

Your Project Calculations



Project Name: Van Kleef - Diamonds (Jinko)

S3D Model Link:
[https://platform.skyciv.com/structural?preload_name=Van%20Kleef%20-%20Diamonds%20\(Jinko\)&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023](https://platform.skyciv.com/structural?preload_name=Van%20Kleef%20-%20Diamonds%20(Jinko)&preload_path=Shared%20Enterprise%20Folder/MT_Solar_Projects/6_2023)

Public Model Link:
https://platform.skyciv.com/structural-viewer?project_id=0YPvj7XGp63RLz06h3r4TnjXUJOvn0rrqHtOmQOEViaR0waHjTrldn2FW7cdP4zW

Array Specification

Product:	Beam
Unique ID:	2P-17-6TOP-SD-45-L-5Hx5W-C71B
Duty Classification:	SD
Module Width:	39.45 in
Module Length:	79.06in
Number of Rows:	5
Number of Columns:	5
Total Number of Modules:	25
Desired Tilt Angle:	5
Front Edge Clearance:	5
Total Array Height at Tilt:	6.44 ft
Total Frame Length:	32.00 ft
Frame Weight:	1097 lbs
Array Dimensions N/S:	16.65 ft
Array Dimensions E/W:	33.36 ft
Rail Length:	199.75 in
Rail Spacing:	3.29 ft
Rail Check:	Not Checked

Support Specifications

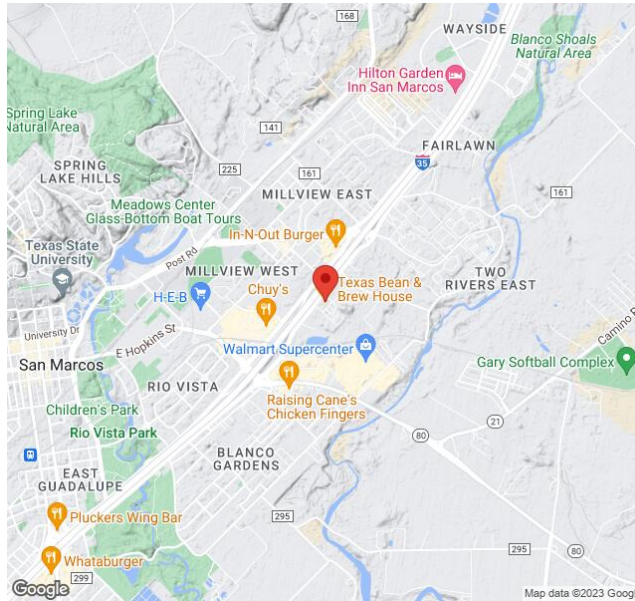
Pole Size:	6in Pipe Sch 40
Pole Length above Grade:	5.73 ft
Number of Poles:	2
Pole Spacing:	17 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 4.50 ft Pile 2: 4.50 ft
Foundation Volume:	5.333 y ³
Foundation Result:	PASSED
Mount Twist:	0.034903 kip

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	1328 N Interstate 35 Frontage Rd, San Marcos, TX 78666, USA
Wind Speed:	101 mph
Snow Load:	5 psf
Design Uplift Pressure:	Multiple pressures
Design Downforce Pressure:	Multiple pressures
Design Snow Pressure:	0.003024 ksf



Design Disclaimer

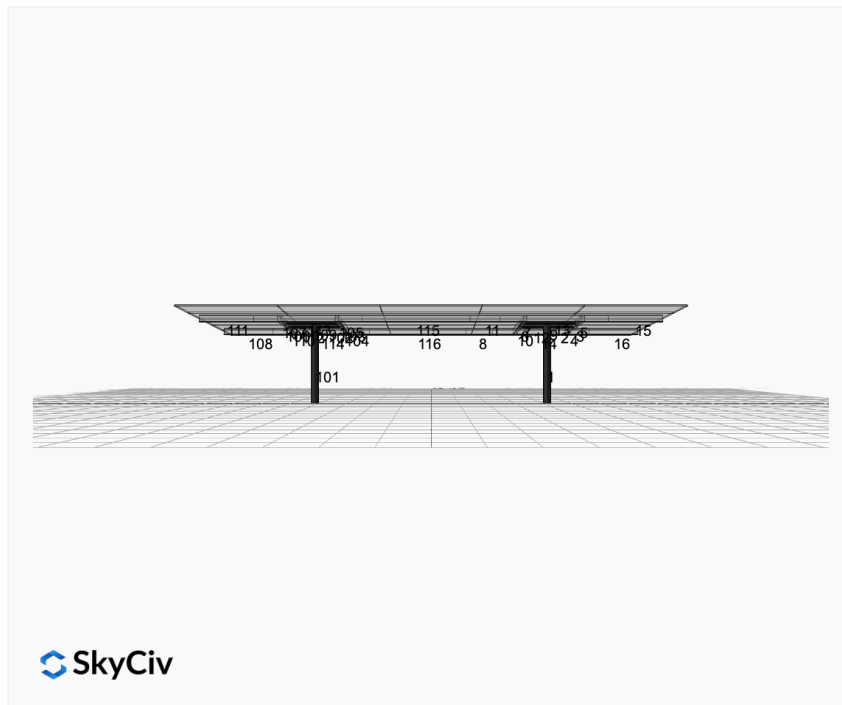
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

