Your Project Calculations

Project Name: Urrutia-Frank RevB- GS

S3D Model Link:
https://platform.skyciv.com/structural?preload_name=Urrutia-Frank%20RevB-%20GS&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/9_2023

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=CGMdxb5L3hnoS8AUm7mIhIfpY6JiIeXNkuUjQzKyJxNOYpIQ8XyDGWs4vcKdhx4D

Array Specification

Product:	Beam
Unique ID:	2P-15-6TOP-SD-12-L-4Hx4W-2FD4
Duty Classification:	SD
Module Width:	40.80 in
Module Length:	75.30in
Number of Rows:	4
Number of Columns:	4
Total Number of Modules:	16
Desired Tilt Angle:	45
Front Edge Clearance:	4
Total Array Height at Tilt:	13.68 ft
Total Frame Length:	24.50 ft
Frame Weight:	1080 lbs
Array Dimensions N/S:	13.77 ft
Array Dimensions E/W:	25.43 ft
Rail Length:	165.20 in
Rail Spacing:	3.14 ft
Rail Check:	Not Checked

Support Specifications

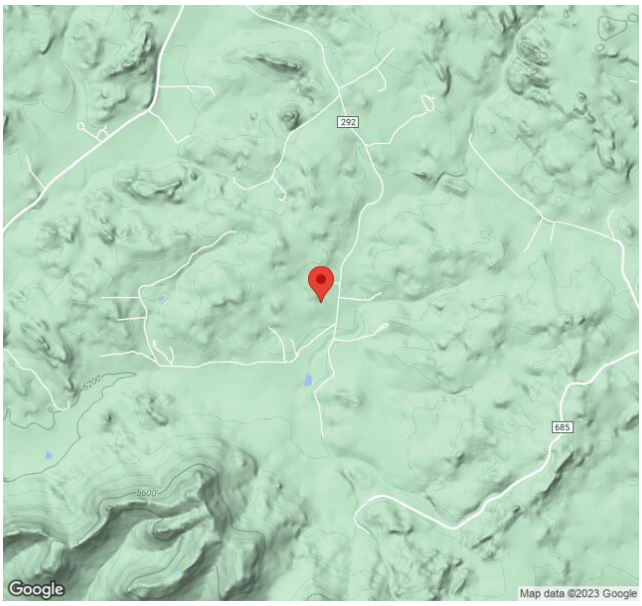
Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	8.87 ft
Number of Poles:	2
Pole Spacing:	15 ft

Foundation Specifications

Foundation Type:	Round
Foundation Dimensions:	Ø36 in
Foundation Depth (below grade):	Pile 1: 6.50 ft Pile 2: 6.50 ft
Foundation Volume:	3.403 y^3
Foundation Result:	PASSED
Mount Twist:	0.754969 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sedimentary
Site Location:	25519 Wind Song Valley Rd, Custer, SD 57730, USA
Wind Speed:	105 mph
Snow Load:	36 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.009897 ksf



Design Disclaimer

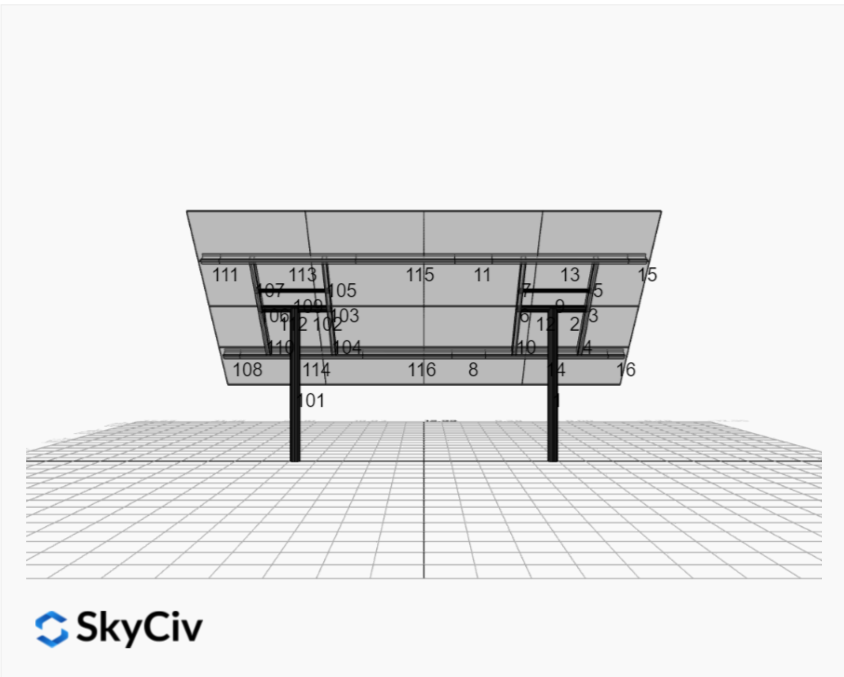
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

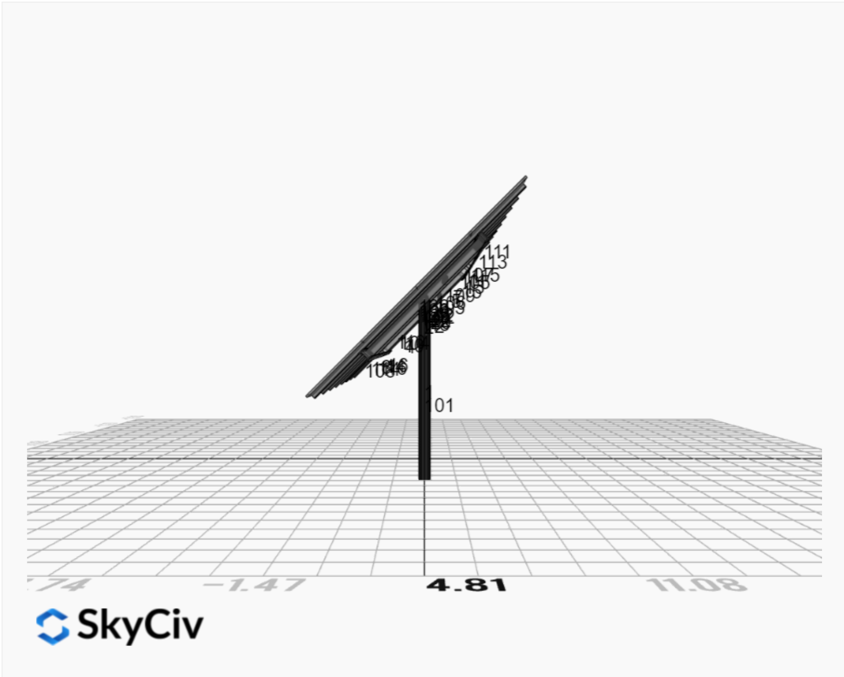
AutoDesigner Input

{"wind_speed_override":105,"snow_load_override":36,"direct_snow_load":false,"product_type":"Beam","project_id":"Urrutia-Frank RevB- GS","site_address":"25519 Wind Song Valley Rd, Custer, SD 57730, USA","module_width":40.8,"module_length":75.3,"number_rows":"4","number_columns":4,"pole_mount_section":"4_40","core_pipe_width":65,"core_pipe_section":"2_40","adjuster_section":"2_40","core_beam_height":65,"core_beam_section":"HSS3x2x1/8","main_pipe_section":"2_12GA","pole_spacing":"15","tilt_angle":45,"ground_clearance":4,"risk_category":"I","exposure_category":"C","frame_duty_override":"auto","pole_override":"auto","soil_type":"sedimentary","customer_foundation_override":"36_Round","foundation_type":"Round","foundation_size":36,"check_rails":false}

Design Notes:

