

Your Project Calculations



Project Name: SolarFest-RevC

S3D Model Link:

https://platform.skyciv.com/structural?preload_name=SolarFest-RevC&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023

Public Model Link:

https://platform.skyciv.com/structural-viewer?project_id=mnUOJXThnqxf1R8vBYLHPMw0tVMwgdyxrBfe4u1j6nVndeXzLk4jhaxbojom4r5

Array Specification

Product:	Beam
Unique ID:	2P-22.5-8TOP-SD-45-L-5Hx6W-HK4B
Duty Classification:	SD
Module Width:	39.10 in
Module Length:	77.00in
Number of Rows:	5
Number of Columns:	6
Total Number of Modules:	30
Desired Tilt Angle:	60
Front Edge Clearance:	5
Total Array Height at Tilt:	19.20 ft
Total Frame Length:	37.50 ft
Frame Weight:	1675 lbs
Array Dimensions N/S:	16.50 ft
Array Dimensions E/W:	39.00 ft
Rail Length:	198.00 in
Rail Spacing:	3.21 ft
Rail Check:	

Support Specifications

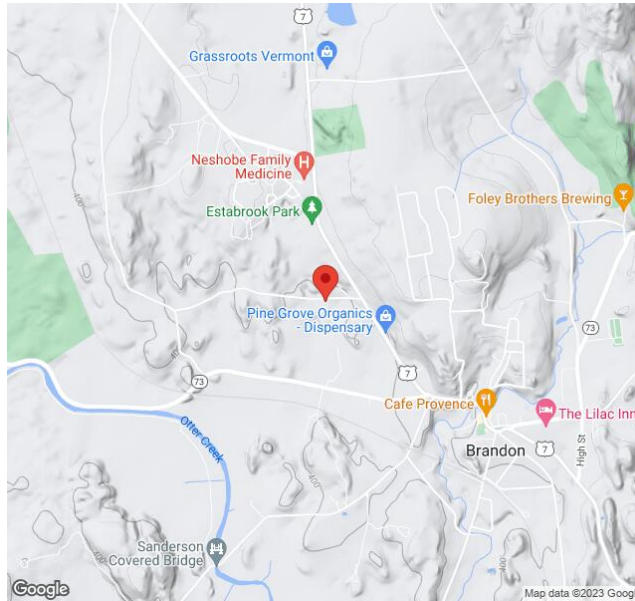
Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	12.14 ft
Number of Poles:	2
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.00 ft Pile 2: 7.00 ft
Foundation Volume:	8.296 y ³
Foundation Result:	PASSED
Mount Twist:	1.855101 kip

Site Info

Risk Category:	I
Exposure:	B
Soil Classification:	sand
Site Location:	144 Steinberg Rd, Brandon, VT 05733, USA
Wind Speed:	100 mph
Snow Load:	50 psf
Design Uplift Pressure:	0.016932 ksf
Design Downforce Pressure:	-0.016932 ksf
Design Snow Pressure:	0.005498 ksf



Design Disclaimer

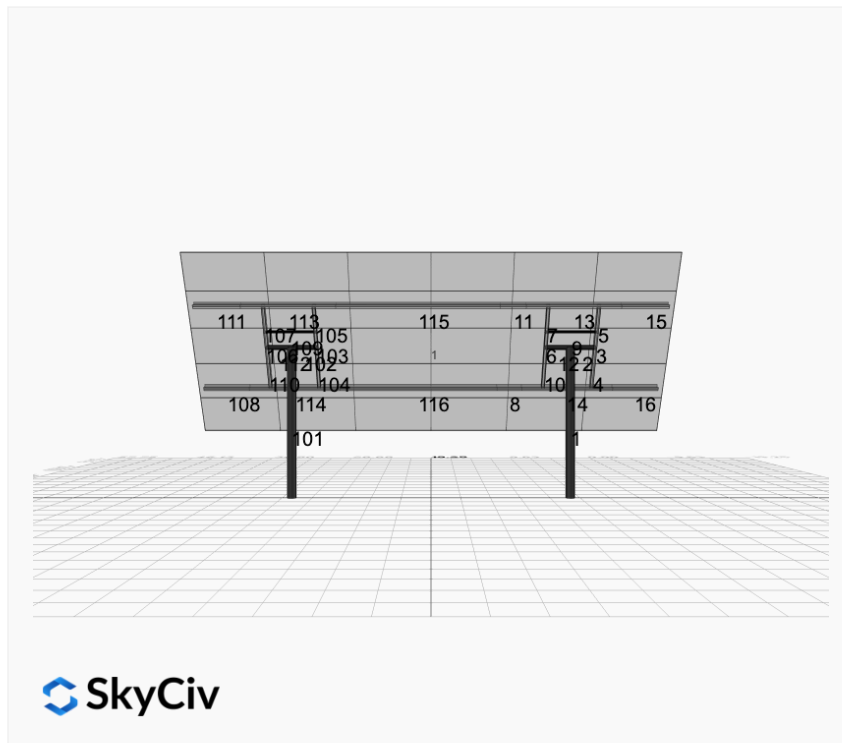
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

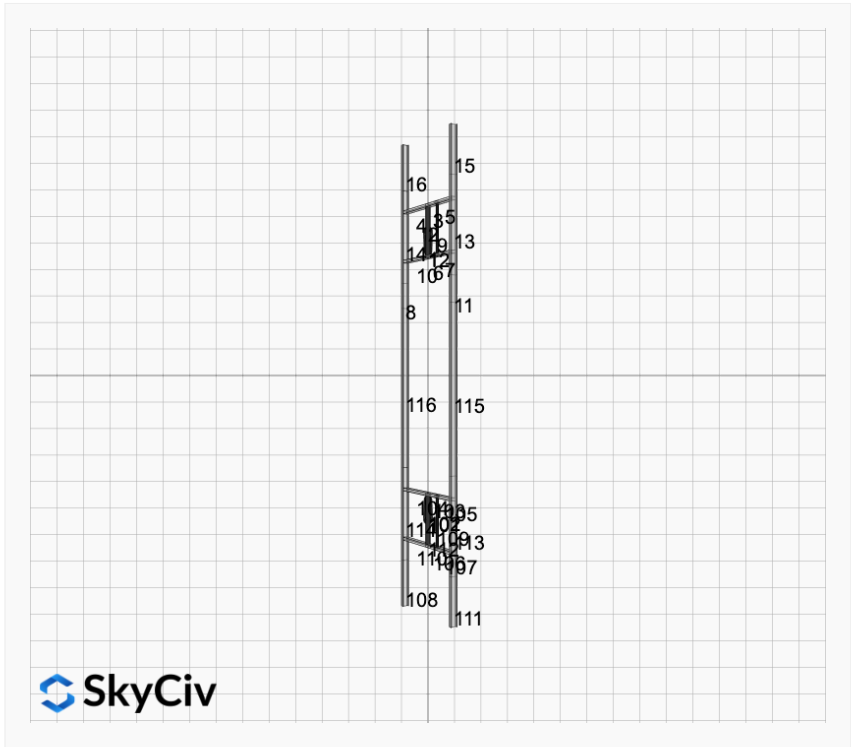
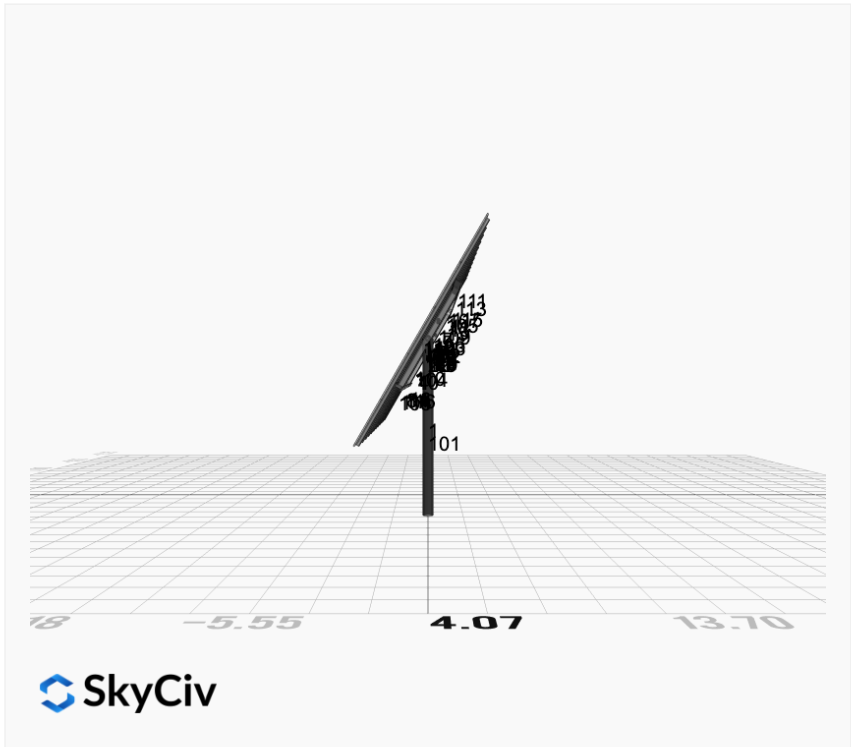
AutoDesigner Input