AutoDesigner Input

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  "snow_load_override": null,
  "direct_snow_load": false,
  "product_type": "Beam",
  "project_id": "Van Kleef - Diamonds (Jinko)",
  "site_address": "1328 N Interstate 35 Frontage Rd, San Marcos, TX 78666, USA",
  "module_width": 39.45,
  "module_length": 79.06,
  "number_rows": 5,
  "number_columns": 5,
  "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": 5,
  "ground_clearance": 5,
  "risk_category": "I",
  "exposure_category": "C",
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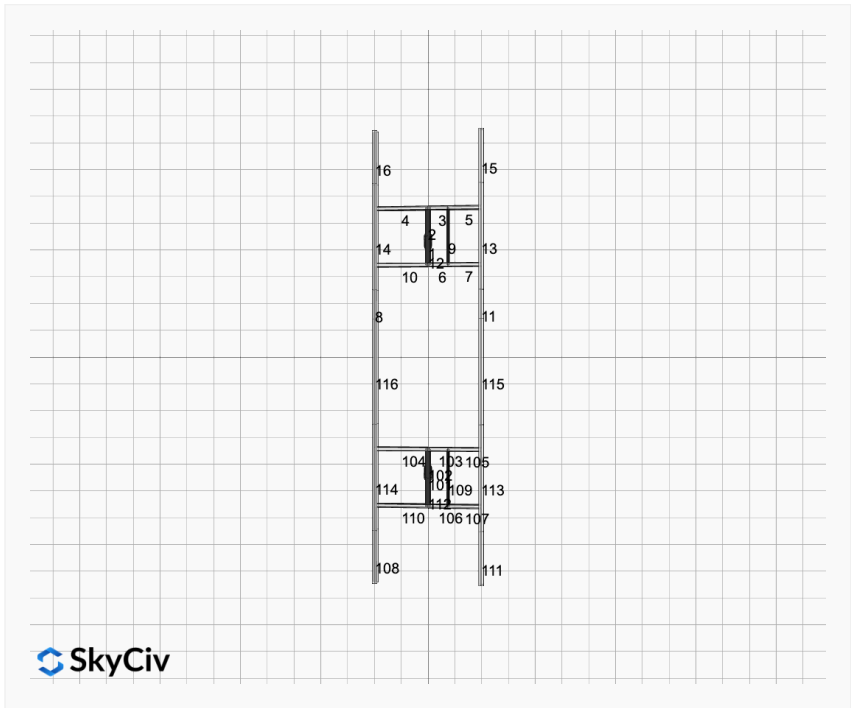
Design Notes:

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



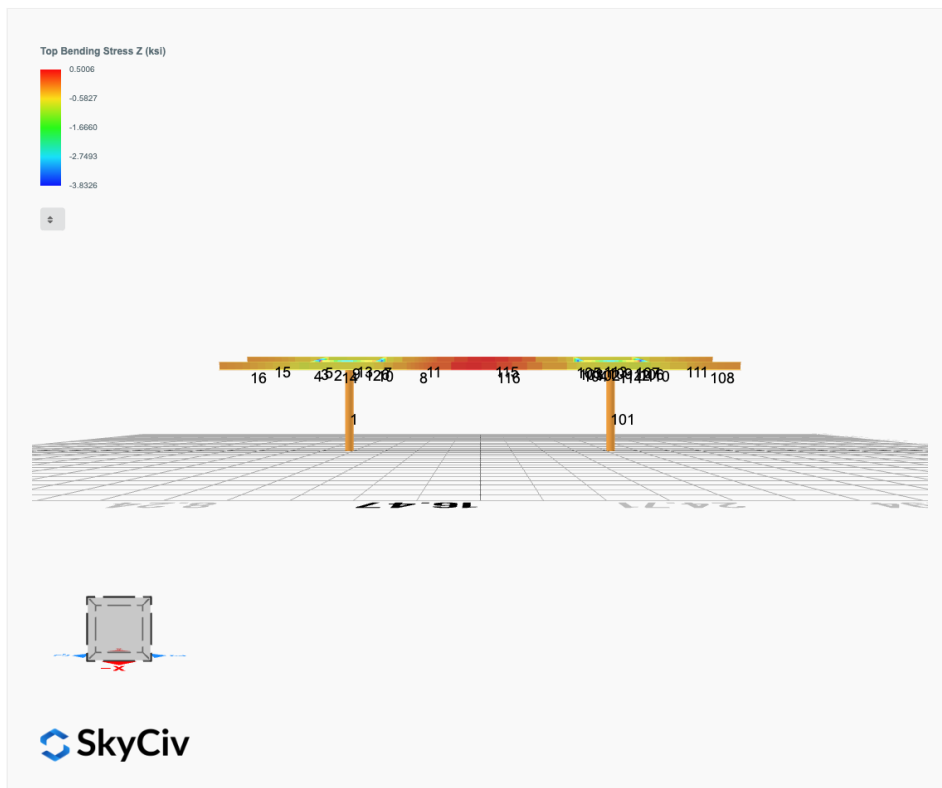
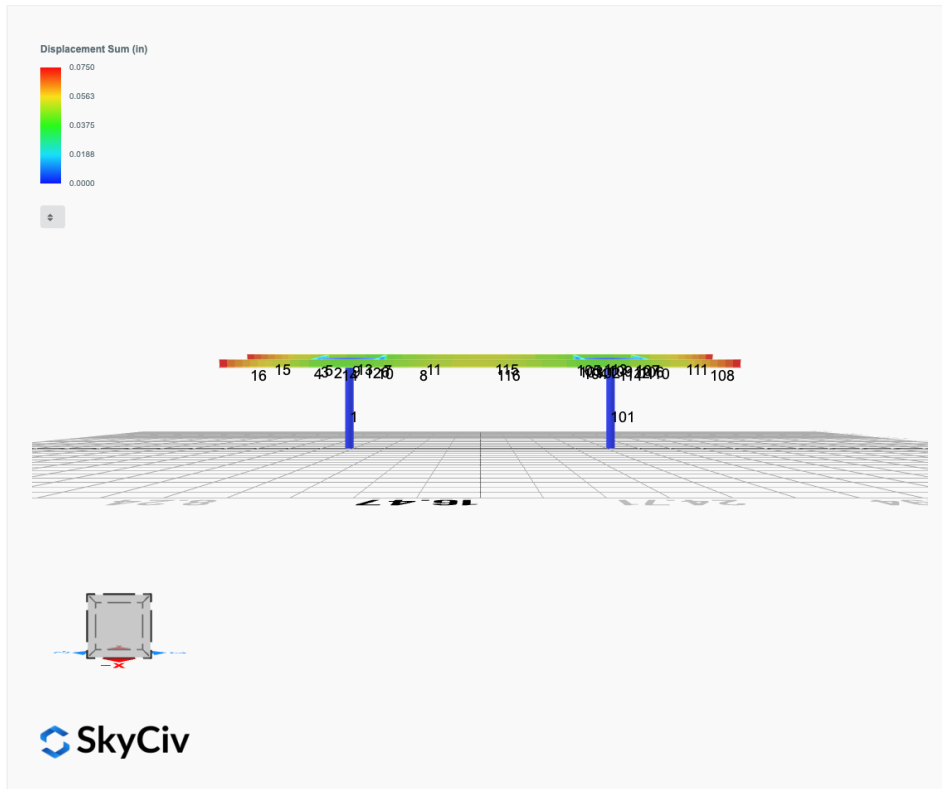