- AISC Deflection checks are set to L/1 due to structure design intent

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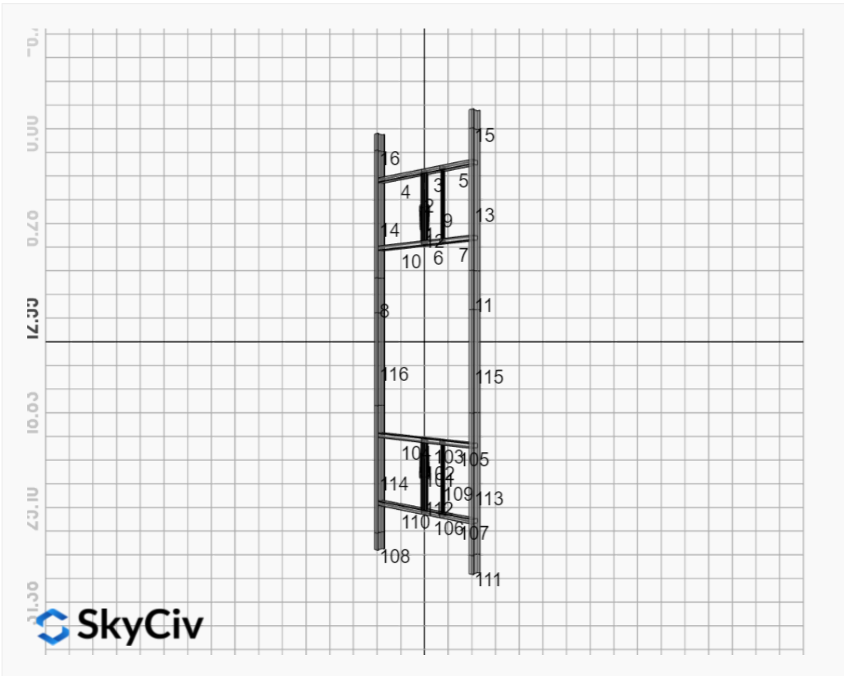
113
101
−1.47
4.81
11.08
SkyCiv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16
4
3
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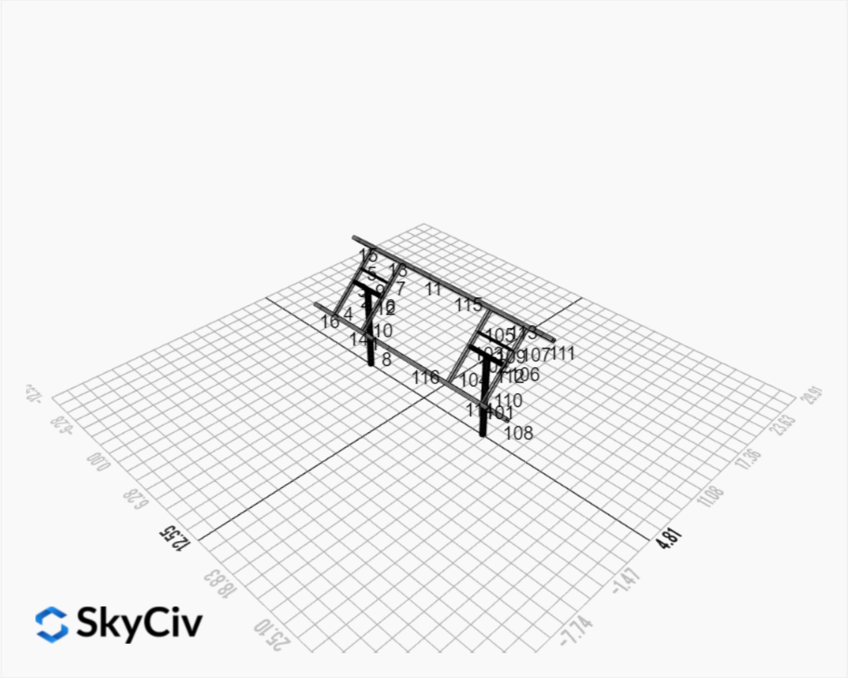
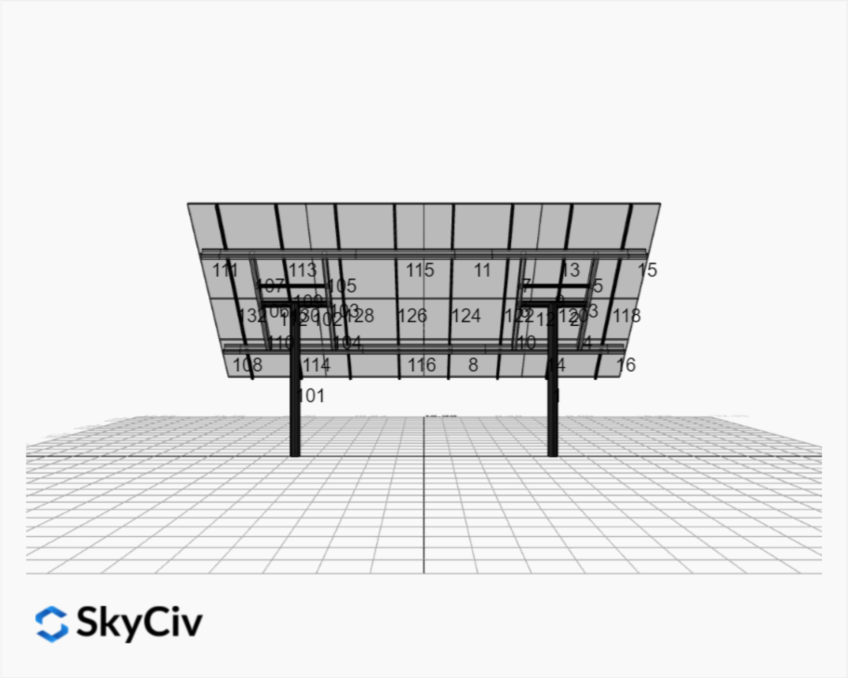
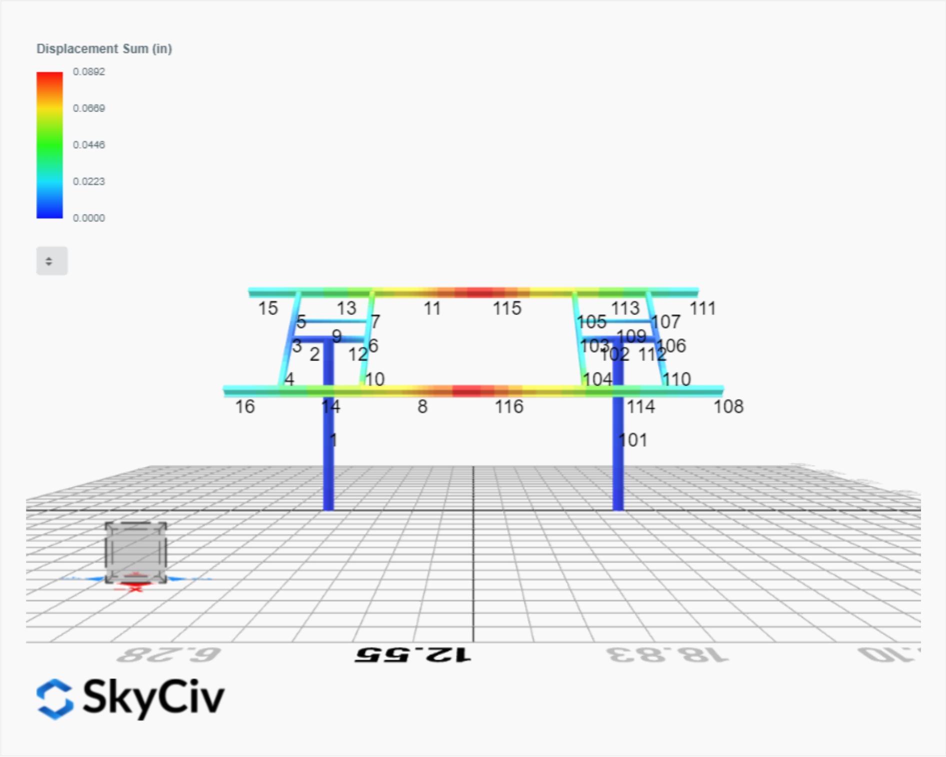
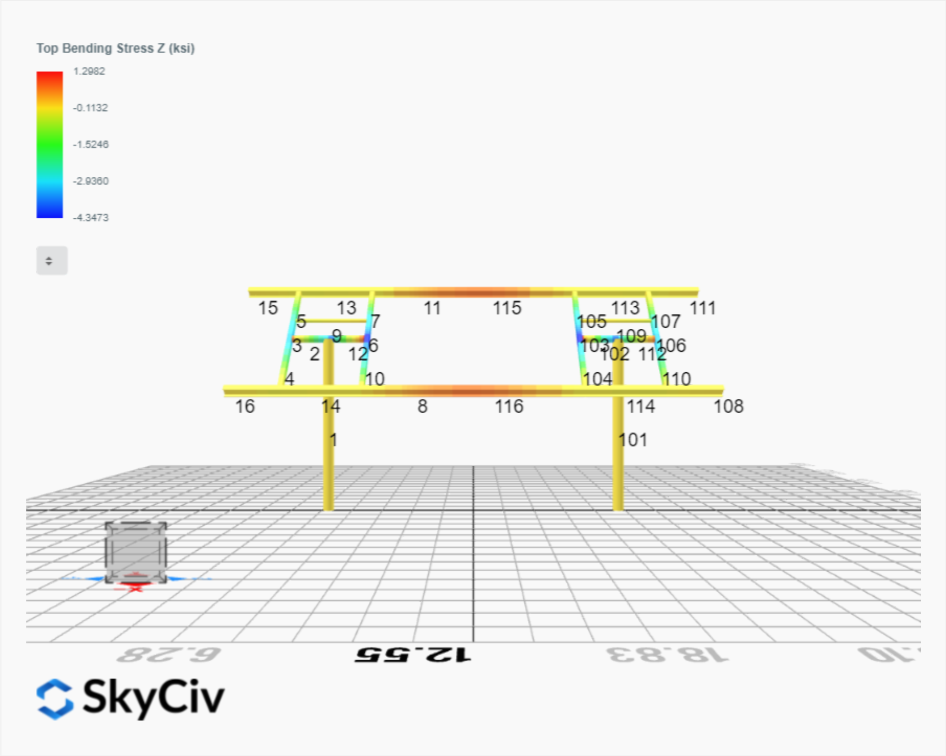
111
SkyCiv

