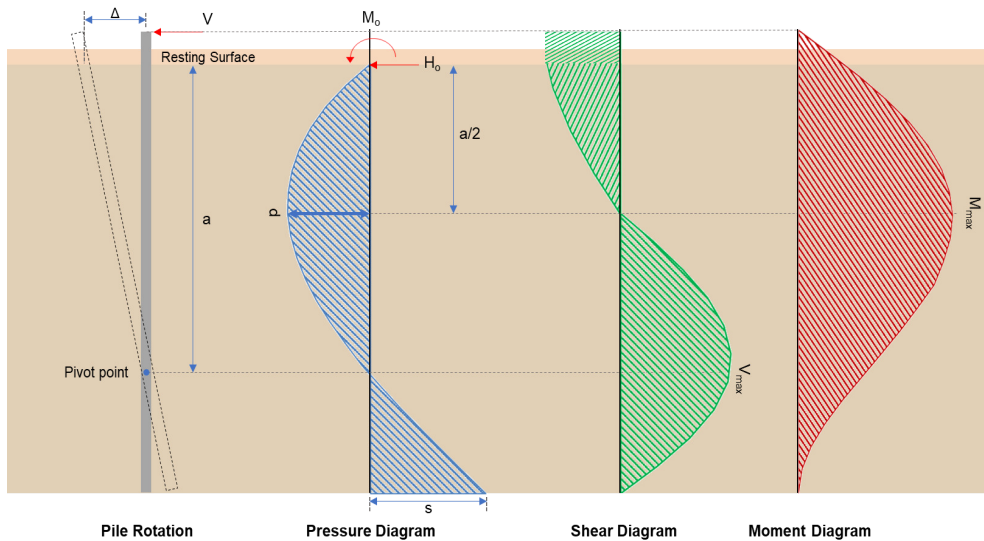
Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0033479 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = 0.0040581$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.598 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.41369 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(29.464 \text{ kipft}) + ((-2.598 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.6917 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.6917 \text{ kipft/ft})}{(-0.41369 \text{ kip/ft})}$$

$$E = 11.341 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.6917 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.41369 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.6917 \text{ kipft/ft})) + (4 \times (-0.41369 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = \frac{(6 \times (4.6917 \text{ kipft/ft})) + (4 \times (-0.41369 \text{ kip/ft}) \times (5.5 \text{ ft}))}{}$$

$$a = 3.7786 \text{ ft}$$

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

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

$$V_{max} = ((-0.41369 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.341 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7786 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (11.341 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7786 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.1306 \text{ kip}$$

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

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

$$M_{max} = ((-0.41369 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(11.341 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7786 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.341 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7786 \text{ ft})}{(2 \times (5.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (11.341 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7786 \text{ ft})}{(2 \times (5.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 18.781 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.125 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.019904 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.422 \text{ kipft}) + ((-0.125 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.067197 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.067197 \text{ kipft/ft})}{(-0.019904 \text{ kip/ft})}$$

$$E = 3.376 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.067197 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.019904 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.067197 \text{ kipft/ft})) + (4 \times (-0.019904 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9053 \text{ ft}$$

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

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

$$V_{max} = ((-0.019904 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.376 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9053 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.376 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9053 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.13936 \text{ kip}$$

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

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

$$M_{max} = ((-0.019904 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(3.376 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9053 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.376 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9053 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.376 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9053 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.34408 \text{ kipft}$$

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, $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(5.721 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.406 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.406 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

$$n_{rebar} = \frac{A_{min}}{A_{rebar}}$$

$$n_{rebar} = \frac{(4.1472 \text{ in}^2)}{(0.3068 \text{ in}^2)}$$

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

$$A_{st} = n_{rebar} \frac{\pi d_{bar}^2}{4}$$

$$A_{st} = (14) \times \frac{\pi \times (0.625 \text{ in})^2}{4}$$

$$A_{st} = 4.2951 \text{ in}^2$$

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

		$Ratio = 0.96556$	Status: PASS Ratio: 0.970
25.2.3	s_{rebar} - Minimum spacing of reinforcement,	$s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ 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, $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ Summary: Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in	
22.4.2.2	ϕP_N - Allowable axial compressive strength	Axial Compression Strength (ACI 318-19, LRFD) $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ Ratio - Capacity $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(5.721 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0021385$	Status: PASS Ratio: 0.000
22.5.2.2	$b_w = 48 \text{ in}$ - Effective width, d - Effective depth	Shear Strength (ACI 318-19, LRFD) Parameters: $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$	
22.5.5.1.3	λ_s - size effect modification factor	$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$	
22.5.5.1.1	$V_{c,max}$ - Max shear strength of concrete	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