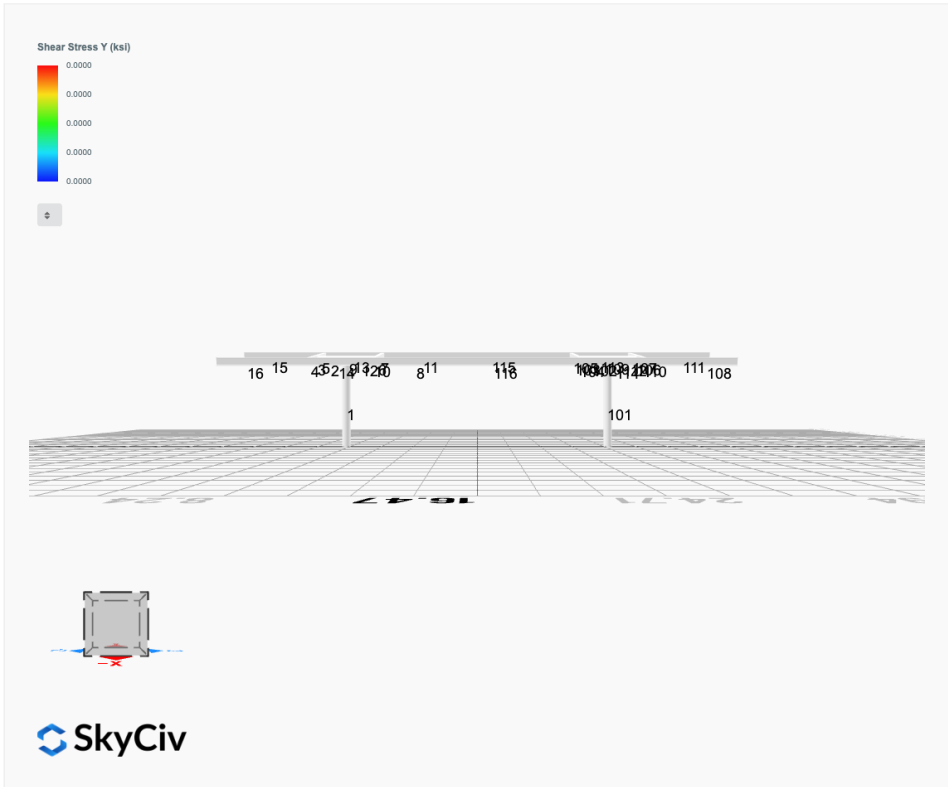
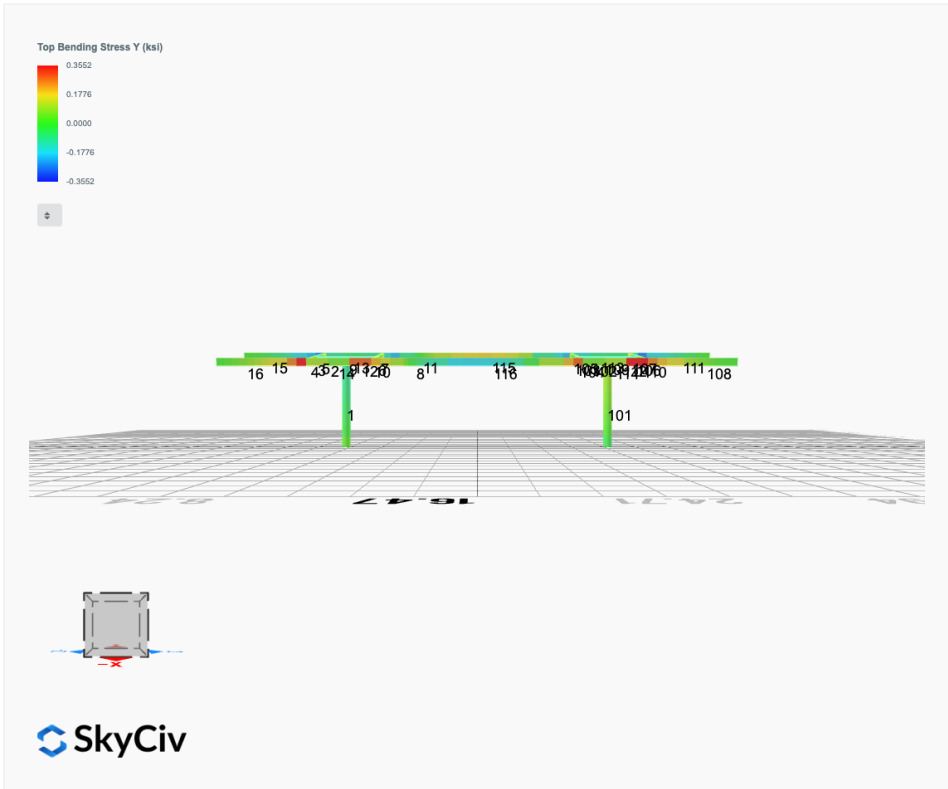
 SkyCiv