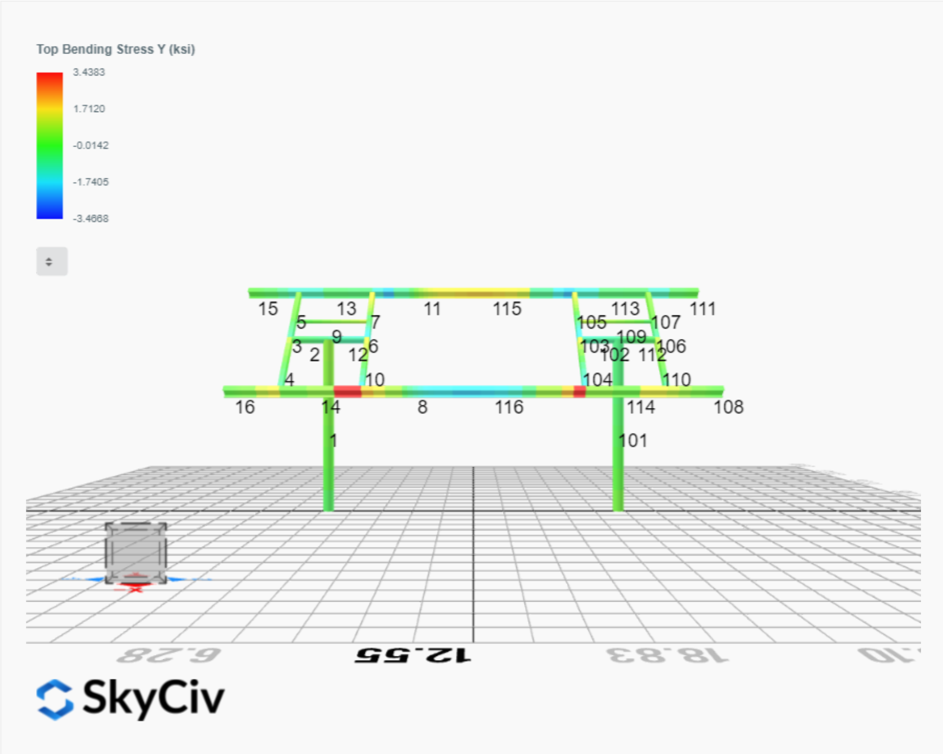


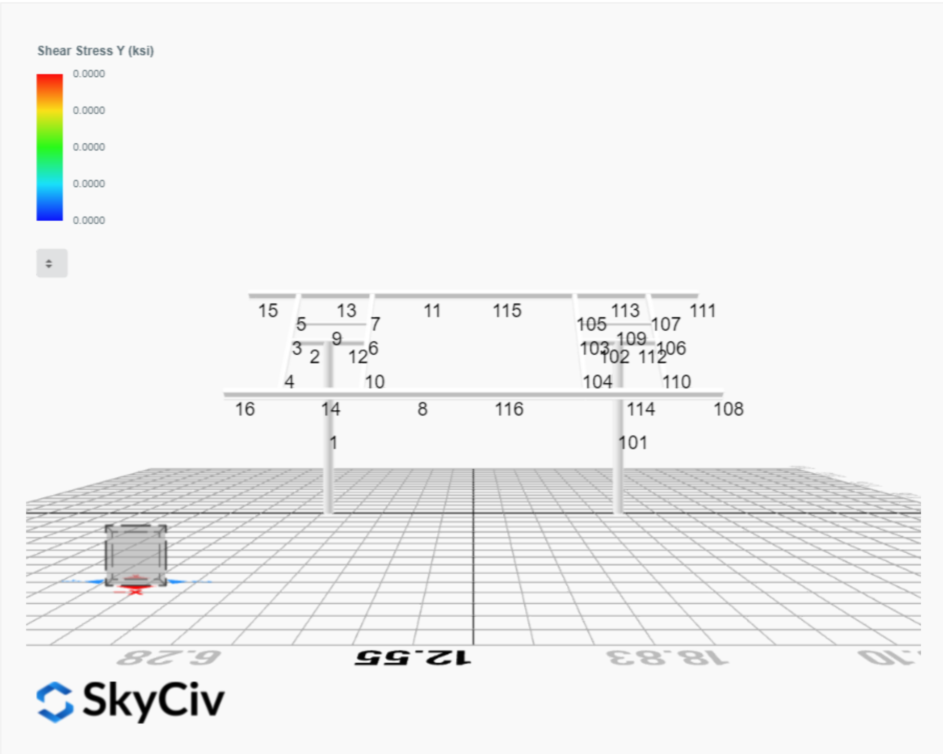


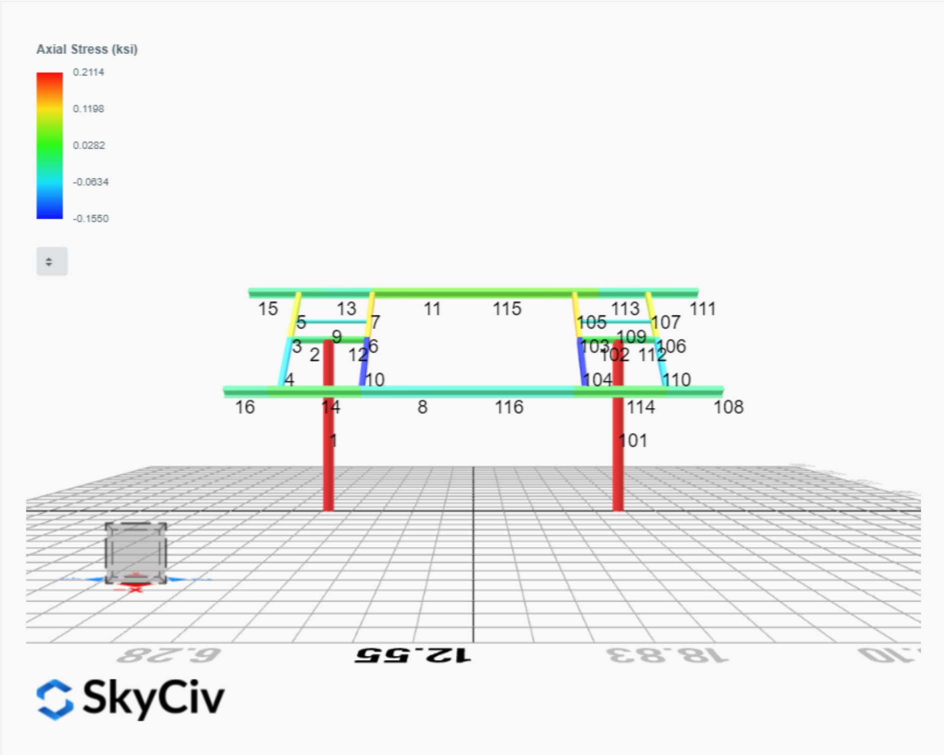
FEM Results (Envelope Worst Case for each member)






Top Bending Stress Y (ksi)
3.4383
1.7120
-0.0142
-1.7405
-3.4668
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101


Shear Stress Y (ksi)
0.0000
0.0000
0.0000
0.0000
0.0000
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101


Axial Stress (ksi)
0.2114
0.1198
0.0282
-0.0634
-0.1550
15
13
11
115
113
111
5
7
105
107
9
109
3
2
12
6
103
102
112
106
4
10
104
110
16
14
8
116
114
108
1
101
6.28
12.55
18.83
SkyCiv