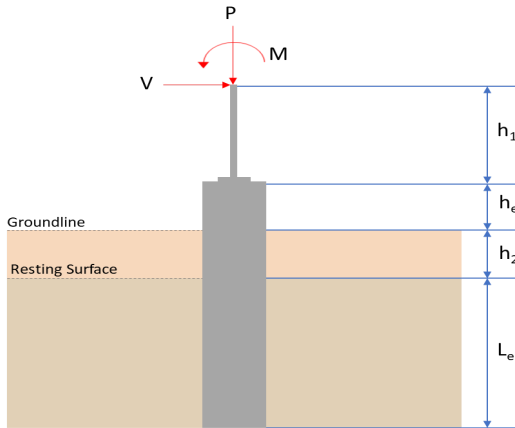
		$V_{c,max} = 296.21 \text{ kip}$	
22.5.5.1.1(a)	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 5.721 \text{ kip} \rightarrow 5721 \text{ lbf}$, $V_{c,a}$ - Shear strength of concrete (a)	$V_{c,a} = \left[2 \lambda_s \sqrt{f'_{ck}} + \frac{P}{6 A_g} \right] b_w d$ $V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(5721 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,a} = 119.25 \text{ kip}$	
22.5.5.1.2	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $V_{c,b}$ - Shear strength of concrete (b)	$V_{c,b} = \left[2 \lambda_s \sqrt{f'_{ck}} + (0.05 f'_{ck}) \right] b_w d$ $V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + (0.05 \times (2500 \text{ psi})) \right] \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{c,b} = 348.89 \text{ kip}$	
	V_c - Governing shear strength of concrete	$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$ $V_c = \text{Min}[(296.21 \text{ kip}), (119.25 \text{ kip}), (348.89 \text{ kip})]$ $V_c = 119.25 \text{ kip}$	
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	$\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((119.25 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 110.59 \text{ kip}$	
	Considering x-direction: $V_{max} = 7.1306 \text{ kip}$ - Maximum shear force in the x-direction, $Ratio$ - Capacity	$Ratio = \frac{V_{max}}{\phi V_n}$	

	$Ratio = \frac{(7.1306 \text{ kip})}{(110.59 \text{ kip})}$ $Ratio = 0.064477$ Considering z-direction: $V_{max} = 0.13936 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.13936 \text{ kip})}{(110.59 \text{ kip})}$ $Ratio = 0.0012602$	Status: PASS Ratio: 0.060 Status: PASS Ratio: 0.000
14.5.2.1b	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ $\phi M_{n,2}$ $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ Therefore, ϕM_n - Allowable flexural strength, $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ Considering x-direction: $M_{max} = 18.781 \text{ kipft}$ - Maximum moment in the x-direction, Ratio - Capacity $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(18.781 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.075245$	Status: PASS Ratio: 0.080
	Considering z-direction: $M_{max} = 0.34408 \text{ kipft}$ - Maximum moment in the z-direction, Ratio - Capacity $Ratio = \frac{M_{max}}{\phi M_n}$	

$$Ratio = \frac{(0.34408 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0013785$$