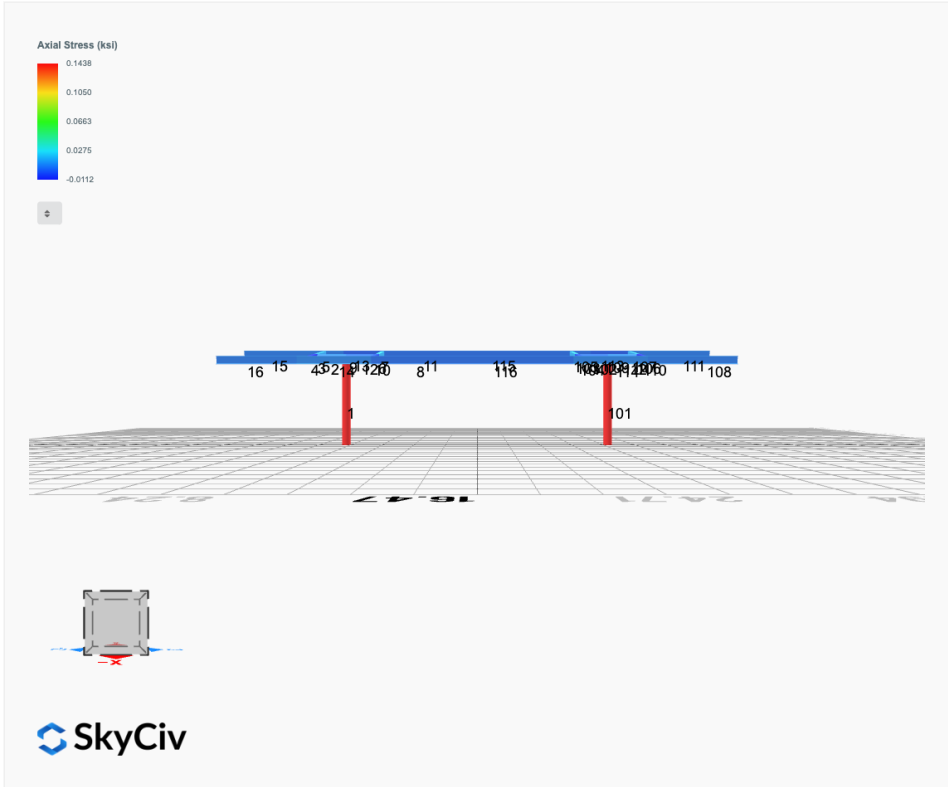


 SkyCiv

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	1.8093	-0.0261	-0.0239	0.0090	0.0212
ULS: 2. D + L	-0.0000	1.8093	-0.0261	-0.0239	0.0090	0.0212
ULS: 3. D + (S or Lr or R)	-0.0000	2.6116	-0.0394	-0.0361	0.0136	0.0214
ULS: 3. D + (S or Lr or R)	-0.0000	1.8093	-0.0261	-0.0239	0.0090	0.0212
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	2.4110	-0.0361	-0.0330	0.0125	0.0214
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0000	1.8093	-0.0261	-0.0239	0.0090	0.0212
ULS: 5b. D + 0.7E	-0.0000	1.8093	-0.0261	-0.0239	0.0090	0.0212
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0000	2.4110	-0.0361	-0.0330	0.0125	0.0214
ULS: 8. 0.6D + 0.7E	-0.0000	1.0856	-0.0156	-0.0143	0.0054	0.0127
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2389	4.5400	-0.0721	-0.0664	0.0221	1.8972
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2389	4.5400	-0.0721	-0.0664	0.0221	1.8972
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0645	1.0724	-0.0138	-0.0125	0.0055	2.4170
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1517	0.0755	0.0031	0.0032	0.0007	-6.9912
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1792	4.4591	-0.0706	-0.0649	0.0223	1.4283
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1792	4.4591	-0.0706	-0.0649	0.0223	1.4283
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0484	1.8584	-0.0268	-0.0245	0.0099	1.8182
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1138	1.1107	-0.0142	-0.0127	0.0062	-5.2380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1792	3.8573	-0.0606	-0.0558	0.0188	1.4282
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1792	3.8573	-0.0606	-0.0558	0.0188	1.4282
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0484	1.2566	-0.0169	-0.0153	0.0064	1.8180
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1138	0.5089	-0.0042	-0.0036	0.0028	-5.2381
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2389	3.8163	-0.0617	-0.0569	0.0185	1.8887
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2389	3.8163	-0.0617	-0.0569	0.0185	1.8887
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0645	0.3487	-0.0034	-0.0030	0.0019	2.4085
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1517	-0.6482	0.0136	0.0127	-0.0029	-6.9997

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	7.1235
Shear X	-0.3982
Shear Z	-0.1149
Moment X	-0.1059
Moment Y (Twist)	0.0349
Moment Z	11.7465

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	4.5400
Shear X	-0.2389
Shear Z	-0.0721
Moment X	-0.0664
Moment Y (Twist)	0.0223
Moment Z	6.9997

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	1.8093	0.0261	0.0239	-0.0090	0.0212
ULS: 2. D + L	0.0000	1.8093	0.0261	0.0239	-0.0090	0.0212
ULS: 3. D + (S or Lr or R)	0.0000	2.6116	0.0394	0.0361	-0.0136	0.0214
ULS: 3. D + (S or Lr or R)	0.0000	1.8093	0.0261	0.0239	-0.0090	0.0212
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	2.4110	0.0361	0.0330	-0.0125	0.0214
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0000	1.8093	0.0261	0.0239	-0.0090	0.0212
ULS: 5b. D + 0.7E	0.0000	1.8093	0.0261	0.0239	-0.0090	0.0212

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0000	2.4110	0.0361	0.0330	-0.0125	0.0214
ULS: 8. 0.6D + 0.7E	0.0000	1.0856	0.0156	0.0143	-0.0054	0.0127
ULS: 5a. D + 0.6W_Wind downforce Case A only	-0.2389	4.5400	0.0721	0.0664	-0.0221	1.8972
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.2389	4.5400	0.0721	0.0664	-0.0221	1.8972
ULS: 5a. D + 0.6W_Wind uplift Case A only	0.0645	1.0724	0.0138	0.0125	-0.0055	2.4170
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.1517	0.0755	-0.0031	-0.0032	-0.0007	-6.9912
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1792	4.4591	0.0706	0.0649	-0.0223	1.4283
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1792	4.4591	0.0706	0.0649	-0.0223	1.4283
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0484	1.8584	0.0268	0.0245	-0.0099	1.8182
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1138	1.1107	0.0142	0.0127	-0.0062	-5.2380
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-0.1792	3.8573	0.0606	0.0558	-0.0188	1.4282
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.1792	3.8573	0.0606	0.0558	-0.0188	1.4282
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	0.0484	1.2566	0.0169	0.0153	-0.0064	1.8180
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.1138	0.5089	0.0042	0.0036	-0.0028	-5.2381
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-0.2389	3.8163	0.0617	0.0569	-0.0185	1.8887
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.2389	3.8163	0.0617	0.0569	-0.0185	1.8887
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	0.0645	0.3487	0.0034	0.0030	-0.0019	2.4085
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.1517	-0.6482	-0.0136	-0.0127	0.0029	-6.9997

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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	4.5400
Shear X	-0.2389
Shear Z	0.0721
Moment X	0.0664
Moment Y (Twist)	0.0223
Moment Z	6.9997

Project Details

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

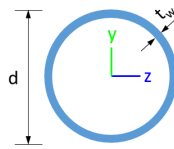


Design Input Information

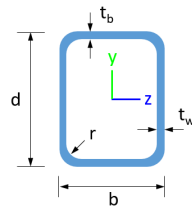
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
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Design Materials			
ID	E (ksi)	F_y (ksi)	F_u (ksi)
1	29000	50	65