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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0000	1.3603	0.0462	0.1219	-0.0373	0.0161
ULS: 2. D + L	0.0000	1.3603	0.0462	0.1219	-0.0373	0.0161
ULS: 3. D + (S or Lr or R)	0.0000	2.5404	0.0986	0.2602	-0.0800	0.0187
ULS: 3. D + (S or Lr or R)	0.0000	1.3603	0.0462	0.1219	-0.0373	0.0161
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.2454	0.0855	0.2256	-0.0693	0.0181
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	1.3603	0.0462	0.1219	-0.0373	0.0161
ULS: 5b. D + 0.7E	0.0000	1.3603	0.0462	0.1219	-0.0373	0.0161
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	2.2454	0.0855	0.2256	-0.0693	0.0181
ULS: 8. 0.6D + 0.7E	0.0000	0.8162	0.0277	0.0731	-0.0224	0.0097
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4931	3.8534	0.2008	0.5103	-0.4517	23.4270
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4931	3.8534	0.2008	0.5103	-0.4517	23.4270
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8035	-0.4433	-0.0652	-0.1571	0.2618	-15.2063
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5913	-0.2311	-0.0529	-0.1264	0.2288	-18.3437
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8698	4.1152	0.2015	0.5170	-0.3801	17.5763
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8698	4.1152	0.2015	0.5170	-0.3801	17.5763
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3526	0.8927	0.0019	0.0164	0.1550	-11.3988
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1935	1.0519	0.0111	0.0395	0.1303	-13.7518
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8698	3.2301	0.1622	0.4132	-0.3481	17.5743
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8698	3.2301	0.1622	0.4132	-0.3481	17.5743
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3526	0.0076	-0.0374	-0.0874	0.1870	-11.4007
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1935	0.1668	-0.0281	-0.0643	0.1623	-13.7538
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4931	3.3093	0.1824	0.4616	-0.4368	23.4206
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4931	3.3093	0.1824	0.4616	-0.4368	23.4206
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8035	-0.9874	-0.0837	-0.2059	0.2767	-15.2128
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5913	-0.7752	-0.0714	-0.1751	0.2437	-18.3502

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	6.3776
Shear X	-4.1552
Shear Z	0.3391
Moment X	0.8631
Moment Y (Twist)	0.7552
Moment Z	39.4996

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	4.1152
Shear X	-2.4931
Shear Z	0.2015
Moment X	0.5170
Moment Y (Twist)	0.4517
Moment Z	23.4270

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	1.3603	-0.0462	-0.1219	0.0373	0.0161
ULS: 2. D + L	-0.0000	1.3603	-0.0462	-0.1219	0.0373	0.0161
ULS: 3. D + (S or Lr or R)	-0.0000	2.5404	-0.0986	-0.2602	0.0800	0.0187
ULS: 3. D + (S or Lr or R)	-0.0000	1.3603	-0.0462	-0.1219	0.0373	0.0161
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	2.2454	-0.0855	-0.2256	0.0693	0.0181
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	1.3603	-0.0462	-0.1219	0.0373	0.0161
ULS: 5b. D + 0.7E	-0.0000	1.3603	-0.0462	-0.1219	0.0373	0.0161

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	2.2454	-0.0855	-0.2256	0.0693	0.0181
ULS: 8. 0.6D + 0.7E	-0.0000	0.8162	-0.0277	-0.0731	0.0224	0.0097
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.4931	3.8534	-0.2008	-0.5103	0.4517	23.4270
ULS: 5a. D + 0.6W_Wind downforce Case B only	-2.4931	3.8534	-0.2008	-0.5103	0.4517	23.4270
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8035	-0.4433	0.0652	0.1571	-0.2618	-15.2063
ULS: 5a. D + 0.6W_Wind uplift Case B only	1.5913	-0.2311	0.0529	0.1264	-0.2288	-18.3437
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8698	4.1152	-0.2015	-0.5170	0.3801	17.5763
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8698	4.1152	-0.2015	-0.5170	0.3801	17.5763
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3526	0.8927	-0.0019	-0.0164	-0.1550	-11.3988
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1935	1.0519	-0.0111	-0.0395	-0.1303	-13.7518
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.8698	3.2301	-0.1622	-0.4132	0.3481	17.5743
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-1.8698	3.2301	-0.1622	-0.4132	0.3481	17.5743
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.3526	0.0076	0.0374	0.0874	-0.1870	-11.4007
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	1.1935	0.1668	0.0281	0.0643	-0.1623	-13.7538
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.4931	3.3093	-0.1824	-0.4616	0.4368	23.4206
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-2.4931	3.3093	-0.1824	-0.4616	0.4368	23.4206
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8035	-0.9874	0.0837	0.2059	-0.2767	-15.2128
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	1.5913	-0.7752	0.0714	0.1751	-0.2437	-18.3502

Worst Case Reactions LRFD

These calculations are taken directly from the FEA via SkyCiv and are used in the Concrete Checks of the Foundatino Module. Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	6.3776
Shear X	-4.1552
Shear Z	-0.3391
Moment X	-0.8631
Moment Y (Twist)	0.7550
Moment Z	39.5005

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	4.1152
Shear X	-2.4931
Shear Z	-0.2015
Moment X	-0.5170
Moment Y (Twist)	0.4517
Moment Z	23.4270

Project Details

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

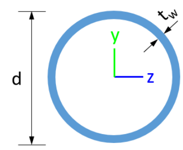
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

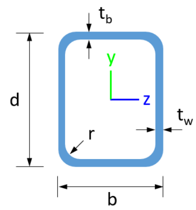
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

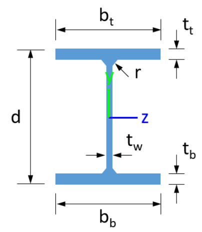
Section Dimensions



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	152.35	2.07	2.93
18	W6x9	2.68	0.04	2.20	16.40	17.70	1.72	6.23

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b (ft)	C_b	LST	LSC	LD
1	7	18.62	18.62	8.87	-	300	200	1
2	4	1.30	1.30	2.00	-	300	200	1
3	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.22,1.16,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
4	15	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.64,1.67,1.67,1.29,1.68,1.67,1.67,1.65,2.00,1.67,1.67,1.66,1.65	300	200	1
5	15	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.73,1.65,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1
6	15	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
7	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.71,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
8	18	1.33	1.33	2.05	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.18,1.18,1.12,1.18,1.18,1.18,1.15,1.19,1.19,1.05,1.22,1.19,1.19,1.18,1.02,1.18,1.18,1.19,1.15	300	200	1
9	1	2.60	2.60	4.00	-	300	200	1
10	15	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.64,1.67,1.67,1.66,1.65,1.67,1.67,2.48,1.68,1.67,1.67,1.65,1.13,1.67,1.67,1.66,1.66	300	200	1
11	18	1.33	1.33	2.05	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.35,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19	300	200	1
12	4	4.20	1.30	2.00	-	300	200	1
13	18	4.88	4.00	7.50	1.50,1.51,1.50,1.52,1.51,1.50,1.65,1.65,1.74,1.79,1.65,1.65,1.71,1.76,1.61,1.61,1.21,2.49,1.64,1.64,1.80,1.83,1.66,1.66,1.70,1.75	300	200	1
14	18	4.88	4.00	7.50	1.47,1.48,1.47,1.49,1.48,1.47,1.61,1.61,1.72,1.53,1.62,1.62,1.69,1.52,1.58,1.58,1.51,1.55,1.60,1.60,1.78,1.73,1.62,1.62,1.68,1.51	300	200	1
15	18	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	18	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.34,2.32,2.33,2.33,2.33,2.35,2.33,2.33,2.33,2.33	300	200	1
101	7	18.62	18.62	8.87	-	300	200	1
102	4	4.20	1.30	2.00	-	300	200	1
103	15	0.92	0.92	1.42	1.19,1.19,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.22,1.17,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
104	15	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.68,1.69,1.67,1.67,1.66,1.64,1.67,1.67,1.66,1.65,1.67,1.67,2.47,1.68,1.67,1.67,1.66,1.13,1.67,1.67,1.66,1.66	300	200	1
105	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.71,1.65,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.67	300	200	1
106	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.17,1.18,1.18,1.17,1.17,1.18,1.18,1.22,1.16,1.18,1.18,1.16,1.17,1.18,1.18,1.17,1.17	300	200	1
107	15	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.66,1.67,1.67,1.66,1.66,1.67,1.67,1.73,1.65,1.67,1.67,1.65,1.66,1.67,1.67,1.66,1.66	300	200	1