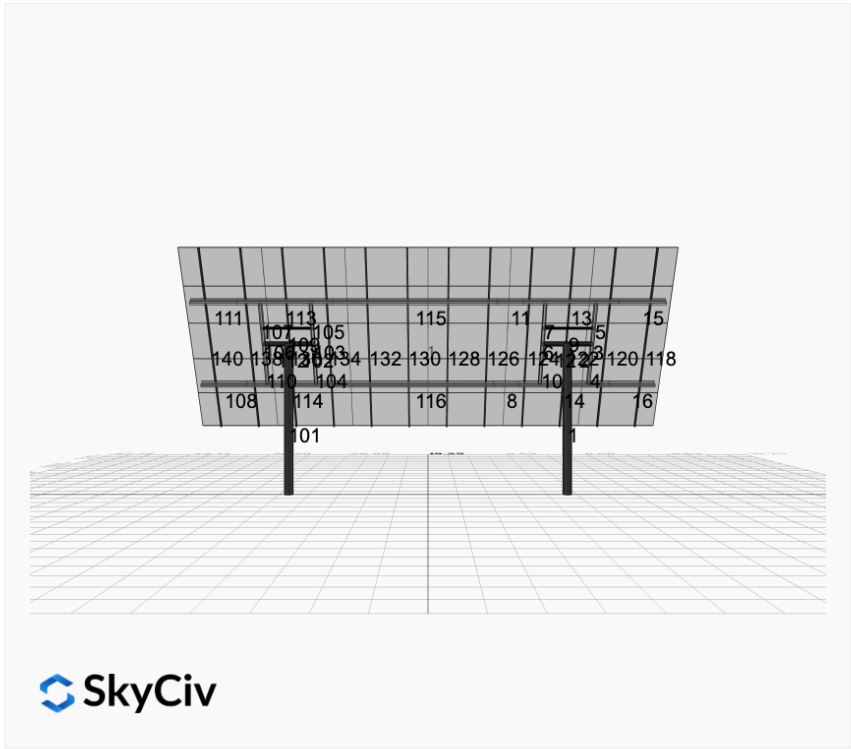
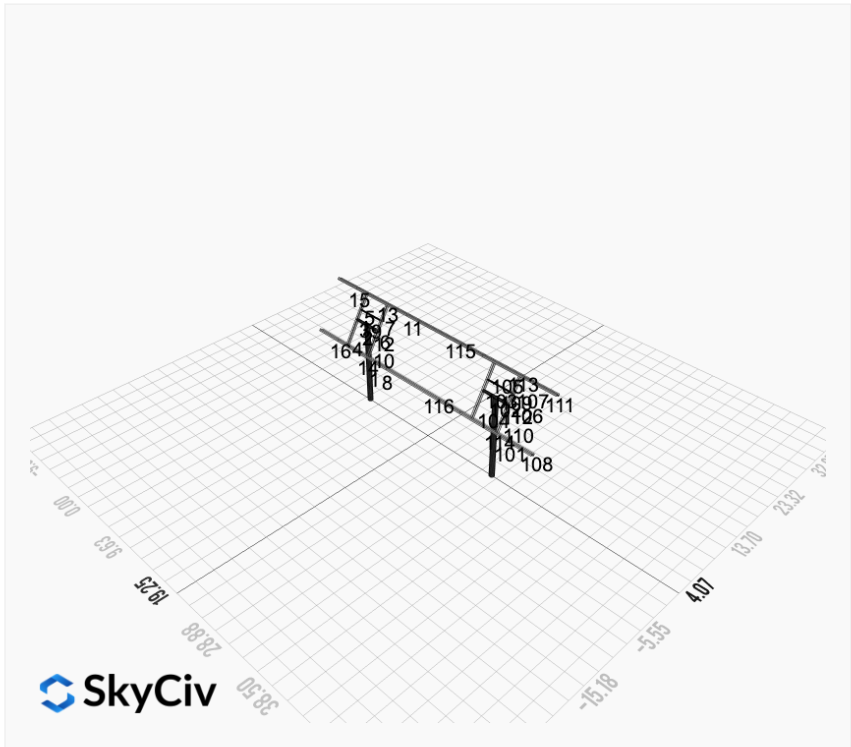
```
{
  "wind_speed_override": 100,
  "snow_load_override": 50,
  "direct_snow_load": false,
  "product_type": "Beam",
  "project_id": "SolarFest-RevC",
  "site_address": "144 Steinberg Rd, Brandon, VT 05733, USA",
  "module_width": 39.1,
  "module_length": 77,
  "number_rows": 5,
  "number_columns": 6,
  "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": 60,
  "ground_clearance": 5,
  "risk_category": "I",
  "exposure_category": "B",
  "frame_duty_override": "auto",
  "pole_override": "auto",
  "soil_type": "sand",
  "foundation_type": "Square",
  "foundation_size": 48,
  "check_rails": true
}
```

Design Notes:

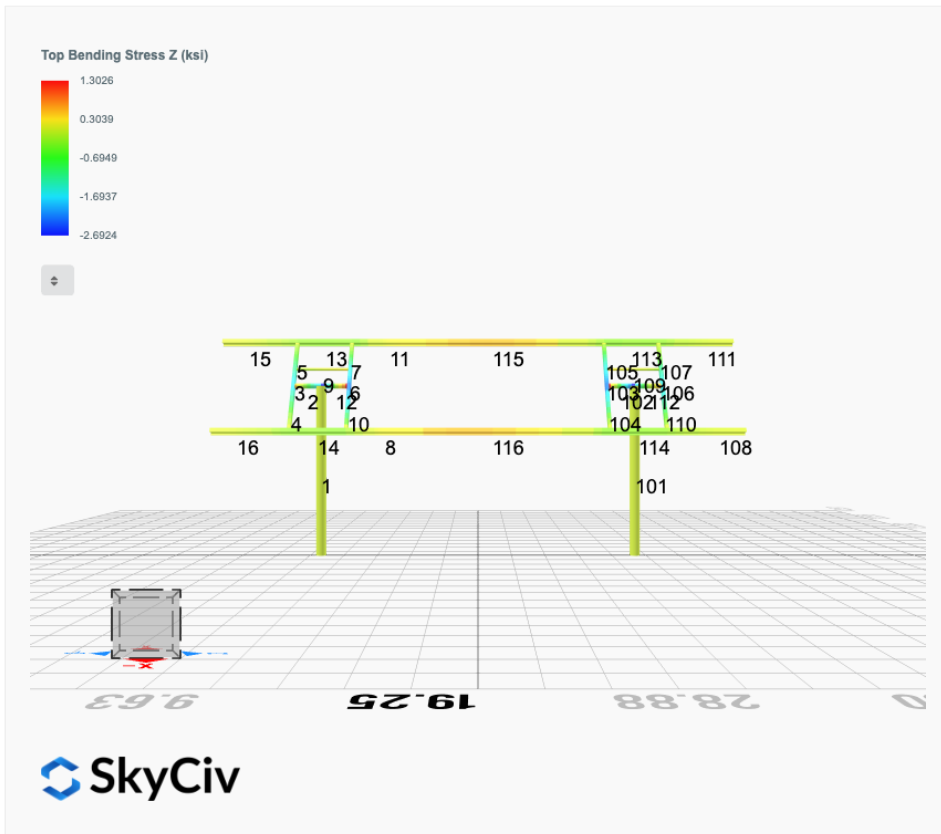
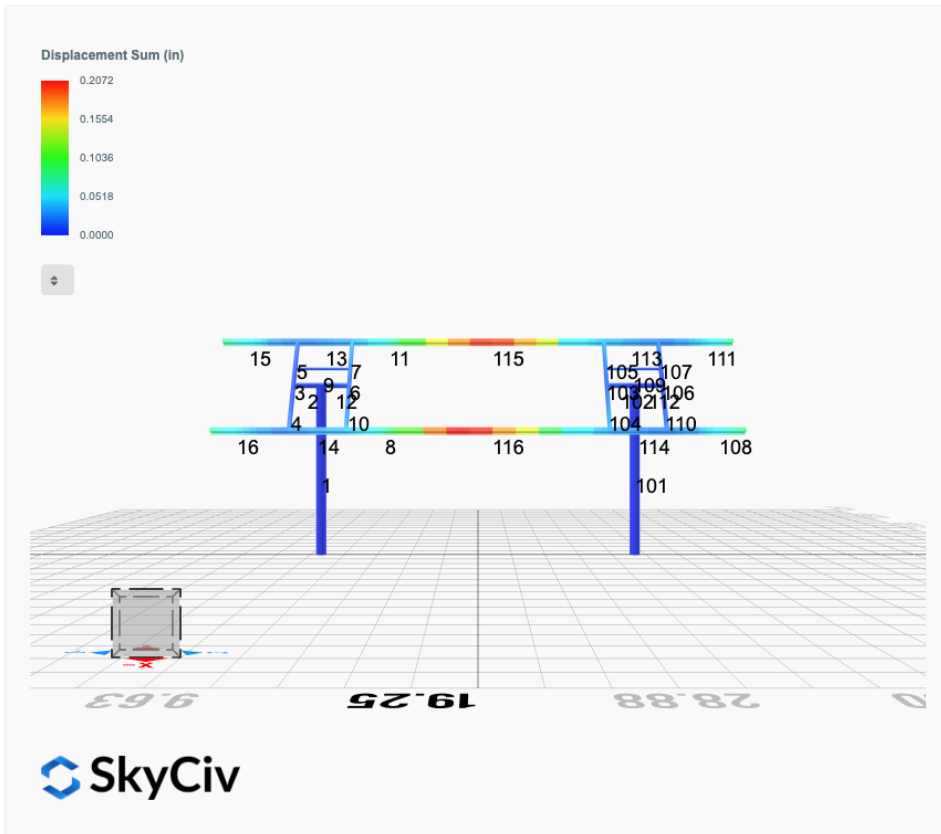
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Design and Sizing is approximate only

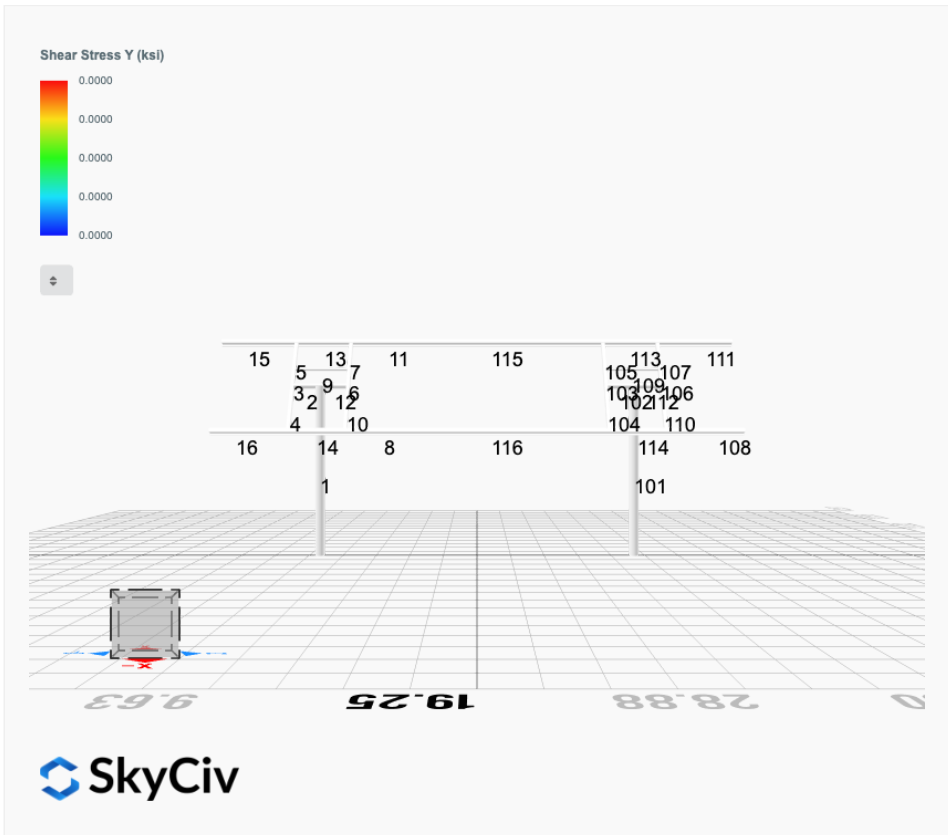
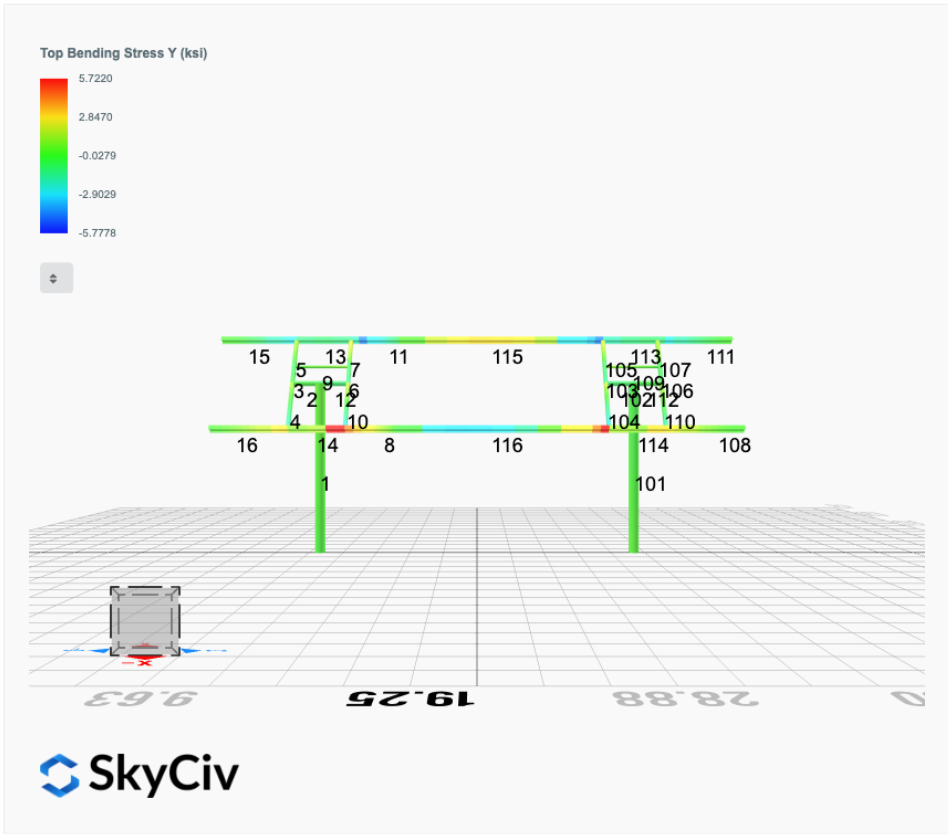