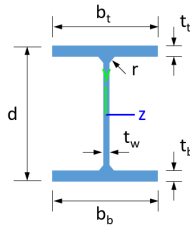
Section Dimensions



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 _z L (ft)	K _y L (ft)	L _b (ft)	C _b	L	S	T
1	7	12.02	12.02	5.73	-	3	2	1
2	4	1.30	1.30	2.00	-	3	2	1
3	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.18,1.18,1.18,1.21,1.18,1.18,1.19,1.16,1.18,1.18,1.19,1.18	3	2	1
4	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.50,1.68,1.67,1.67,1.62,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.70,1.68,1.67,1.67,1.65,1.68	3	2	1
5	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.71,1.67,1.67,1.68,1.65,1.67,1.67,1.68,1.66	3	2	1
6	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.22,1.18,1.18,1.18,1.16,1.18,1.18,1.17	3	2	1
7	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.72,1.67,1.67,1.68,1.65,1.67,1.67,1.68,1.66	3	2	1
8	18	1.33	1.33	2.05	1.91,1.91,1.91,1.91,1.91,1.91,1.91,1.91,2.05,2.00,1.91,1.91,2.03,2.02,1.91,1.91,1.89,1.94,1.91,1.91,1.84,1.96,1.91,1.91,2.00,2.03	3	2	1
9	1	2.60	2.60	4.00	-	3	2	1
10	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.53,1.68,1.67,1.67,1.62,1.68,1.67,1.67,1.68,1.68,1.67,1.67,1.71,1.68,1.67,1.67,1.65,1.68	3	2	1
11	18	1.33	1.33	2.05	1.91,1.92,1.91,1.92,1.91,1.91,1.92,1.92,1.95,1.97,1.92,1.92,1.95,1.96,1.92,1.92,1.93,1.71,1.92,1.92,1.93,2.01,1.92,1.92,1.97,1.96	3	2	1
12	4	1.30	1.30	2.00	-	3	2	1
13	18	4.88	4.00	7.50	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.15,1.19,1.13,1.13,1.16,1.18,1.13,1.13,1.13,1.12,1.13,1.13,1.13,1.29,1.13,1.13,1.19,1.17	3	2	1
14	18	4.88	4.00	7.50	1.13,1.13,1.13,1.13,1.13,1.13,1.13,1.13,3.94,1.24,1.13,1.13,1.43,1.29,1.13,1.13,1.12,1.13,1.13,1.13,1.12,1.16,1.13,1.13,1.24,1.41	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	7	12.02	12.02	5.73	-	3	2	1
102	4	1.30	1.30	2.00	-	3	2	1
103	15	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.22,1.18,1.18,1.18,1.16,1.18,1.18,1.17	3	2	1
104	15	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.67,1.53,1.68,1.67,1.67,1.62,1.68,1.67,1.67,1.68,1.68,1.67,1.67,1.71,1.68,1.67,1.67,1.65,1.68	3	2	1
105	15	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.72,1.67,1.67,1.68,1.65,1.67,1.67,1.68,1.66	3	2	1
106	15	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.18,1.18,1.21,1.18,1.18,1.19,1.16,1.18,1.18,1.19,1.18	3	2	1
107	15	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.67,1.67,1.67,1.71,1.67,1.67,1.68,1.65,1.67,1.67,1.68,1.66	3	2	1

115	120.00	89.27	20.32	6.45	30.09	45.74
116	120.60	89.27	20.32	6.45	30.09	45.74

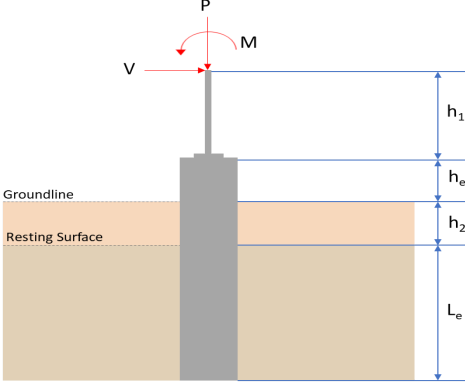
Design Ratio

Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	δ	Status
1	0.038	0.278	0.013	0.005	0.002	0.280	#32	0.321	Not Required	Pass
2	0.000	0.406	0.027	0.084	0.005	0.434	#13	0.052	Not Required	Pass
3	0.001	0.623	0.019	0.064	0.003	0.642	#13	0.044	Not Required	Pass
4	0.001	0.584	0.016	0.059	0.002	0.589	#13	0.078	Not Required	Pass
5	0.001	0.386	0.025	0.063	0.004	0.394	#13	0.073	Not Required	Pass
6	0.001	0.590	0.009	0.060	0.001	0.594	#13	0.044	Not Required	Pass
7	0.001	0.366	0.016	0.059	0.002	0.370	#13	0.073	Not Required	Pass
8	0.000	0.050	0.006	0.033	0.001	0.054	#13	0.088	Not Required	Pass
9	0.000	0.073	0.012	0.001	0.001	0.085	#13	0.198	Not Required	Pass
10	0.001	0.552	0.026	0.056	0.004	0.576	#13	0.078	Not Required	Pass
11	0.000	0.053	0.006	0.035	0.001	0.058	#13	0.088	Not Required	Pass
12	0.000	0.372	0.025	0.079	0.004	0.398	#13	0.052	Not Required	Pass
13	0.001	0.175	0.020	0.048	0.001	0.182	#13	0.265	Not Required	Pass
14	0.000	0.169	0.020	0.045	0.001	0.181	#13	0.177	Not Required	Pass
15	0.000	0.066	0.009	0.027	0.001	0.073	#13	Not Required	Not Required	Pass
16	0.000	0.062	0.009	0.026	0.001	0.069	#13	Not Required	Not Required	Pass
101	0.038	0.278	0.013	0.005	0.002	0.280	#32	0.321	Not Required	Pass
102	0.000	0.372	0.025	0.079	0.004	0.398	#13	0.052	Not Required	Pass
103	0.001	0.590	0.009	0.060	0.001	0.594	#13	0.044	Not Required	Pass
104	0.001	0.552	0.026	0.056	0.004	0.576	#13	0.078	Not Required	Pass
105	0.001	0.366	0.016	0.059	0.002	0.370	#13	0.073	Not Required	Pass
106	0.001	0.623	0.019	0.064	0.003	0.642	#13	0.044	Not Required	Pass
107	0.001	0.386	0.025	0.063	0.004	0.394	#13	0.073	Not Required	Pass
108	0.000	0.062	0.009	0.026	0.001	0.069	#13	Not Required	Not Required	Pass
109	0.000	0.073	0.012	0.001	0.001	0.085	#13	0.198	Not Required	Pass
110	0.001	0.584	0.016	0.059	0.002	0.589	#13	0.078	Not Required	Pass
111	0.000	0.066	0.009	0.027	0.001	0.073	#13	Not Required	Not Required	Pass
112	0.000	0.406	0.027	0.084	0.005	0.434	#13	0.052	Not Required	Pass
113	0.001	0.175	0.020	0.048	0.001	0.182	#13	0.177	Not Required	Pass
114	0.000	0.169	0.020	0.045	0.001	0.181	#13	0.265	Not Required	Pass
115	0.000	0.100	0.011	0.035	0.001	0.108	#13	0.321	Not Required	Pass
116	0.000	0.094	0.010	0.033	0.001	0.101	#13	0.321	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</p> <p>Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 4.5$ 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 1288 935 1458"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>4.540</td> <td>7.124</td> </tr> <tr> <td>V_x (kip)</td> <td>-0.239</td> <td>-0.398</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.072</td> <td>-0.115</td> </tr> <tr> <td>M_x (kipft)</td> <td>-0.066</td> <td>-0.106</td> </tr> <tr> <td>M_z (kipft)</td> <td>7.000</td> <td>11.747</td> </tr> </tbody> </table> <p>Material Properties</p> <p>$f'_{ck} = 3$ 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)	4.540	7.124	V_x (kip)	-0.239	-0.398	V_z (kip)	-0.072	-0.115	M_x (kipft)	-0.066	-0.106	M_z (kipft)	7.000	11.747	
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	<p>Required depth to resist lateral loads (ASD)</p> <p>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:</p> <p>H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-0.239 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.038057 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(7 \text{ kipft}) + ((-0.239 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.1146 \text{ kipft/ft}$$