108	18	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.34,2.32,2.33, 2.33,2.33,2.35,2.33,2.33,2.33,2.33	300	200	1
109	1	2.60	2.60	4.00	-	300	200	1
110	15	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.67,1.66,1.62,1.67,1.67,1.66,1.64,1.67,1.67,1.29,1.68,1.67, 1.67,1.65,2.00,1.67,1.67,1.66,1.65	300	200	1
111	18	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33, 2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
112	4	1.30	1.30	2.00	-	300	200	1
113	18	4.88	4.00	7.50	1.50,1.51,1.50,1.52,1.51,1.50,1.65,1.65,1.74,1.79,1.65,1.65,1.71,1.76,1.61,1.61,1.21,2.49,1.64, 1.64,1.79,1.83,1.66,1.66,1.69,1.75	300	200	1
114	18	4.88	4.00	7.50	1.47,1.48,1.47,1.49,1.48,1.47,1.61,1.61,1.72,1.54,1.62,1.62,1.69,1.53,1.58,1.58,1.51,1.55,1.60, 1.60,1.78,1.76,1.62,1.62,1.68,1.51	300	200	1
115	18	3.54	3.54	5.45	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.06,1.07,1.07,1.07,1.10,1.07,1.07, 1.07,1.06,1.07,1.07,1.07,1.06,1.07	300	200	1
116	18	3.54	3.54	5.45	1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.07,1.06,1.04,1.06,1.06,1.07,1.05,1.07,1.07,1.02,1.07,1.07, 1.07,1.06,1.04,1.06,1.06,1.07,1.06	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	251.16	121.76	42.30	42.30	75.35	75.35
2	142.83	141.72	16.17	16.17	42.85	42.85
3	79.65	74.02	10.99	4.60	29.14	16.61
4	79.65	72.01	10.99	4.60	29.14	16.61
5	79.65	73.44	10.99	4.60	29.14	16.61
6	79.65	74.02	10.99	4.60	29.14	16.61
7	79.65	73.44	10.99	4.60	29.14	16.61
8	120.60	117.88	23.36	6.45	30.09	45.74
9	48.35	43.11	2.85	2.85	14.51	14.51
10	79.65	72.01	10.99	4.60	29.14	16.61
11	120.60	117.88	23.36	6.45	30.09	45.74
12	142.83	131.65	16.17	16.17	42.85	42.85
13	120.60	98.23	21.30	6.45	30.09	45.74
14	120.60	98.23	23.36	6.45	30.09	45.74
15	120.60	113.97	23.36	6.45	30.09	45.74
16	120.60	113.97	23.36	6.45	30.09	45.74
101	251.16	121.76	42.30	42.30	75.35	75.35
102	142.83	131.65	16.17	16.17	42.85	42.85
103	79.65	74.02	10.99	4.60	29.14	16.61
104	79.65	72.01	10.99	4.60	29.14	16.61
105	79.65	73.44	10.99	4.60	29.14	16.61
106	79.65	74.02	10.99	4.60	29.14	16.61
107	79.65	73.44	10.99	4.60	29.14	16.61
108	120.60	113.97	23.36	6.45	30.09	45.74
109	48.35	43.11	2.85	2.85	14.51	14.51
110	79.65	72.01	10.99	4.60	29.14	16.61
111	120.60	113.97	23.36	6.45	30.09	45.74
112	142.83	141.72	16.17	16.17	42.85	42.85
113	120.60	98.23	21.30	6.45	30.09	45.74
114	120.60	98.23	23.36	6.45	30.09	45.74
115	120.60	102.67	21.57	6.45	30.09	45.74

115	120.60	102.67	21.57	6.45	30.09	45.74
116	120.60	102.67	20.76	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	0.052	0.934	0.051	0.055	0.005	0.980	#13	0.498	Not Required	Warn
2	0.001	0.251	0.216	0.061	0.046	0.468	#13	0.052	Not Required	Pass
3	0.007	0.586	0.066	0.058	0.012	0.611	#13	0.044	Not Required	Pass
4	0.005	0.523	0.087	0.053	0.012	0.610	#13	0.078	Not Required	Pass
5	0.006	0.364	0.029	0.059	0.003	0.377	#13	0.073	Not Required	Pass
6	0.009	0.721	0.153	0.073	0.028	0.826	#13	0.044	Not Required	Pass
7	0.010	0.447	0.136	0.072	0.019	0.471	#13	0.073	Not Required	Pass
8	0.002	0.143	0.060	0.035	0.007	0.180	#13	0.088	Not Required	Pass
9	0.003	0.045	0.064	0.002	0.003	0.109	#13	0.132	Not Required	Pass
10	0.010	0.651	0.131	0.065	0.018	0.666	#13	0.078	Not Required	Pass
11	0.002	0.156	0.060	0.038	0.007	0.189	#13	0.088	Not Required	Pass
12	0.002	0.384	0.263	0.083	0.052	0.647	#13	0.167	Not Required	Pass
13	0.003	0.082	0.135	0.056	0.011	0.154	#21	0.265	Not Required	Pass
14	0.002	0.077	0.132	0.051	0.011	0.147	#21	0.177	Not Required	Pass
15	0.000	0.007	0.007	0.010	0.002	0.012	#21	Not Required	Not Required	Pass
16	0.000	0.006	0.007	0.009	0.002	0.011	#21	Not Required	Not Required	Pass
101	0.052	0.934	0.051	0.055	0.005	0.980	#13	0.498	Not Required	Warn
102	0.002	0.384	0.263	0.083	0.052	0.647	#13	0.167	Not Required	Pass
103	0.009	0.721	0.153	0.073	0.028	0.826	#13	0.044	Not Required	Pass
104	0.010	0.651	0.131	0.065	0.018	0.666	#13	0.078	Not Required	Pass
105	0.010	0.447	0.136	0.072	0.019	0.471	#13	0.073	Not Required	Pass
106	0.007	0.586	0.066	0.058	0.012	0.611	#13	0.044	Not Required	Pass
107	0.006	0.364	0.029	0.059	0.003	0.377	#13	0.073	Not Required	Pass
108	0.000	0.006	0.007	0.009	0.002	0.011	#21	Not Required	Not Required	Pass
109	0.003	0.045	0.064	0.002	0.003	0.109	#13	0.132	Not Required	Pass
110	0.005	0.523	0.087	0.053	0.012	0.610	#13	0.078	Not Required	Pass
111	0.000	0.007	0.007	0.010	0.002	0.012	#21	Not Required	Not Required	Pass
112	0.001	0.251	0.216	0.061	0.046	0.468	#13	0.052	Not Required	Pass
113	0.003	0.082	0.135	0.056	0.011	0.154	#21	0.177	Not Required	Pass
114	0.002	0.077	0.132	0.051	0.011	0.147	#21	0.265	Not Required	Pass
115	0.003	0.187	0.080	0.038	0.007	0.231	#13	0.235	Not Required	Pass
116	0.002	0.171	0.080	0.035	0.007	0.219	#13	0.235	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

L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

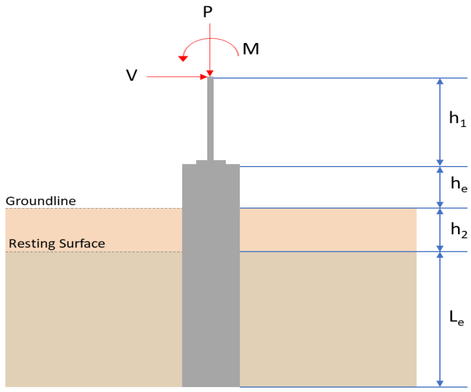
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36\ \mathrm{in}$ - Pile diameter
$L = 6.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) $(\mathrm{psf/ft})$
1	Sedimentary & foliated rock	4000.000	400.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.115	6.378
V_x (kip)	-2.493	-4.155
V_z (kip)	0.201	0.339
M_x (kipft)	0.517	0.863
M_z (kipft)	23.427	39.500

Material Properties

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.493\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -0.831\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.427 \text{ kipft}) + ((-2.493 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 7.809 \text{ kipft/ft}$$

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:
$L_{e,x} = 5.8192 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.201 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.067 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.517 \text{ kipft}) + ((0.201 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.17233 \text{ kipft/ft}$$

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:
$L_{e,z} = 2.3987 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