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

REFERENCES	CALCULATIONS	RESULTS																											
	SkyCiv Foundation Design Pile Foundation Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial																												
	Pile Input  Geometry Pile shape: rectangular b = 48 in - Pile width D = 48 in - Pile depth L = 5.5 ft - Total pile length h1 = 0 ft - Lateral load height from the top of the pile, h2 = 0 ft - Depth to resisting surface he = 0 ft - Length of pile above the ground Tabulation of Soil Parameters <table><tr><th>Layer</th><th>Label</th><th>Allowable Bearing Pressure (qa) (psf)</th><th>Allowable Lateral Pressure (R) (psf/ft)</th></tr><tr><td>1</td><td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td><td>2000.000</td><td>150.000</td></tr></table> Tabulation of Loads <table><tr><th>Load Component</th><th>ASD</th><th>LRFD</th></tr><tr><td>P (kip)</td><td>3.872</td><td>5.720</td></tr><tr><td>Vx (kip)</td><td>-1.559</td><td>-2.598</td></tr><tr><td>Vz (kip)</td><td>0.084</td><td>0.125</td></tr><tr><td>Mx (kipft)</td><td>0.282</td><td>0.419</td></tr><tr><td>Mz (kipft)</td><td>17.292</td><td>29.461</td></tr></table> Material Properties f'ck = 2.5 ksi - Concrete strength,	Layer	Label	Allowable Bearing Pressure (qa) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	3.872	5.720	Vx (kip)	-1.559	-2.598	Vz (kip)	0.084	0.125	Mx (kipft)	0.282	0.419	Mz (kipft)	17.292	29.461	Required depth to resist lateral loads (ASD) H - Point of application of the lateral load $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ Considering x-direction: Ho - Lateral force per length of pile, $H_o = \frac{V_x}{1.57 \text{ } D}$ $H_o = \frac{(-1.559 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.24825 \text{ kip/ft}$	
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																											
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Vx (kip)	-1.559	-2.598																											
Vz (kip)	0.084	0.125																											
Mx (kipft)	0.282	0.419																											
Mz (kipft)	17.292	29.461																											

	M_o - Moment per length of pile, $M_o = \frac{M_z + (V_x H)}{1.57 D}$ $M_o = \frac{(17.292 \text{ kipft}) + ((-1.559 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 2.7535 \text{ kipft/ft}$ Required depth of embedment in earth: $L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ Solving the cubic equation: $L_{e,x} = 5.223 \text{ ft}$ - Required depth in x-direction, Considering z-direction: H_o - Lateral force per length of pile, $H_o = \frac{V_z}{1.57 b}$ $H_o = \frac{(0.084 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = 0.013376 \text{ kip/ft}$ M_o - Moment per length of pile, $M_o = \frac{M_x + (V_z H)}{1.57 b}$ $M_o = \frac{(0.282 \text{ kipft}) + ((0.084 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$ $M_o = 0.044904 \text{ kipft/ft}$ Required depth of embedment in earth: $L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$ Solving the cubic equation: $L_{e,z} = 1.7055 \text{ ft}$ - Required depth in z-direction, Minimum embedded depth required: $L_{e,req}$ - Depth of pile required, $L_{e,req} = \text{MAX}[L_{e,x}, L_{e,z}]$ $L_{e,req} = \text{MAX}[(5.223 \text{ ft}), (1.7055 \text{ ft})]$ $L_{e,req} = 5.223 \text{ ft}$ L_e - Actual embedded length of pile, $L_e = L - h_e - h_2$ $L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$ $L_e = 5.5 \text{ ft}$ <i>Ratio</i> - Embedded depth $\text{Ratio} = \frac{L_{e,req}}{L_e}$ $\text{Ratio} = \frac{(5.223 \text{ ft})}{(5.5 \text{ ft})}$ $\text{Ratio} = 0.94964$	Status: PASS Ratio: 0.950
	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	

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

$$q = \frac{(3.872 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.242 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.242 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.121$$