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:

$L_{e,x} = 4.2973 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.072 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.011465 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.066 \text{ kipft}) + ((-0.072 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.01051 \text{ kipft/ft}$$

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:

$L_{e,z} = 0.70758 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(4.2973 \text{ ft}), (0.70758 \text{ ft})]$$

$$L_{e,req} = 4.297 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (4.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(4.297 \text{ ft})}{(4.5 \text{ ft})}$$

$$\text{Ratio} = 0.95489$$

Status: **PASS**
Ratio: **0.950**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

$$A = (48 \text{ in}) \times (48 \text{ in})$$

$$A = 16 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(4.54 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.28375 \text{ kip/ft}^2$$

$$q = 0.28375 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.28375 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.14188$$

Status: **PASS**
Ratio: **0.140**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.038057 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.1146 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.1146 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.1146 \text{ kipft/ft})) + (4 \times (-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0348 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.1146 \text{ kipft/ft})) + (3 \times (-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.1146 \text{ kipft/ft})) + (2 \times (-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.19203 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.1146 \text{ kipft/ft})) + ((-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.60979 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.0348 \text{ ft})}{2}$$

$$p_a = 0.22761 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.19203 \text{ kip/ft}^2)}{(0.22761 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.84366$$

p_a - Allowable lateral soil pressure at depth L_e ,

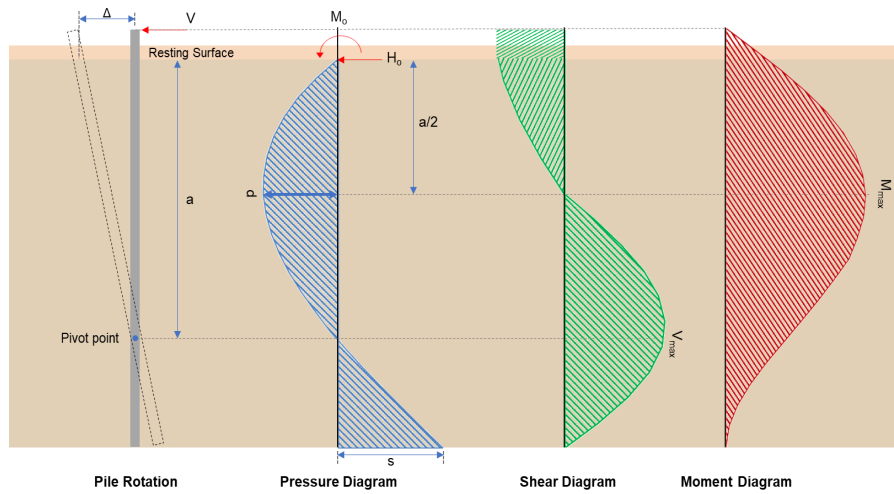
Status: **PASS**
Ratio: **0.840**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (4.5 \text{ ft})$ $p_s = 0.675 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.60979 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.90339$	Status: PASS Ratio: 0.900
	<p>Considering z-direction:</p> <p>$H_o = -0.011465 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.01051 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.01051 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.011465 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.01051 \text{ kipft/ft})) + (4 \times (-0.011465 \text{ kip/ft}) \times (4.5 \text{ ft}))}$ $a = 3.2872 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.01051 \text{ kipft/ft})) + (3 \times (-0.011465 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (0.01051 \text{ kipft/ft})) + (2 \times (-0.011465 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$ $p = -0.0065695 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.01051 \text{ kipft/ft})) + ((-0.011465 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$ $s = -0.0090587 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.2872 \text{ ft})}{2}$ $p_a = 0.24654 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(-0.0065695 \text{ kip/ft}^2)}{(0.24654 \text{ kip/ft}^2)}$ $\text{Ratio} = -0.026646$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (4.5 \text{ ft})$ $p_s = 0.675 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	Status: PASS Ratio: -0.030

$$Ratio = \frac{(-0.0090587 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = -0.01342$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.398 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.063376 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(11.747 \text{ kipft}) + ((-0.398 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.8705 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.8705 \text{ kipft/ft})}{(-0.063376 \text{ kip/ft})}$$

$$E = 29.515 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.8705 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.063376 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.8705 \text{ kipft/ft})) + (4 \times (-0.063376 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0346 \text{ ft}$$

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

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

$$V_{max} = ((-0.063376 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (29.515 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0346 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (29.515 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0346 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 3.1168 \text{ kip}$$

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

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

$$M_{max} = ((-0.063376 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(29.515 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0346 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (29.515 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0346 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (29.515 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0346 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 6.908 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.115 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.018312 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.106 \text{ kipft}) + ((-0.115 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016879 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.016879 \text{ kipft/ft})}{(-0.018312 \text{ kip/ft})}$$

$$E = 0.92174 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.016879 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.018312 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.016879 \text{ kipft/ft})) + (4 \times (-0.018312 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.2869 \text{ ft}$$

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

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

$$V_{max} = ((-0.018312 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.92174 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.2869 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (0.92174 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.2869 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.076004 \text{ kip}$$

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

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

$$M_{max} = ((-0.018312 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(0.92174 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.2869 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (0.92174 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.2869 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (0.92174 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.2869 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.1419 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.124 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -102.03 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-102.03 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

$$\text{Ratio} = \frac{(7.124 \text{ kip})}{(3183.4 \text{ kip})}$$

$$\text{Ratio} = 0.0022378$$

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 $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$, $P = 7.124 \text{ kip} \rightarrow 7124 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(7124 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 130.74 \text{ kip}$$