$L_{e,req}$ - Depth of pile required,

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

$$L_{e,req} = MAX[(5.8192 \text{ ft}), (2.3987 \text{ ft})]$$

$$L_{e,req} = 5.819 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6.5 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.819 \text{ ft})}{(6.5 \text{ ft})}$$

$$Ratio = 0.89523$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36 \text{ in})}{2}\right)^2$$

$$A = 7.0686 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(4.115 \text{ kip})}{(7.0686 \text{ ft}^2)}$$

	$$q = 0.58215 \text{ kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{(0.58215 \text{ kip/ft}^2)}{(4000 \text{ psf})}$$ $$Ratio = 0.14554$$	Status: **PASS** Ratio: **0.150**
Czerniak	**Lateral Soil Pressure (ASD):**	

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5 \text{ ft})}{(36 \text{ in})}$$

$$L/D = 2.1667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.831 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 7.809 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.809 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.831 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (7.809 \text{ kipft/ft})) + (4 \times (-0.831 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.5043 \text{ ft}$$

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

$$p = \frac{1.178\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.809 \text{ kipft/ft})) + (3 \times (-0.831 \text{ kip/ft}) \times (6.5 \text{ ft}))]^2}{(6.5 \text{ ft})^2 \times [(3 \times (7.809 \text{ kipft/ft})) + (2 \times (-0.831 \text{ kip/ft}) \times (6.5 \text{ ft}))]}$$

$$p = 0.49903 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.809 \text{ kipft/ft})) + ((-0.831 \text{ kip/ft}) \times (6.5 \text{ ft}))]}{(6.5 \text{ ft})^2}$$

$$s = 2.2791 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (400 \text{ psf/ft}) \times \frac{(4.5043 \text{ ft})}{2}$$

$$p_a = 0.90086 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{(0.49903 \text{ kip/ft}^2)}{(0.90086 \text{ kip/ft}^2)}$$

$$Ratio = 0.55395$$

Status: **PASS**
Ratio: **0.550**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (400\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 2.6\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(2.2791\ \mathrm{kip/ft^2}\right)}{\left(2.6\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.87656$$

Status: **PASS**
Ratio: **0.880**

Considering z-direction:

$H_o = 0.067\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.17233\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17233\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.17233\ \mathrm{kipft/ft})) + (4 \times (0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6732\ \mathrm{ft}$$

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

$$p = \frac{1.178\,\left[(4\,M_o) + (3\,H_o\,L_e)\right]^2}{L_e^2\,\left[(3\,M_o) + (2\,H_o\,L_e)\right]}$$

$$p = \frac{1.178 \times \left[(4 \times (0.17233\ \mathrm{kipft/ft})) + (3 \times (0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))\right]^2}{(6.5\ \mathrm{ft})^2 \times \left[(3 \times (0.17233\ \mathrm{kipft/ft})) + (2 \times (0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))\right]}$$

$$p = 0.080016\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,\left[(2\,M_o) + (H_o\,L_e)\right]}{L_e^2}$$

$$s = \frac{9.425 \times \left[(2 \times (0.17233\ \mathrm{kipft/ft})) + ((0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))\right]}{(6.5\ \mathrm{ft})^2}$$

$$s = 0.17404\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (400\ \mathrm{psf/ft}) \times \frac{(4.6732\ \mathrm{ft})}{2}$$

$$p_a = 0.93465\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.080016\ \mathrm{kip/ft^2}\right)}{\left(0.93465\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.085611$$

Status: **PASS**
Ratio: **0.090**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (400\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 2.6\ \mathrm{kip/ft^2}$$

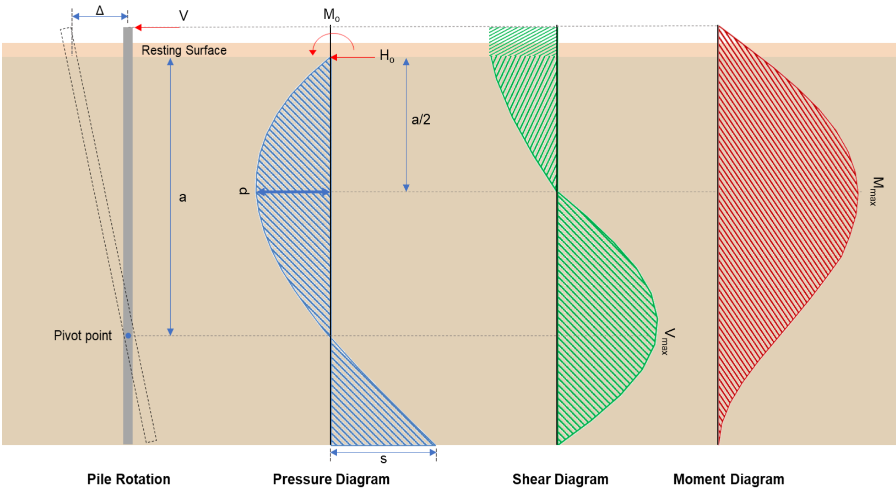
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.17404\ \mathrm{kip/ft^2}\right)}{\left(2.6\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.066937$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.155\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.385\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.5\ \mathrm{kipft}) + ((-4.155\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 13.167\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(13.167\ \mathrm{kipft/ft})}{(-1.385\ \mathrm{kip/ft})}$$

$$E = 9.5066\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.167\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-1.385\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (13.167\ \mathrm{kipft/ft})) + (4 \times (-1.385\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.5029\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.385\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.5066\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.5029\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.5066\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.5029\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.493 \text{ kip}$$

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

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

$$M_{max} = ((-1.385 \text{ kip/ft}) \times (36 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(9.5066 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.5029 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (9.5066 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.5029 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.5066 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.5029 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 41.405 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(0.339 \text{ kip})}{(36 \text{ in})}$$

$$H_o = 0.113 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{D}$$

$$M_o = \frac{(0.863 \text{ kipft}) + ((0.339 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.28767 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.28767 \text{ kipft/ft})}{(0.113 \text{ kip/ft})}$$

$$E = 2.5457 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.28767 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (0.113 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.28767 \text{ kipft/ft})) + (4 \times (0.113 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6745 \text{ ft}$$

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

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

$$V_{max} = ((0.113 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.5457 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6745 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.5457 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6745 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.46165 \text{ kip}$$

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

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

$$M_{max} = ((0.113 \text{ kip/ft}) \times (36 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(2.5457 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6745 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.5457 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6745 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.5457 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6745 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.3045 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(6.378\text{ kip})}{(0.65)\times(0.85)} - \left(0.85 \times (2.5\text{ ksi}) \times \left(1017.9\text{ in}^2\right)\right)}{(60\text{ ksi}) - (0.85 \times (2.5\text{ ksi}))}, \left(0.08 \times \left(1017.9\text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -37.174 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-37.174\text{ in}^2\right), \left(0.0018 \times \left(1017.9\text{ in}^2\right)\right)\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{\left(1.8322\text{ in}^2\right)}{\left(0.3068\text{ in}^2\right)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625\text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(1.8322\text{ in}^2\right)}{\left(1.8408\text{ in}^2\right)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

$$s_{ties} = Min\left[(16 \times (0.625\text{ in})), (48 \times (0.375\text{ in})), (36\text{ in})\right]$$

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

Summary:

	Main reinforcement: **6 - #5 (0.625 in)** Ties: **#3(0.375 in) - 10 in**	

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \mathrm{ksi}) \times \left[\left(1017.9\ \mathrm{in}^2\right) - \left(1.8408\ \mathrm{in}^2\right)\right]\right) + \left((60\ \mathrm{ksi}) \times \left(1.8408\ \mathrm{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \mathrm{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.378\ \mathrm{kip})}{(1253.9\ \mathrm{kip})}$$

$$Ratio = 0.0050865$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \mathrm{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \mathrm{in})$$

$$d = 28.8\ \mathrm{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1+\frac{(28.8\ \mathrm{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,max} = 186.09\ \mathrm{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \mathrm{ksi} \rightarrow 2500\ \mathrm{psi}$, $P = 6.378\ \mathrm{kip} \rightarrow 6378\ \mathrm{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + \frac{(6378\ \mathrm{lbf})}{6 \times \left(1017.9\ \mathrm{in}^2\right)}\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,a} = 75.521\ \mathrm{kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \mathrm{psi})} + (0.05 \times (2500\ \mathrm{psi}))\right] \times (36\ \mathrm{in}) \times (28.8\ \mathrm{in})$$

$$V_{c,b} = 204.04\ \mathrm{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \mathrm{kip}), (75.521\ \mathrm{kip}), (204.04\ \mathrm{kip})\right]$$

$$V_c = 75.521\ \text{kip}$$

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

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

$$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi\, d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$

$$A_v = 0.11045\ \text{in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.521\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 73.899\ \text{kip}$$