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

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(5.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.24825 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 2.7535 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.7535 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.7535 \text{ kipft/ft})) + (4 \times (-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7805 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.7535 \text{ kipft/ft})) + (3 \times (-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.7535 \text{ kipft/ft})) + (2 \times (-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.21457 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (2.7535 \text{ kipft/ft})) + ((-0.24825 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.82148 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7805 \text{ ft})}{2}$$

$$p_a = 0.28354 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

	$Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.21457 \text{ kip/ft}^2)}{(0.28354 \text{ kip/ft}^2)}$ $Ratio = 0.75677$ p_s - Allowable lateral soil pressure at depth L_e, $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (5.5 \text{ ft})$ $p_s = 0.825 \text{ kip/ft}^2$ Ratio - Lateral soil capacity $Ratio = \frac{s}{p_s}$ $Ratio = \frac{(0.82148 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$ $Ratio = 0.99574$	Status: PASS Ratio: 0.760 Status: PASS Ratio: 1.000
	Considering z-direction: $H_o = 0.013376 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.044904 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.044904 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.013376 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.044904 \text{ kipft/ft})) + (4 \times (0.013376 \text{ kip/ft}) \times (5.5 \text{ ft}))}$ $a = 3.9059 \text{ ft}$ p - Earth pressure against the pile at distance $a/2$ from resting surface, $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.044904 \text{ kipft/ft})) + (3 \times (0.013376 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.044904 \text{ kipft/ft})) + (2 \times (0.013376 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$ $p = 0.014097 \text{ kip/ft}^2$ s - Earth pressure against the pile at distance L_e, $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.044904 \text{ kipft/ft})) + ((0.013376 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$ $s = 0.032405 \text{ kip/ft}^2$ Check lateral soil pressure capacity: p_a - Allowable lateral soil pressure at depth $a/2$, $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.9059 \text{ ft})}{2}$ $p_a = 0.29294 \text{ kip/ft}^2$ Ratio - Lateral soil capacity $Ratio = \frac{p}{p_a}$ $Ratio = \frac{(0.014097 \text{ kip/ft}^2)}{(0.29294 \text{ kip/ft}^2)}$	

$$Ratio = 0.048122$$

Status: **PASS**
Ratio: **0.050**

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

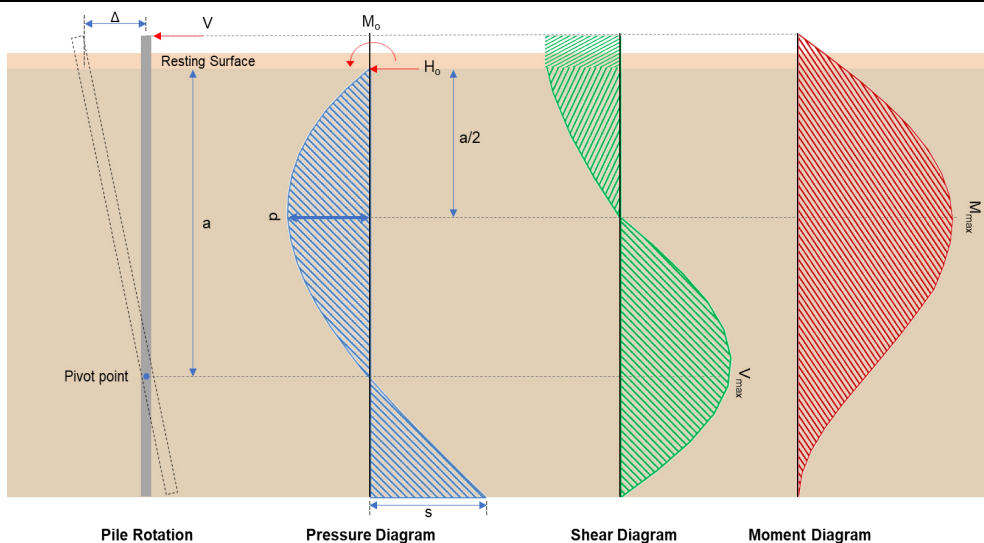
Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.032405 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = 0.039279$$

Status: **PASS**
Ratio: **0.040**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.598 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.41369 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(29.461 \text{ kipft}) + ((-2.598 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.6912 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.6912 \text{ kipft/ft})}{(-0.41369 \text{ kip/ft})}$$

$$E = 11.34 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.6912 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.41369 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.6912 \text{ kipft/ft})) + (4 \times (-0.41369 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = \frac{(6 \times (4.6912 \text{ kipft/ft})) + (4 \times (-0.41369 \text{ kip/ft}) \times (5.5 \text{ ft}))}{}$$

$$a = 3.7787 \text{ ft}$$

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

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

$$V_{max} = ((-0.41369 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (11.34 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7787 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (11.34 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7787 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.13 \text{ kip}$$