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

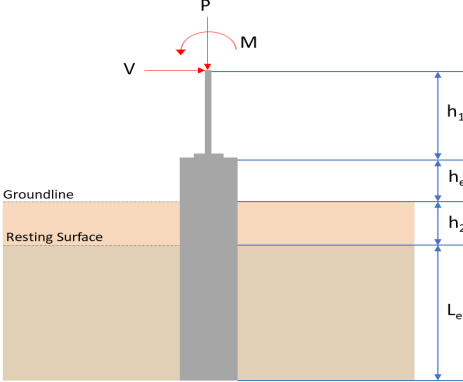
$$V_c = \text{Min}[V_{c,max}, V_{c,a}, V_{c,b}]$$

$$V_c = \text{Min}[(324.49 \text{ kip}), (130.74 \text{ kip}), (406.27 \text{ kip})]$$

$$V_c = 130.74 \text{ kip}$$

<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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((130.74 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 118.06 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 3.1168 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(3.1168 \text{ kip})}{(118.06 \text{ kip})}$ $\text{Ratio} = 0.026399$ <p>Considering z-direction:</p> <p>$V_{max} = 0.076004 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.076004 \text{ kip})}{(118.06 \text{ kip})}$ $\text{Ratio} = 0.00064375$	<p>Status: PASS Ratio: 0.030</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: $M_{max} = 6.908\text{kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(6.908\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.025265$	<p>Status: PASS Ratio: 0.030</p>
	<p>Considering z-direction: $M_{max} = 0.1419\text{kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.1419\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.00051899$	<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 $L = 4.5$ 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 933 1458"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>4.540</td> <td>7.124</td> </tr> <tr> <td>V_x (kip)</td> <td>-0.239</td> <td>-0.398</td> </tr> <tr> <td>V_z (kip)</td> <td>0.072</td> <td>0.115</td> </tr> <tr> <td>M_x (kipft)</td> <td>0.066</td> <td>0.106</td> </tr> <tr> <td>M_z (kipft)</td> <td>7.000</td> <td>11.747</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)	4.540	7.124	V_x (kip)	-0.239	-0.398	V_z (kip)	0.072	0.115	M_x (kipft)	0.066	0.106	M_z (kipft)	7.000	11.747	
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M_z (kipft)	7.000	11.747																										
	<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> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-0.239 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.038057 \text{ kip/ft}$ <p>M_o - Moment per length of pile,</p> $M_o = \frac{M_x + (V_x H)}{1.57 D}$																											

$$M_o = \frac{(7 \text{ kipft}) + ((-0.239 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.1146 \text{ kipft/ft}$$

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:

$L_{e,x} = 4.2973 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.072 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.011465 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.066 \text{ kipft}) + ((0.072 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.01051 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.1826 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(4.2973 \text{ ft}), (1.1826 \text{ ft})]$$

$$L_{e,req} = 4.297 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_c - h_2$$

$$L_e = (4.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 4.5 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(4.297 \text{ ft})}{(4.5 \text{ ft})}$$

$$\text{Ratio} = 0.95489$$

Status: **PASS**
Ratio: **0.950**

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b D$$

$$A = (48 \text{ in}) \times (48 \text{ in})$$

$$A = 16 \text{ ft}^2$$

q - End-bearing pressure

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

$$q = \frac{(4.54 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.28375 \text{ kip/ft}^2$$

$$q = 0.28375 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.28375 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.14188$$

Status: **PASS**
Ratio: **0.140**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(4.5 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.125$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.038057 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 1.1146 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.1146 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.1146 \text{ kipft/ft})) + (4 \times (-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0348 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (1.1146 \text{ kipft/ft})) + (3 \times (-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (1.1146 \text{ kipft/ft})) + (2 \times (-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$$

$$p = 0.19203 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (1.1146 \text{ kipft/ft})) + ((-0.038057 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$$

$$s = 0.60979 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.0348 \text{ ft})}{2}$$

$$p_a = 0.22761 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.19203 \text{ kip/ft}^2)}{(0.22761 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.84366$$