Considering x-direction:

$V_{max} = 13.493\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.493\ \text{kip})}{(73.899\ \text{kip})}$$

$$Ratio = 0.18258$$

Status: **PASS**
Ratio: **0.180**

Considering z-direction:

$V_{max} = 0.46165\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.46165\ \text{kip})}{(73.899\ \text{kip})}$$

$$Ratio = 0.0062471$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

$$S_m = 4580.4\ \text{in}^3$$

$\lambda = 1$ - Concrete modification factor (Normal concrete),
Allowable flexural strength:
M_n shall be the lesser of:
$\phi M_{n,1}$

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$$

$$\phi M_{n,1} = 62.027kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(4580.4\ \text{in}^3\right)$$

$$\phi M_{n,2} = 527.23\ \text{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(62.027\ \text{kipft}), (527.23\ \text{kipft})]$$

$$\phi M_n = 62.027\ \text{kipft}$$

Considering x-direction:

$M_{max} = 41.405\ \text{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(41.405\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.66753$$

Status: **PASS**
Ratio: **0.670**

Considering z-direction:

$M_{max} = 1.3045\ \text{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(1.3045\ \text{kipft})}{(62.027\ \text{kipft})}$$

$$Ratio = 0.021031$$

Status: **PASS**
Ratio: **0.020**

REFERENCES	CALCULATIONS	RESULTS

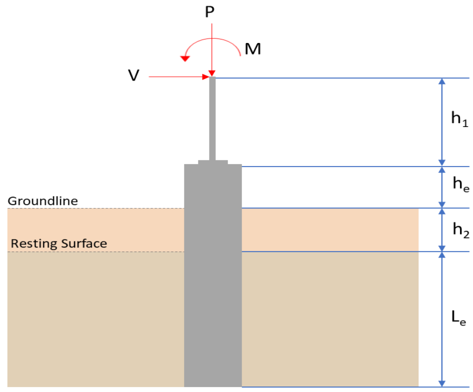
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: round
$D = 36 \text{ in}$ - Pile diameter
$L = 6.5 \text{ ft}$ - Total pile length
$h_1 = 0 \text{ ft}$ - Lateral load height from the top of the pile,
$h_2 = 0 \text{ ft}$ - Depth to resisting surface
$h_e = 0 \text{ ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sedimentary & foliated rock	4000.000	400.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	4.115	6.378
V_x (kip)	-2.493	-4.155
V_z (kip)	-0.201	-0.339
M_x (kipft)	-0.517	-0.863
M_z (kipft)	23.427	39.500

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.493 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.831 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.427\ \text{kipft}) + ((-2.493\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 7.809\ \text{kipft/ft}$$

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:
$L_{e,x} = 5.8192\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.201\ \text{kip})}{(36\ \text{in})}$$

$$H_o = -0.067\ \text{kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{D}$$

$$M_o = \frac{(0.517\ \text{kipft}) + ((-0.201\ \text{kip}) \times (0\ \text{ft}))}{(36\ \text{in})}$$

$$M_o = 0.17233\ \text{kipft/ft}$$

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:
$L_{e,z} = 1.6232\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

$L_{e,req}$ - Depth of pile required,

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

$$L_{e,req} = MAX[(5.8192\ \text{ft}), (1.6232\ \text{ft})]$$

$$L_{e,req} = 5.819\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 6.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(5.819\ \text{ft})}{(6.5\ \text{ft})}$$

$$Ratio = 0.89523$$

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

End-bearing Capacity (ASD)

A - Pile cros-section area

$$A = \pi \left(\frac{D}{2}\right)^2$$

$$A = \pi \times \left(\frac{(36\ \text{in})}{2}\right)^2$$

$$A = 7.0686\ \text{ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(4.115\ \text{kip})}{(7.0686\ \text{ft}^2)}$$

$$q = 0.58215\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.58215\ \mathrm{kip/ft^2}\right)}{(4000\ \mathrm{psf})}$$

$$Ratio = 0.14554$$

Status: **PASS**
Ratio: **0.150**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6.5\ \mathrm{ft})}{(36\ \mathrm{in})}$$

$$L/D = 2.1667$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.831\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 7.809\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (7.809\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.831\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (7.809\ \mathrm{kipft/ft})) + (4 \times (-0.831\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.5043\ \mathrm{ft}$$

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

$$p = \frac{1.178\ [(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\ [(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (7.809\ \mathrm{kipft/ft})) + (3 \times (-0.831\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^2}{(6.5\ \mathrm{ft})^2 \times [(3 \times (7.809\ \mathrm{kipft/ft})) + (2 \times (-0.831\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = 0.49903\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\ [(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (7.809\ \mathrm{kipft/ft})) + ((-0.831\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = 2.2791\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (400\ \mathrm{psf/ft}) \times \frac{(4.5043\ \mathrm{ft})}{2}$$

$$p_a = 0.90086\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.49903\ \mathrm{kip/ft^2}\right)}{\left(0.90086\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.55395$$

Status: **PASS**
Ratio: **0.550**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (400\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 2.6\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(2.2791\ \mathrm{kip/ft^2}\right)}{\left(2.6\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.87656$$

Status: **PASS**
Ratio: **0.880**

Considering z-direction:

$H_o = -0.067\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.17233\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17233\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (0.17233\ \mathrm{kipft/ft})) + (4 \times (-0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.6732\ \mathrm{ft}$$

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

$$p = \frac{1.178\,[(4\,M_o) + (3\,H_o\,L_e)]^2}{L_e^2\,[(3\,M_o) + (2\,H_o\,L_e)]}$$

$$p = \frac{1.178 \times [(4 \times (0.17233\ \mathrm{kipft/ft})) + (3 \times (-0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]^{\ 2}}{(6.5\ \mathrm{ft})^2 \times [(3 \times (0.17233\ \mathrm{kipft/ft})) + (2 \times (-0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}$$

$$p = -0.03\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

$$s = \frac{9.425\,[(2\,M_o) + (H_o\,L_e)]}{L_e^2}$$

$$s = \frac{9.425 \times [(2 \times (0.17233\ \mathrm{kipft/ft})) + ((-0.067\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))]}{(6.5\ \mathrm{ft})^2}$$

$$s = -0.020263\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (400\ \mathrm{psf/ft}) \times \frac{(4.6732\ \mathrm{ft})}{2}$$

$$p_a = 0.93465\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.03\ \mathrm{kip/ft^2}\right)}{\left(0.93465\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.032098$$

Status: **PASS**
Ratio: **-0.030**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (400\ \mathrm{psf/ft}) \times (6.5\ \mathrm{ft})$$

$$p_s = 2.6\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

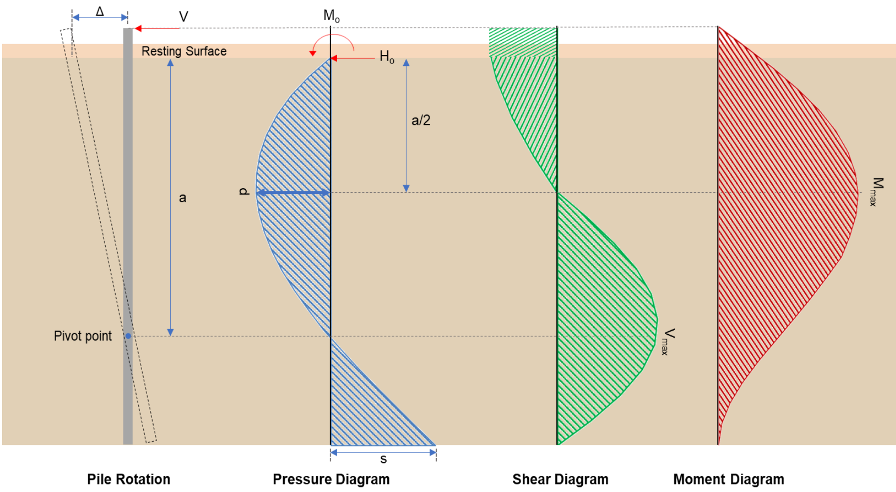
$$Ratio = \frac{s}{\ }$$

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

$$Ratio = \frac{\left(-0.020263\ \mathrm{kip/ft^2}\right)}{\left(2.6\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = -0.0077934$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.155\ \mathrm{kip})}{(36\ \mathrm{in})}$$

$$H_o = -1.385\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(39.5\ \mathrm{kipft}) + ((-4.155\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{(36\ \mathrm{in})}$$

$$M_o = 13.167\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(13.167\ \mathrm{kipft/ft})}{(-1.385\ \mathrm{kip/ft})}$$

$$E = 9.5066\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (13.167\ \mathrm{kipft/ft}) \times (6.5\ \mathrm{ft})) + \left(3 \times (-1.385\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft})^2\right)}{(6 \times (13.167\ \mathrm{kipft/ft})) + (4 \times (-1.385\ \mathrm{kip/ft}) \times (6.5\ \mathrm{ft}))}$$

$$a = 4.5029\ \mathrm{ft}$$

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

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

$$V_{max} = ((-1.385\ \mathrm{kip/ft}) \times (36\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.5066\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(4.5029\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (9.5066\ \mathrm{ft})}{(6.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(4.5029\ \mathrm{ft})}{(6.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 13.493 \text{ kip}$$