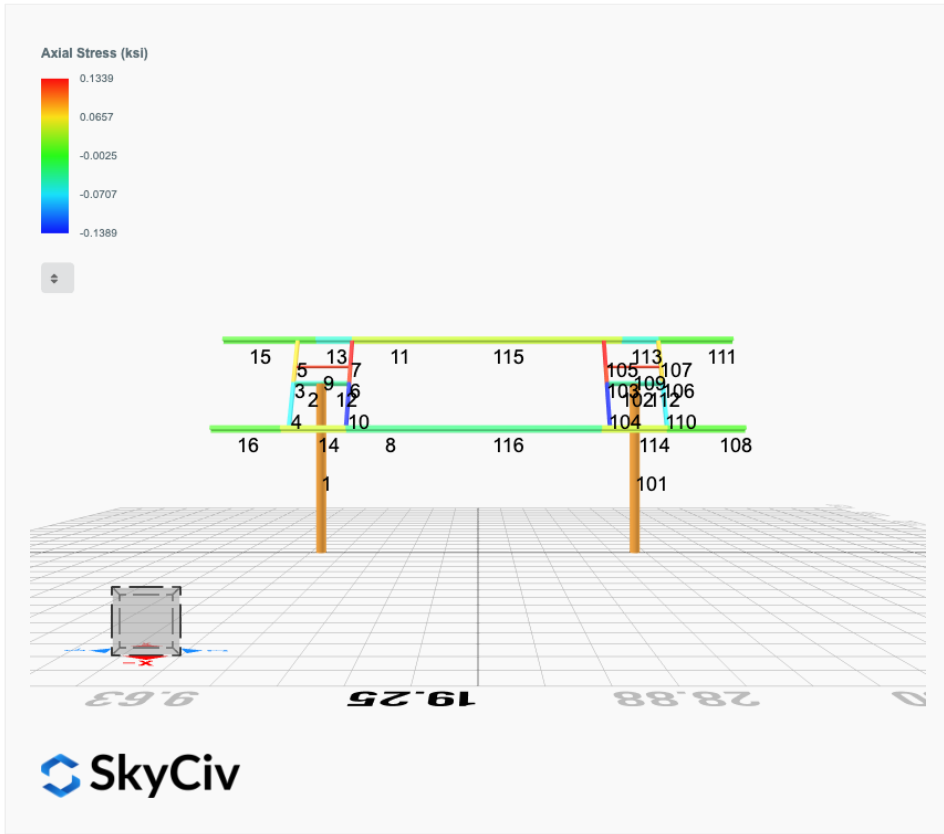




FEM Results (Envelope Worst Case for each member)







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

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 2. D + L	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 3. D + (S or Lr or R)	0.0000	3.1548	0.1063	0.3898	-0.2046	0.0154
ULS: 3. D + (S or Lr or R)	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.9421	0.0978	0.3587	-0.1882	0.0151
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 5b. D + 0.7E	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	2.9421	0.0978	0.3587	-0.1882	0.0151
ULS: 8. 0.6D + 0.7E	0.0000	1.3826	0.0434	0.1591	-0.0834	0.0085
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.8308	3.9386	0.1983	0.6941	-1.1339	34.7127
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.8308	0.6699	-0.0533	-0.1617	0.8540	-34.0527
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1231	4.1679	0.1923	0.6804	-0.9344	26.0389
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	2.9421	0.0978	0.3587	-0.1882	0.0151
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1231	1.7164	0.0036	0.0385	0.5566	-25.5351
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	2.9421	0.0978	0.3587	-0.1882	0.0151
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1231	3.5300	0.1668	0.5869	-0.8852	26.0380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1231	1.0785	-0.0219	-0.0550	0.6058	-25.5360
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0000	2.3043	0.0723	0.2652	-0.1391	0.0142
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.8308	3.0169	0.1694	0.5881	-1.0783	34.7070
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0000	1.3826	0.0434	0.1591	-0.0834	0.0085
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.8308	-0.2518	-0.0822	-0.2677	0.9096	-34.0584
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0000	1.3826	0.0434	0.1591	-0.0834	0.0085

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	5.9143
Shear X	-4.7180
Shear Z	0.3139
Moment X	1.0967
Moment Y (Twist)	1.8550
Moment Z	58.5427

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	4.1679
Shear X	-2.8308
Shear Z	0.1983
Moment X	0.6941
Moment Y (Twist)	1.1339
Moment Z	34.7127

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	2.3043	-0.0723	-0.2652	0.1391	0.0142
ULS: 2. D + L	-0.0000	2.3043	-0.0723	-0.2652	0.1391	0.0142
ULS: 3. D + (S or Lr or R)	-0.0000	3.1548	-0.1063	-0.3899	0.2046	0.0154
ULS: 3. D + (S or Lr or R)	-0.0000	2.3043	-0.0723	-0.2652	0.1391	0.0142
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	2.9421	-0.0978	-0.3587	0.1883	0.0151
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	2.3043	-0.0723	-0.2652	0.1391	0.0142
ULS: 5b. D + 0.7E	-0.0000	2.3043	-0.0723	-0.2652	0.1391	0.0142

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	2.9421	-0.0978	-0.3587	0.1883	0.0151
ULS: 8. 0.6D + 0.7E	-0.0000	1.3826	-0.0434	-0.1591	0.0835	0.0085
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.8308	3.9386	-0.1983	-0.6942	1.1339	34.7127
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0000	2.3043	-0.0723	-0.2652	0.1391	0.0142
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.8308	0.6699	0.0533	0.1616	-0.8540	-34.0527
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0000	2.3043	-0.0723	-0.2652	0.1391	0.0142
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1231	4.1679	-0.1923	-0.6804	0.9344	26.0390
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	2.9421	-0.0978	-0.3587	0.1883	0.0151
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1231	1.7164	-0.0036	-0.0386	-0.5566	-25.5350
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	2.9421	-0.0978	-0.3587	0.1883	0.0151
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1231	3.5300	-0.1668	-0.5869	0.8852	26.0381
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0000	2.3043	-0.0723	-0.2652	0.1391	0.0142
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1231	1.0785	0.0219	0.0549	-0.6057	-25.5359
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0000	2.3043	-0.0723	-0.2652	0.1391	0.0142
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.8308	3.0169	-0.1694	-0.5881	1.0783	34.7070
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0000	1.3826	-0.0434	-0.1591	0.0835	0.0085
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.8308	-0.2518	0.0822	0.2677	-0.9096	-34.0583
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0000	1.3826	-0.0434	-0.1591	0.0835	0.0085