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

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

$$M_{max} = ((-0.41369 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(11.34 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7787 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (11.34 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7787 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (11.34 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7787 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 18.779 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.125 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.019904 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.419 \text{ kipft}) + ((0.125 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.06672 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.06672 \text{ kipft/ft})}{(0.019904 \text{ kip/ft})}$$

$$E = 3.352 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.06672 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.019904 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.06672 \text{ kipft/ft})) + (4 \times (0.019904 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9061 \text{ ft}$$

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

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

$$V_{max} = ((0.019904 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.352 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9061 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.352 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9061 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.13875 \text{ kip}$$

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

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

$$M_{max} = ((0.019904 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(3.352 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9061 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.352 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9061 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.352 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9061 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.34241 \text{ kipft}$$

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, $A_{st,required}$

$A_{st,required}$

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

$$A_{st,required} = Min \left[\frac{\frac{(5.72 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.406 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max[(-84.406 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

		$Ratio = 0.96556$	Status: PASS Ratio: 0.970
25.2.3	s_{rebar} - Minimum spacing of reinforcement,	$s_{rebar} = Max[1.5, (1.5 d_{bar})]$ $s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ 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, $s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$ $s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ Summary: Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in	
22.4.2.2	ϕP_N - Allowable axial compressive strength	Axial Compression Strength (ACI 318-19, LRFD) $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ Ratio - Capacity $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(5.72 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0021382$	Status: PASS Ratio: 0.000
22.5.2.2	$b_w = 48 \text{ in}$ - Effective width, d - Effective depth	Shear Strength (ACI 318-19, LRFD) Parameters: $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$	
22.5.5.1.3	λ_s - size effect modification factor	$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$	
22.5.5.1.1	The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $V_{c,max}$ - Max shear strength of concrete	$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 5.72 \text{ kip} \rightarrow 5720 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(5720 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.25 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.25 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.25 \text{ kip}$$

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

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

$$\phi V_n = (0.65) \times ((119.25 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.59 \text{ kip}$$

Considering x-direction:

$V_{max} = 7.13 \text{ kip}$ - Maximum shear force in the x-direction,
 $Ratio$ - Capacity

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

	$Ratio = \frac{(7.13 \text{ kip})}{(110.59 \text{ kip})}$ $Ratio = 0.064471$ Considering z-direction: $V_{max} = 0.13875 \text{ kip}$ - Maximum shear force in the z-direction, <i>Ratio</i> - Capacity $Ratio = \frac{V_{max}}{\phi V_n}$ $Ratio = \frac{(0.13875 \text{ kip})}{(110.59 \text{ kip})}$ $Ratio = 0.0012547$	Status: PASS Ratio: 0.060 Status: PASS Ratio: 0.000
14.5.2.1b	Flexural Strength (ACI 318-19, LRFD) S_m - Section modulus $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 \text{ ksi})} \times 18432.001 \text{ in}^3$ $\phi M_{n,1} = 249.600 \text{ kipft}$ $\phi M_{n,2}$ $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times (18432 \text{ in}^3)$ $\phi M_{n,2} = 2121.6 \text{ kipft}$ Therefore, ϕM_n - Allowable flexural strength, $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$ $\phi M_n = 249.6 \text{ kipft}$ Considering x-direction: $M_{max} = 18.779 \text{ kipft}$ - Maximum moment in the x-direction, <i>Ratio</i> - Capacity $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(18.779 \text{ kipft})}{(249.6 \text{ kipft})}$ $Ratio = 0.075238$	Status: PASS Ratio: 0.080
	Considering z-direction: $M_{max} = 0.34241 \text{ kipft}$ - Maximum moment in the z-direction, <i>Ratio</i> - Capacity $Ratio = \frac{M_{max}}{\phi M_n}$	

$$Ratio = \frac{(0.34241 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0013718$$

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