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

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

$$M_{max} = ((-1.385 \text{ kip/ft}) \times (36 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(9.5066 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.5029 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (9.5066 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.5029 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (9.5066 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.5029 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 41.405 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

$$H_o = \frac{V_z}{D}$$

$$H_o = \frac{(-0.339 \text{ kip})}{(36 \text{ in})}$$

$$H_o = -0.113 \text{ kip/ft}$$

M_o - Moment per length of pile,

$$M_o = \frac{M_x + (V_z\, H)}{D}$$

$$M_o = \frac{(0.863 \text{ kipft}) + ((-0.339 \text{ kip}) \times (0 \text{ ft}))}{(36 \text{ in})}$$

$$M_o = 0.28767 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.28767 \text{ kipft/ft})}{(-0.113 \text{ kip/ft})}$$

$$E = 2.5457 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.28767 \text{ kipft/ft}) \times (6.5 \text{ ft})) + \left(3 \times (-0.113 \text{ kip/ft}) \times (6.5 \text{ ft})^2\right)}{(6 \times (0.28767 \text{ kipft/ft})) + (4 \times (-0.113 \text{ kip/ft}) \times (6.5 \text{ ft}))}$$

$$a = 4.6745 \text{ ft}$$

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

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

$$V_{max} = ((-0.113 \text{ kip/ft}) \times (36 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.5457 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6745 \text{ ft})}{(6.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (2.5457 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6745 \text{ ft})}{(6.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.46165 \text{ kip}$$

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

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

$$M_{max} = ((-0.113 \text{ kip/ft}) \times (36 \text{ in}) \times (6.5 \text{ ft})) \times \left[\left(\frac{(2.5457 \text{ ft})}{(6.5 \text{ ft})} + \frac{(4.6745 \text{ ft})}{2 \times (6.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (2.5457 \text{ ft})}{(6.5 \text{ ft})} + 3\right) \times \left(\frac{(4.6745 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (2.5457 \text{ ft})}{(6.5 \text{ ft})} + 2\right) \times \left(\frac{(4.6745 \text{ ft})}{2 \times (6.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 1.3045 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.85$ - Alpha factor for axial strength,
$A_g = 1017.9 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

Required reinforcement due to axial load, $A_{st,required}$
22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(6.378\text{ kip})}{(0.65)\times(0.85)} - (0.85 \times (2.5\text{ ksi}) \times (1017.9\text{ in}^2))}{(60\text{ ksi}) - (0.85 \times (2.5\text{ ksi}))}, (0.08 \times (1017.9\text{ in}^2))\right]$$

$$A_{st,required} = -37.174 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-37.174\text{ in}^2), (0.0018 \times (1017.9\text{ in}^2))\right]$$

$$A_{min} = 1.8322 \text{ in}^2$$

n_{rebar} - Required number of reinforcement,

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

$$n_{rebar} = \frac{(1.8322\text{ in}^2)}{(0.3068\text{ in}^2)}$$

$$n_{rebar} = 6$$

A_{st} - Actual total reinforcement area,

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

$$A_{st} = (6) \times \frac{\pi \times (0.625\text{ in})^2}{4}$$

$$A_{st} = 1.8408 \text{ in}^2$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(1.8322\text{ in}^2)}{(1.8408\text{ in}^2)}$$

$$Ratio = 0.99533$$

Status: **PASS**
Ratio: **1.000**

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

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

$$s_{ties} = Min\left[(16 \times (0.625\text{ in})), (48 \times (0.375\text{ in})), (36\text{ in})\right]$$

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

Summary:

Main reinforcement: **6 - #5 (0.625 in)**
Ties: **#3(0.375 in) - 10 in**

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2 ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.85 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(1017.9\ \text{in}^2\right) - \left(1.8408\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(1.8408\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 1253.9\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(6.378\ \text{kip})}{(1253.9\ \text{kip})}$$

$$Ratio = 0.0050865$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

$b_w = 36\ \text{in}$ - Effective width,

22.5.2.2 d - Effective depth

$$d = 0.80\, D$$

$$d = 0.80 \times (36\ \text{in})$$

$$d = 28.8\ \text{in}$$

22.5.5.1.3 λ_s - size effect modification factor

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

$$\lambda_s = MIN\left[\sqrt{\frac{2}{1 + \frac{(28.8\ \text{in})}{10}}}, 1\right]$$

$$\lambda_s = 0.71796$$

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

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

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

$$V_{c,max} = 5 \times (0.71796) \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,max} = 186.09\ \text{kip}$$

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 6.378\ \text{kip} \rightarrow 6378\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + \frac{(6378\ \text{lbf})}{6 \times \left(1017.9\ \text{in}^2\right)}\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,a} = 75.521\ \text{kip}$$

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

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

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

$$V_{c,b} = \left[2 \times (0.71796) \times \sqrt{(2500\ \text{psi})} + (0.05 \times (2500\ \text{psi}))\right] \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{c,b} = 204.04\ \text{kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(186.09\ \text{kip}), (75.521\ \text{kip}), (204.04\ \text{kip})\right]$$

$$V_c = 75.521\ \text{kip}$$

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

22.5.1.2 $V_{s,a}$ - Shear strength of steel (a)

$$V_{s,a} = 8\sqrt{f'_{ck}}\, b_w\, d$$

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (36\ \text{in}) \times (28.8\ \text{in})$$

$$V_{s,a} = 414.72\ \text{kip}$$

A_v - Ties rebar area,

$$A_v = \frac{\pi\, d_{ties}^2}{4}$$

$$A_v = \frac{\pi \times (0.375\ \text{in})^2}{4}$$

$$A_v = 0.11045\ \text{in}^2$$

22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)

$$V_{s,b} = \frac{2\, A_v\, f_{ywk}\, d}{s_{ties}}$$

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (28.8\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 38.17\ \text{kip}$$

V_s - Governing shear strength of steel

$$V_s = MIN\left[V_{s,a}, V_{s,b}\right]$$

$$V_s = MIN\left[(414.72\ \text{kip}), (38.17\ \text{kip})\right]$$

$$V_s = 38.17\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((75.521\ \text{kip}) + (38.17\ \text{kip}))$$

$$\phi V_n = 73.899\ \text{kip}$$

Considering x-direction:

$V_{max} = 13.493\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(13.493\ \text{kip})}{(73.899\ \text{kip})}$$

$$Ratio = 0.18258$$

Status: **PASS**
Ratio: **0.180**

Considering z-direction:

$V_{max} = 0.46165\ \text{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.46165\ \text{kip})}{(73.899\ \text{kip})}$$

$$Ratio = 0.0062471$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{\pi\, D^3}{32}$$

$$S_m = \frac{\pi \times (36\ \text{in})^3}{32}$$

$$S_m = 4580.4\ \text{in}^3$$

14.5.2.1b	$S_m = 4580.4\ \mathrm{in}^3$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 4580.442in^3$ $\phi M_{n,1} = 62.027kipft$ $\phi M_{n,2}$ $\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(4580.4\ \mathrm{in}^3\right)$ $\phi M_{n,2} = 527.23\ \mathrm{kipft}$ Therefore, ϕM_n - Allowable flexural strength, $\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = MIN[(62.027\ \mathrm{kipft}), (527.23\ \mathrm{kipft})]$ $\phi M_n = 62.027\ \mathrm{kipft}$ **Considering x-direction:** $M_{max} = 41.405\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(41.405\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$ $Ratio = 0.66753$	Status: **PASS** Ratio: **0.670**
	Considering z-direction: $M_{max} = 1.3045\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $Ratio = \frac{M_{max}}{\phi M_n}$ $Ratio = \frac{(1.3045\ \mathrm{kipft})}{(62.027\ \mathrm{kipft})}$ $Ratio = 0.021031$	Status: **PASS** Ratio: **0.020**