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	5.9143
Shear X	-4.7180
Shear Z	-0.3139
Moment X	-1.0973
Moment Y (Twist)	1.8551
Moment Z	58.5437

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	4.1679
Shear X	-2.8308
Shear Z	-0.1983
Moment X	-0.6942
Moment Y (Twist)	1.1339
Moment Z	34.7127

Project Details

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



Design Input Information

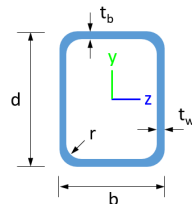
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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				
9	8in Pipe Sch 40	8.63	0.32				



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
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21

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 _z L (ft)	K _y L (ft)	L _b (ft)	C _b	L	S	T
1	9	25.50	25.50	12.14	-	3	2	1
2	4	1.30	1.30	2.00	-	3	2	1
3	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18	3	2	1
4	15	2.44	2.44	3.75	1.68,1.68,1.68,1.68,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	3	2	1
5	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	3	2	1
6	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	3	2	1
7	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	3	2	1
8	18	1.33	1.33	2.05	1.75,1.75,1.75,1.75,1.75,1.75,1.68,1.75,1.65,1.75,1.68,1.75,1.66,1.75,1.70,1.75,1.56,1.75,1.69,1.75,1.63,1.75,1.68,1.75,1.66,1.75	3	2	1
9	1	2.60	2.60	4.00	-	3	2	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.67,1.68,1.67,1.68	3	2	1
11	18	1.33	1.33	2.05	1.77,1.77,1.77,1.77,1.77,1.77,1.70,1.77,1.67,1.77,1.70,1.77,1.67,1.77,1.72,1.77,1.57,1.77,1.71,1.77,1.64,1.77,1.70,1.77,1.68,1.77	3	2	1
12	4	1.30	1.30	2.00	-	3	2	1
13	18	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.09,1.07,1.08,1.07,1.09,1.07,1.08,1.07,1.11,1.07,1.08,1.07,1.09,1.07,1.08,1.07,1.08,1.07	3	2	1
14	18	4.88	4.00	7.50	1.06,1.06,1.06,1.06,1.06,1.06,1.08,1.06,1.08,1.06,1.08,1.06,1.08,1.06,1.08,1.06,1.07,1.06,1.11,1.06,1.07,1.06,1.09,1.06,1.08,1.06,1.08,1.06	3	2	1
15	18	7.88	7.88	3.75	2.33,2.33	3	2	1
16	18	7.88	7.88	3.75	2.33,2.33	3	2	1
101	9	25.50	25.50	12.14	-	3	2	1
102	4	1.30	1.30	2.00	-	3	2	1
103	15	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19,1.18,1.19	3	2	1
104	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.67,1.68,1.67,1.68	3	2	1
105	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	3	2	1
106	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18,1.17,1.18	3	2	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	3	2	1

115	120.00	46.00	10.93	6.45	30.09	45.74
116	120.60	48.60	10.93	6.45	30.09	45.74

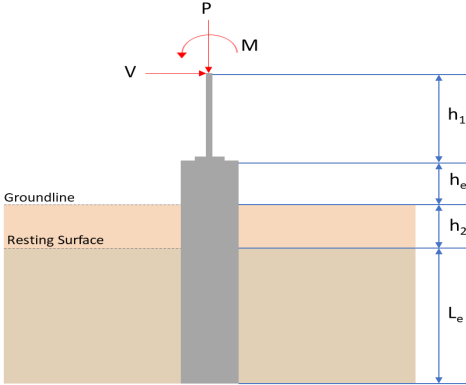
Design Ratio

Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	δ	Status
1	0.035	0.703	0.033	0.042	0.003	0.733	#13	0.521	Not Required	Pass
2	0.004	0.185	0.229	0.049	0.048	0.415	#13	0.034	Not Required	Pass
3	0.008	0.491	0.065	0.048	0.004	0.517	#13	0.044	Not Required	Pass
4	0.007	0.487	0.221	0.049	0.028	0.638	#13	0.078	Not Required	Pass
5	0.008	0.306	0.198	0.049	0.029	0.341	#13	0.073	Not Required	Pass
6	0.013	0.679	0.157	0.069	0.019	0.805	#13	0.044	Not Required	Pass
7	0.014	0.420	0.357	0.067	0.052	0.488	#13	0.073	Not Required	Pass
8	0.003	0.094	0.157	0.045	0.013	0.164	#21	0.088	Not Required	Pass
9	0.013	0.056	0.095	0.004	0.004	0.129	#13	0.198	Not Required	Pass
10	0.014	0.675	0.343	0.068	0.043	0.791	#13	0.078	Not Required	Pass
11	0.003	0.093	0.163	0.045	0.013	0.171	#21	0.088	Not Required	Pass
12	0.003	0.352	0.343	0.080	0.065	0.696	#13	0.034	Not Required	Pass
13	0.004	0.167	0.349	0.055	0.016	0.452	#21	0.265	Not Required	Pass
14	0.005	0.170	0.343	0.055	0.016	0.444	#21	0.177	Not Required	Pass
15	0.000	0.054	0.089	0.022	0.007	0.125	#21	Not Required	Not Required	Pass
16	0.000	0.054	0.089	0.022	0.007	0.125	#21	Not Required	Not Required	Pass
101	0.035	0.703	0.033	0.042	0.003	0.733	#13	0.521	Not Required	Pass
102	0.003	0.352	0.343	0.080	0.065	0.696	#13	0.034	Not Required	Pass
103	0.013	0.679	0.157	0.069	0.019	0.805	#13	0.044	Not Required	Pass
104	0.014	0.675	0.343	0.068	0.043	0.791	#13	0.078	Not Required	Pass
105	0.014	0.420	0.357	0.067	0.052	0.488	#13	0.073	Not Required	Pass
106	0.008	0.491	0.065	0.048	0.004	0.517	#13	0.044	Not Required	Pass
107	0.008	0.306	0.198	0.049	0.029	0.341	#13	0.073	Not Required	Pass
108	0.000	0.054	0.089	0.022	0.007	0.125	#21	Not Required	Not Required	Pass
109	0.013	0.056	0.095	0.004	0.004	0.129	#13	0.198	Not Required	Pass
110	0.007	0.487	0.221	0.049	0.028	0.638	#13	0.078	Not Required	Pass
111	0.000	0.054	0.089	0.022	0.007	0.125	#21	Not Required	Not Required	Pass
112	0.004	0.185	0.229	0.049	0.048	0.415	#13	0.034	Not Required	Pass
113	0.004	0.167	0.348	0.055	0.016	0.452	#21	0.177	Not Required	Pass
114	0.005	0.170	0.343	0.055	0.016	0.444	#21	0.265	Not Required	Pass
115	0.008	0.436	0.196	0.045	0.013	0.580	#13	0.557	Not Required	Pass
116	0.003	0.439	0.195	0.045	0.013	0.583	#13	0.557	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	Length between brace 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																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 7$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1" data-bbox="416 1102 1193 1191"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1" data-bbox="676 1285 935 1458"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>4.168</td> <td>5.914</td> </tr> <tr> <td>V_x (kip)</td> <td>-2.831</td> <td>-4.718</td> </tr> <tr> <td>V_z (kip)</td> <td>0.198</td> <td>0.314</td> </tr> <tr> <td>M_x (kipft)</td> <td>0.694</td> <td>1.097</td> </tr> <tr> <td>M_z (kipft)</td> <td>34.713</td> <td>58.543</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 3$ ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	4.168	5.914	V_x (kip)	-2.831	-4.718	V_z (kip)	0.198	0.314	M_x (kipft)	0.694	1.097	M_z (kipft)	34.713	58.543	
Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)																									
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000																									
Load Component	ASD	LRFD																										
P (kip)	4.168	5.914																										
V_x (kip)	-2.831	-4.718																										
V_z (kip)	0.198	0.314																										
M_x (kipft)	0.694	1.097																										
M_z (kipft)	34.713	58.543																										
	<p>Required depth to resist lateral loads (ASD) H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction: H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.831 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.4508 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(34.713 \text{ kipft}) + ((-2.831 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.5275 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.4461 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.198 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.031529 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.694 \text{ kipft}) + ((0.198 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.11051 \text{ kipft/ft}$$