p_a - Allowable lateral soil pressure at depth L_e ,

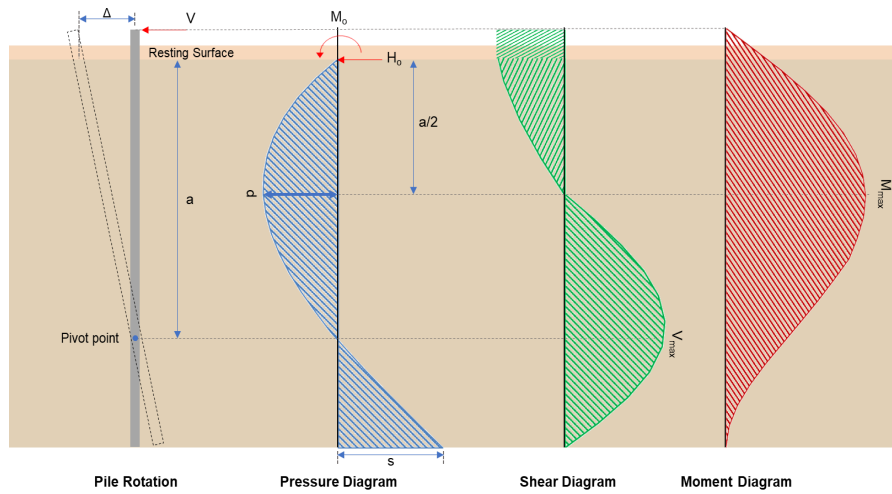
Status: **PASS**
Ratio: **0.840**

	$p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (4.5 \text{ ft})$ $p_s = 0.675 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$ $\text{Ratio} = \frac{(0.60979 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.90339$	<p>Status: PASS Ratio: 0.900</p>
	<p>Considering z-direction:</p> <p>$H_o = 0.011465 \text{ kip/ft}$ - Lateral force per length of pile, $M_o = 0.01051 \text{ kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point,</p> $a = \frac{(4 M_o L_e) + (3 H_o L_e^2)}{(6 M_o) + (4 H_o L_e)}$ $a = \frac{(4 \times (0.01051 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (0.011465 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.01051 \text{ kipft/ft})) + (4 \times (0.011465 \text{ kip/ft}) \times (4.5 \text{ ft}))}$ $a = 3.2872 \text{ ft}$ <p>p - Earth pressure against the pile at distance $a/2$ from resting surface,</p> $p = \frac{0.75 [(4 M_o) + (3 H_o L_e)]^2}{L_e^2 [(3 M_o) + (2 H_o L_e)]}$ $p = \frac{0.75 \times [(4 \times (0.01051 \text{ kipft/ft})) + (3 \times (0.011465 \text{ kip/ft}) \times (4.5 \text{ ft}))]^2}{(4.5 \text{ ft})^2 \times [(3 \times (0.01051 \text{ kipft/ft})) + (2 \times (0.011465 \text{ kip/ft}) \times (4.5 \text{ ft}))]}$ $p = 0.01065 \text{ kip/ft}^2$ <p>s - Earth pressure against the pile at distance L_e,</p> $s = \frac{6 [(2 M_o) + (H_o L_e)]}{L_e^2}$ $s = \frac{6 \times [(2 \times (0.01051 \text{ kipft/ft})) + ((0.011465 \text{ kip/ft}) \times (4.5 \text{ ft}))]}{(4.5 \text{ ft})^2}$ $s = 0.021515 \text{ kip/ft}^2$ <p>Check lateral soil pressure capacity:</p> <p>p_a - Allowable lateral soil pressure at depth $a/2$,</p> $p_a = R \frac{a}{2}$ $p_a = (150 \text{ psf/ft}) \times \frac{(3.2872 \text{ ft})}{2}$ $p_a = 0.24654 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{p}{p_a}$ $\text{Ratio} = \frac{(0.01065 \text{ kip/ft}^2)}{(0.24654 \text{ kip/ft}^2)}$ $\text{Ratio} = 0.043197$ <p>p_s - Allowable lateral soil pressure at depth L_e,</p> $p_s = R L_e$ $p_s = (150 \text{ psf/ft}) \times (4.5 \text{ ft})$ $p_s = 0.675 \text{ kip/ft}^2$ <p>Ratio - Lateral soil capacity</p> $\text{Ratio} = \frac{s}{p_s}$	<p>Status: PASS Ratio: 0.040</p>

$$Ratio = \frac{(0.021515 \text{ kip/ft}^2)}{(0.675 \text{ kip/ft}^2)}$$

$$Ratio = 0.031873$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.398 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.063376 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(11.747 \text{ kipft}) + ((-0.398 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 1.8705 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(1.8705 \text{ kipft/ft})}{(-0.063376 \text{ kip/ft})}$$

$$E = 29.515 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (1.8705 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (-0.063376 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (1.8705 \text{ kipft/ft})) + (4 \times (-0.063376 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.0346 \text{ ft}$$

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

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

$$V_{max} = ((-0.063376 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (29.515 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0346 \text{ ft})}{(4.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (29.515 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0346 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 3.1168 \text{ kip}$$

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

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

$$M_{max} = ((-0.063376 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(29.515 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.0346 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (29.515 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.0346 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (29.515 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.0346 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 6.908 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.115 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.018312 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.106 \text{ kipft}) + ((0.115 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016879 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.016879 \text{ kipft/ft})}{(0.018312 \text{ kip/ft})}$$

$$E = 0.92174 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.016879 \text{ kipft/ft}) \times (4.5 \text{ ft})) + (3 \times (0.018312 \text{ kip/ft}) \times (4.5 \text{ ft})^2)}{(6 \times (0.016879 \text{ kipft/ft})) + (4 \times (0.018312 \text{ kip/ft}) \times (4.5 \text{ ft}))}$$

$$a = 3.2869 \text{ ft}$$

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

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

$$V_{max} = ((0.018312 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (0.92174 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.2869 \text{ ft})}{(4.5 \text{ ft})} \right)^2 + 4 \times \left(\frac{3 \times (0.92174 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.2869 \text{ ft})}{(4.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.076004 \text{ kip}$$

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

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

$$M_{max} = ((0.018312 \text{ kip/ft}) \times (48 \text{ in}) \times (4.5 \text{ ft})) \times \left[\left(\frac{(0.92174 \text{ ft})}{(4.5 \text{ ft})} + \frac{(3.2869 \text{ ft})}{2 \times (4.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (0.92174 \text{ ft})}{(4.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.2869 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^3 + \left[\left(\frac{3 \times (0.92174 \text{ ft})}{(4.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.2869 \text{ ft})}{2 \times (4.5 \text{ ft})} \right)^4 \right] \right] \right]$$

$$M_{max} = 0.1419 \text{ kipft}$$

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.124 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (3 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (3 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -102.03 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-102.03 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

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

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

$$\text{Ratio} = \frac{(7.124 \text{ kip})}{(3183.4 \text{ kip})}$$

$$\text{Ratio} = 0.0022378$$

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 $f'_{ck} = 3 \text{ ksi} \rightarrow 3000 \text{ psi}$, $P = 7.124 \text{ kip} \rightarrow 7124 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(3000 \text{ psi})} + \frac{(7124 \text{ lbf})}{6 \times (2304 \text{ in}^2)} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 130.74 \text{ kip}$$

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

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

$$V_c = \text{Min}[(324.49 \text{ kip}), (130.74 \text{ kip}), (406.27 \text{ kip})]$$

$$V_c = 130.74 \text{ kip}$$

<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> $\phi V_n = \phi (V_c + V_s)$ $\phi V_n = (0.65) \times ((130.74 \text{ kip}) + (50.894 \text{ kip}))$ $\phi V_n = 118.06 \text{ kip}$ <p>Considering x-direction:</p> <p>$V_{max} = 3.1168 \text{ kip}$ - Maximum shear force in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(3.1168 \text{ kip})}{(118.06 \text{ kip})}$ $\text{Ratio} = 0.026399$ <p>Considering z-direction:</p> <p>$V_{max} = 0.076004 \text{ kip}$ - Maximum shear force in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{V_{max}}{\phi V_n}$ $\text{Ratio} = \frac{(0.076004 \text{ kip})}{(118.06 \text{ kip})}$ $\text{Ratio} = 0.00064375$	<p>Status: PASS Ratio: 0.030</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: $M_{max} = 6.908\text{kipft}$ - Maximum moment in the x-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(6.908\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.025265$	<p>Status: PASS Ratio: 0.030</p>
	<p>Considering z-direction: $M_{max} = 0.1419\text{kipft}$ - Maximum moment in the z-direction, Ratio - Capacity</p> $\text{Ratio} = \frac{M_{max}}{\phi M_n}$ $\text{Ratio} = \frac{(0.1419\text{kipft})}{(273.42\text{kipft})}$ $\text{Ratio} = 0.00051899$	<p>Status: PASS Ratio: 0.000</p>