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:

$L_{e,z} = 2.3708 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(6.4461 \text{ ft}), (2.3708 \text{ ft})]$$

$$L_{e,req} = 6.446 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(6.446 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.92086$$

Status: **PASS**
Ratio: **0.920**

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

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

$$q = \frac{(4.168 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.2605 \text{ kip/ft}^2$$

$$q = 0.2000 \text{ kip/ft}$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$Ratio = \frac{(0.2605 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$Ratio = 0.13025$$

Status: **PASS**
Ratio: **0.130**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.4508 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 5.5275 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.5275 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.4508 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (5.5275 \text{ kipft/ft})) + (4 \times (-0.4508 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8275 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.5275 \text{ kipft/ft})) + (3 \times (-0.4508 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.5275 \text{ kipft/ft})) + (2 \times (-0.4508 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.23821 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (5.5275 \text{ kipft/ft})) + ((-0.4508 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.96729 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8275 \text{ ft})}{2}$$

$$p_a = 0.36206 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.23821 \text{ kip/ft}^2)}{(0.36206 \text{ kip/ft}^2)}$$

$$Ratio = 0.65793$$

p_a - Allowable lateral soil pressure at depth L_e ,

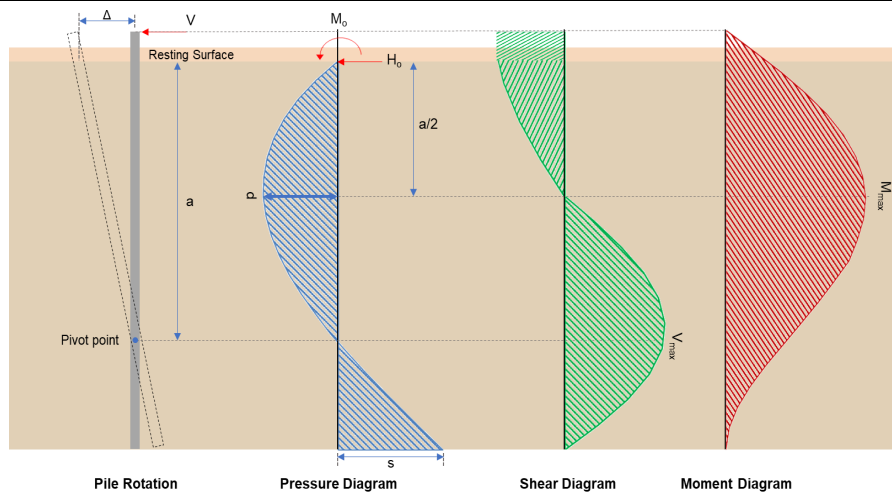
Status: **PASS**
Ratio: **0.660**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.96729 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.92123$	Status: PASS Ratio: 0.920
	<p>Considering z-direction:</p> <p>$H_o = 0.031529 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.11051 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.11051 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.031529 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.11051 \text{ kipft/ft})) + (4 \times (0.031529 \text{ kip/ft}) \times (7 \text{ ft}))}$ $a = 4.9998 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.11051 \text{ kipft/ft})) + (3 \times (0.031529 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.11051 \text{ kipft/ft})) + (2 \times (0.031529 \text{ kip/ft}) \times (7 \text{ ft}))]}$ $p = 0.024142 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.11051 \text{ kipft/ft})) + ((0.031529 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$ $s = 0.054088 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(4.9998 \text{ ft})}{2}$ $p_a = 0.37498 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(0.024142 \text{ kip/ft}^2)}{(0.37498 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.064381$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	Status: PASS Ratio: 0.060

$$Ratio = \frac{(0.054088 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$Ratio = 0.051513$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.718 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.75127 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(58.543 \text{ kipft}) + ((-4.718 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 9.3221 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.3221 \text{ kipft/ft})}{(-0.75127 \text{ kip/ft})}$$

$$E = 12.408 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.3221 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.75127 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (9.3221 \text{ kipft/ft})) + (4 \times (-0.75127 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8261 \text{ ft}$$

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

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

$$V_{max} = ((-0.75127 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.408 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8261 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (12.408 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8261 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 11.408 \text{ kip}$$

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

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

$$M_{max} = ((-0.75127 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(12.408 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8261 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.408 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8261 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (12.408 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8261 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 38.019 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.314 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.05 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.097 \text{ kipft}) + ((0.314 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.17468 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.17468 \text{ kipft/ft})}{(0.05 \text{ kip/ft})}$$

$$E = 3.4936 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17468 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (0.05 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.17468 \text{ kipft/ft})) + (4 \times (0.05 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0003 \text{ ft}$$

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

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

$$V_{max} = ((0.05 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4936 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.0003 \text{ ft})}{(7 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (3.4936 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.0003 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.30989 \text{ kip}$$

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

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

$$M_{max} = ((0.05 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.4936 \text{ ft})}{(7 \text{ ft})} + \frac{(5.0003 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.4936 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.0003 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (3.4936 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.0003 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 0.95973 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
 $f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
 $\phi = 0.65$ - Reduction factor for axial strength,
 $\alpha = 0.8$ - Alpha factor for axial strength,
 $A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(5.914 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -102.07 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-102.07 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$\text{Ratio} = 0.96556$$

Status: **PASS**
Ratio: **0.970**

25.2.3

s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

25.7.2.2 Since longitudinal reinforcement is \leq No. 10: Use #3(0.375 in)

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

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

Ties: #3(0.375 in) - 10 in

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2

ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (3 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$

$$\phi P_N = 3183.4 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(5.914 \text{ kip})}{(3183.4 \text{ kip})}$$

$$\text{Ratio} = 0.0018578$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2

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

$$d = 0.80 D$$

$$d = 0.80 \times (48 \text{ in})$$

$$d = 38.4 \text{ in}$$

22.5.5.1.3

λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,
 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,max} = 324.49 \text{ kip}$$

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$, $P = 5.914 \text{ kip} \rightarrow 5914 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(5914 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 130.58 \text{ kip}$$

22.5.5.1.2

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,
 $V_{c,b}$ - Shear strength of concrete (b)

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + (0.05 \times (3000 \text{ psi})) \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 406.27 \text{ kip}$$

V_c - Governing shear strength of concrete

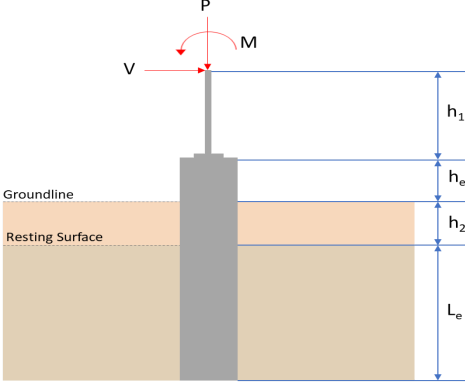
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(324.49 \text{ kip}), (130.58 \text{ kip}), (406.27 \text{ kip})]$$

$$V_c = 130.58 \text{ kip}$$

<p>22.5.1.2</p>	<p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$, $V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 807.65 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(807.65 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((130.58 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 117.96 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 11.408 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(11.408 \text{ kip})}{(117.96 \text{ kip})}$ $\text{Ratio} = 0.096714$ <p>Considering z-direction:</p> <p>$V_{max} = 0.30989 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.30989 \text{ kip})}{(117.96 \text{ kip})}$ $\text{Ratio} = 0.002627$	<p>Status: PASS Ratio: 0.100</p> <p>Status: PASS Ratio: 0.000</p>
	<p>Flexural Strength (ACI 318-19, LRFD)</p> <p>S_m - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{3\text{ksi}} \times 18432.001\text{in}^3$ $\phi M_{n,1} = 273.423\text{kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ksi}) \times (18432\text{in}^3)$ $\phi M_{n,2} = 2545.9\text{kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(273.42\text{kipft}), (2545.9\text{kipft})]$ $\phi M_n = 273.42\text{kipft}$ <p>Considering x-direction: $M_{max} = 38.019\text{kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(38.019\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.13905$	<p>Status: PASS Ratio: 0.140</p>
	<p>Considering z-direction: $M_{max} = 0.95973\text{kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.95973\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.0035101$	<p>Status: PASS Ratio: 0.000</p>

REFERENCES	CALCULATIONS	RESULTS																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 7$ ft - Total pile length $h_1 = 0$ ft - Lateral load height from the top of the pile, $h_2 = 0$ ft - Depth to resting surface $h_e = 0$ ft - Length of pile above the ground</p> <p>Tabulation of Soil Parameters</p> <table border="1" data-bbox="416 1102 1193 1191"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1" data-bbox="676 1285 935 1458"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>4.168</td> <td>5.914</td> </tr> <tr> <td>V_x (kip)</td> <td>-2.831</td> <td>-4.718</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.198</td> <td>-0.314</td> </tr> <tr> <td>M_x (kipft)</td> <td>-0.694</td> <td>-1.097</td> </tr> <tr> <td>M_z (kipft)</td> <td>34.713</td> <td>58.544</td> </tr> </tbody> </table> <p>Material Properties $f'_{ck} = 3$ ksi - Concrete strength,</p>	Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	4.168	5.914	V_x (kip)	-2.831	-4.718	V_z (kip)	-0.198	-0.314	M_x (kipft)	-0.694	-1.097	M_z (kipft)	34.713	58.544	
Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)																									
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000																									
Load Component	ASD	LRFD																										
P (kip)	4.168	5.914																										
V_x (kip)	-2.831	-4.718																										
V_z (kip)	-0.198	-0.314																										
M_x (kipft)	-0.694	-1.097																										
M_z (kipft)	34.713	58.544																										
	<p>Required depth to resist lateral loads (ASD) H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction: H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-2.831 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.4508 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_z + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(34.713 \text{ kipft}) + ((-2.831 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 5.5275 \text{ kipft/ft}$$

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:

$L_{e,x} = 6.4461 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.198 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.031529 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.694 \text{ kipft}) + ((-0.198 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.11051 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.7653 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(6.4461 \text{ ft}), (1.7653 \text{ ft})]$$

$$L_{e,req} = 6.446 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (7 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 7 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(6.446 \text{ ft})}{(7 \text{ ft})}$$

$$\text{Ratio} = 0.92086$$

Status: **PASS**
Ratio: **0.920**

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

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

$$q = \frac{(4.168 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.2605 \text{ kip/ft}^2$$

$$q = 0.2000 \text{ kip/ft}$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.2605 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.13025$$

Status: **PASS**
Ratio: **0.130**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.75$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.4508 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 5.5275 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (5.5275 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.4508 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (5.5275 \text{ kipft/ft})) + (4 \times (-0.4508 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8275 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (5.5275 \text{ kipft/ft})) + (3 \times (-0.4508 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (5.5275 \text{ kipft/ft})) + (2 \times (-0.4508 \text{ kip/ft}) \times (7 \text{ ft}))]}$$

$$p = 0.23821 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (5.5275 \text{ kipft/ft})) + ((-0.4508 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$$

$$s = 0.96729 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.8275 \text{ ft})}{2}$$

$$p_a = 0.36206 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.23821 \text{ kip/ft}^2)}{(0.36206 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.65793$$

p_a - Allowable lateral soil pressure at depth L_e ,

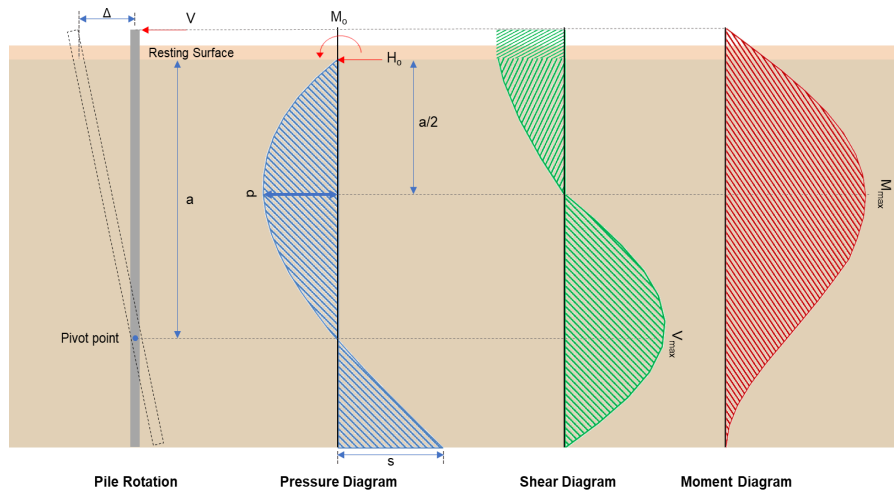
Status: **PASS**
Ratio: **0.660**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.96729 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.92123$	<p>Status: PASS Ratio: 0.920</p>
	<p>Considering z-direction:</p> <p>$H_o = -0.031529 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.11051 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.11051 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.031529 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.11051 \text{ kipft/ft})) + (4 \times (-0.031529 \text{ kip/ft}) \times (7 \text{ ft}))}$ $a = 4.9998 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.11051 \text{ kipft/ft})) + (3 \times (-0.031529 \text{ kip/ft}) \times (7 \text{ ft}))]^2}{(7 \text{ ft})^2 \times [(3 \times (0.11051 \text{ kipft/ft})) + (2 \times (-0.031529 \text{ kip/ft}) \times (7 \text{ ft}))]}$ $p = -0.0067464 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.11051 \text{ kipft/ft})) + ((-0.031529 \text{ kip/ft}) \times (7 \text{ ft}))]}{(7 \text{ ft})^2}$ $s = 0.000038997 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(4.9998 \text{ ft})}{2}$ $p_a = 0.37498 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(-0.0067464 \text{ kip/ft}^2)}{(0.37498 \text{ kip/ft}^2)}$ $\text{Ratio} = -0.017991$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (7 \text{ ft})$ $p_s = 1.05 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	<p>Status: PASS Ratio: -0.020</p>

$$\text{Ratio} = \frac{(0.000038997 \text{ kip/ft}^2)}{(1.05 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.00003714$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.718 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.75127 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(58.544 \text{ kipft}) + ((-4.718 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 9.3223 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(9.3223 \text{ kipft/ft})}{(-0.75127 \text{ kip/ft})}$$

$$E = 12.409 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (9.3223 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.75127 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (9.3223 \text{ kipft/ft})) + (4 \times (-0.75127 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 4.8261 \text{ ft}$$

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

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

$$V_{max} = ((-0.75127 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (12.409 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8261 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (12.409 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8261 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 11.409 \text{ kip}$$

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

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

$$M_{max} = ((-0.75127 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(12.409 \text{ ft})}{(7 \text{ ft})} + \frac{(4.8261 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (12.409 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(4.8261 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (12.409 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(4.8261 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 38.019 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.314 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.05 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.097 \text{ kipft}) + ((-0.314 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.17468 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.17468 \text{ kipft/ft})}{(-0.05 \text{ kip/ft})}$$

$$E = 3.4936 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.17468 \text{ kipft/ft}) \times (7 \text{ ft})) + (3 \times (-0.05 \text{ kip/ft}) \times (7 \text{ ft})^2)}{(6 \times (0.17468 \text{ kipft/ft})) + (4 \times (-0.05 \text{ kip/ft}) \times (7 \text{ ft}))}$$

$$a = 5.0003 \text{ ft}$$

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

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

$$V_{max} = ((-0.05 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.4936 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.0003 \text{ ft})}{(7 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (3.4936 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.0003 \text{ ft})}{(7 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.30989 \text{ kip}$$

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

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

$$M_{max} = ((-0.05 \text{ kip/ft}) \times (48 \text{ in}) \times (7 \text{ ft})) \times \left[\left(\frac{(3.4936 \text{ ft})}{(7 \text{ ft})} + \frac{(5.0003 \text{ ft})}{2 \times (7 \text{ ft})} \right) - \left[\left(\frac{4 \times (3.4936 \text{ ft})}{(7 \text{ ft})} + 3 \right) \times \left(\frac{(5.0003 \text{ ft})}{2 \times (7 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (3.4936 \text{ ft})}{(7 \text{ ft})} + 2 \right) \times \left(\frac{(5.0003 \text{ ft})}{2 \times (7 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.95973 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 3 \text{ ksi}$ - Concrete strength,
 $f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
 $\phi = 0.65$ - Reduction factor for axial strength,
 $\alpha = 0.8$ - Alpha factor for axial strength,
 $A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Table 22.4.2.1

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(5.914 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -102.07 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-102.07 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

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

$$\text{Ratio} = 0.96556$$

25.2.3

s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

25.7.2.2 Since longitudinal reinforcement is \leq No. 10: Use #3(0.375 in)

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

Summary:

Main reinforcement: 14 - #5 (0.625 in)

Status: **PASS**
Ratio: **0.970**

Ties: #3(0.375 in) - 10 in

Axial Compression Strength (ACI 318-19, LRFD)

22.4.2.2

ϕP_N - Allowable axial compressive strength

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

$$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (3 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$$

$$\phi P_N = 3183.4 \text{ kip}$$

Ratio - Capacity

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

$$\text{Ratio} = \frac{(5.914 \text{ kip})}{(3183.4 \text{ kip})}$$

$$\text{Ratio} = 0.0018578$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

22.5.2.2

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

$$d = 0.80 D$$

$$d = 0.80 \times (48 \text{ in})$$

$$d = 38.4 \text{ in}$$

22.5.5.1.3

λ_s - size effect modification factor

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

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

$$\lambda_s = 0.64282$$

22.5.5.1.1

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,
 $V_{c,max}$ - Max shear strength of concrete

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,max} = 324.49 \text{ kip}$$

22.5.5.1.1(a)

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$, $P = 5.914 \text{ kip} \rightarrow 5914 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(5914 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 130.58 \text{ kip}$$

22.5.5.1.2

The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$,
 $V_{c,b}$ - Shear strength of concrete (b)

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

$$V_{c,b} = \left[2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + (0.05 \times (3000 \text{ psi})) \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,b} = 406.27 \text{ kip}$$

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(324.49 \text{ kip}), (130.58 \text{ kip}), (406.27 \text{ kip})]$$

$$V_c = 130.58 \text{ kip}$$

<p>22.5.1.2</p>	<p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$, $V_{s,a}$ - Shear strength of steel (a)</p> $V_{s,a} = 8 \sqrt{f'_{ck}} b_w d$ $V_{s,a} = 8 \times \sqrt{(3000 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$ $V_{s,a} = 807.65 \text{ kip}$ <p>A_v - Ties rebar area,</p> $A_v = \frac{\pi d_{ties}^2}{4}$ $A_v = \frac{\pi \times (0.375 \text{ in})^2}{4}$ $A_v = 0.11045 \text{ in}^2$ <p>22.5.8.5.3 $V_{s,b}$ - Shear strength of steel (b)</p> $V_{s,b} = \frac{2 A_v f_{yt} d}{s_{ties}}$ $V_{s,b} = \frac{2 \times (0.11045 \text{ in}^2) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$ $V_{s,b} = 50.894 \text{ kip}$ <p>V_s - Governing shear strength of steel</p> $V_s = \text{MIN}[V_{s,a}, V_{s,b}]$ $V_s = \text{MIN}[(807.65 \text{ kip}), (50.894 \text{ kip})]$ $V_s = 50.894 \text{ kip}$ <p>22.5.1.1 ϕV_n - Allowable shear strength</p> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((130.58 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 117.96 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 11.409 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(11.409 \text{ kip})}{(117.96 \text{ kip})}$ $\text{Ratio} = 0.096715$ <p>Considering z-direction:</p> <p>$V_{max} = 0.30989 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.30989 \text{ kip})}{(117.96 \text{ kip})}$ $\text{Ratio} = 0.002627$	<p>Status: PASS Ratio: 0.100</p> <p>Status: PASS Ratio: 0.000</p>
	<p>Flexural Strength (ACI 318-19, LRFD)</p> <p>S_m - Section modulus</p> $S_m = \frac{b D^2}{6}$ $S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$ $S_m = 18432 \text{ in}^3$	

<p>14.5.2.1b</p>	<p>$\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$</p> $\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$ $\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{3\text{ksi}} \times 18432.001\text{in}^3$ $\phi M_{n,1} = 273.423\text{kipft}$ <p>$\phi M_{n,2}$</p> $\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$ $\phi M_{n,2} = (0.65) \times 0.85 \times (3\text{ksi}) \times (18432\text{in}^3)$ $\phi M_{n,2} = 2545.9\text{kipft}$ <p>Therefore, ϕM_n - Allowable flexural strength,</p> $\phi M_n = \text{MIN}[\phi M_{n,1}, \phi M_{n,2}]$ $\phi M_n = \text{MIN}[(273.42\text{kipft}), (2545.9\text{kipft})]$ $\phi M_n = 273.42\text{kipft}$ <p>Considering x-direction: $M_{max} = 38.019\text{kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(38.019\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.13905$	<p>Status: PASS Ratio: 0.140</p>
	<p>Considering z-direction: $M_{max} = 0.95973\text{kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.95973\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.0035101$	<p>Status: PASS Ratio: 0.000</p>