Project Details

Project Name: MTSOLAR_JAG856E73DII-Brennan-Solar

Location: Havre, MT 59501, USA

Unique ID: 5P-22.5-8TOP-HD-24-L-5Hx14W-LL9F

Dealer: ______________________________

Date: Wed Aug 14 2024

Number of Modules: 70

Number of Poles: 5

Date Sold:

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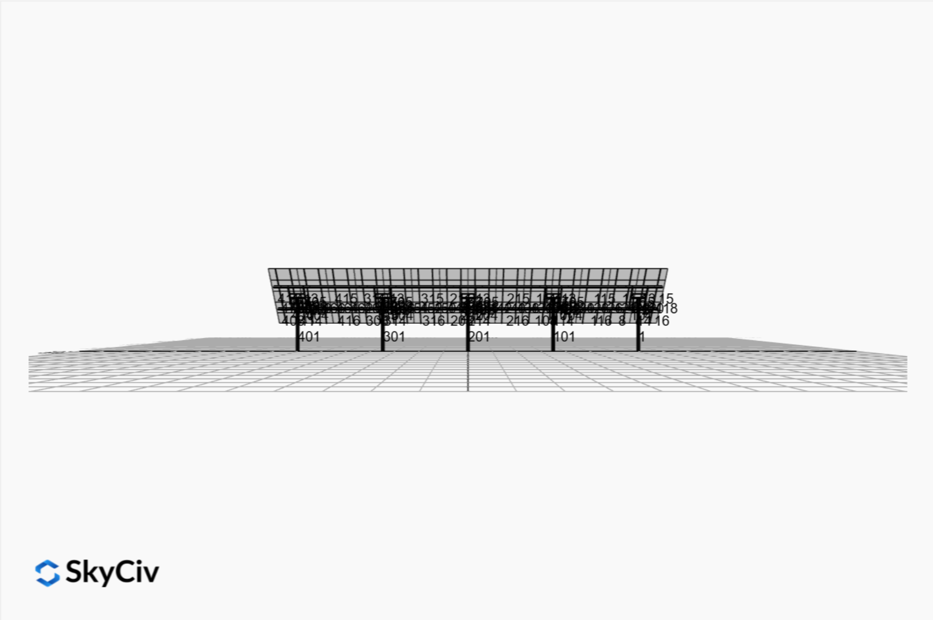


Array Dimensions N/S	18.54 ft
Array Dimensions E/W	102.67 ft
Winter Tilt Angle	50
Front Edge Clearance	7 ft

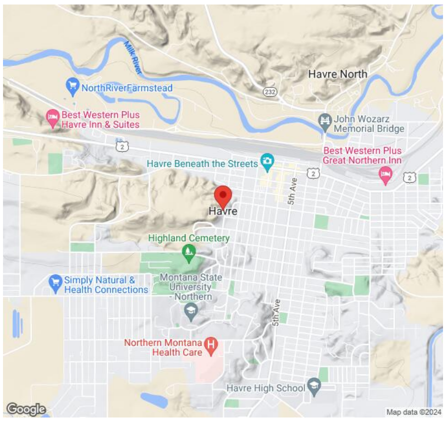
MT Solar Bill of Materials (5P-22.5-8TOP-HD-24-L-5Hx14W-LL9F)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	5
MTS-HF-HD	H-Frame Assembly-HD	5
MTS-HD-Wing-24	24IN HD Wing	4
MTS-HD-Splice-90	90IN HD Splice	16
MTS-CLAMP-ANGLE-4PK	Angle Clamp	14

Rail Bill of Materials

Part	Qty
Rails (220in)	28
Rail Attachment	112
Module Mid Clamp	112
Module End Clamp	56
Ground Lug	14

Site Details:



Site Address: Havre, MT 59501, USA

Array Specification

Duty Classification:	HD
Module Width:	44.00 in
Module Length:	87.00in
Number of Rows:	5
Number of Columns:	14
Total Number of Modules:	70
Winter Tilt Angle:	50
Front Edge Clearance:	7
Total Array Height at Tilt:	21.20 ft
Total Frame Length:	101.50 ft
Frame Weight:	7628 lbs
Array Dimensions N/S:	18.54 ft
Array Dimensions E/W:	102.67 ft
Rail Length:	222.50 in
Rail Spacing:	3.67 ft

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	14.10 ft
Number of Poles:	5
Pole Spacing:	22.5 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 7.50 ft Pile 2: 8.25 ft Pile 3: 8.25 ft Pile 4: 8.25 ft Pile 5: 7.50 ft
Foundation Volume:	23.556 y^3

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	Havre, MT 59501, USA
Wind Speed:	102 mph

Snow Load:	49 psf

Design Disclaimer

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

AutoDesigner Input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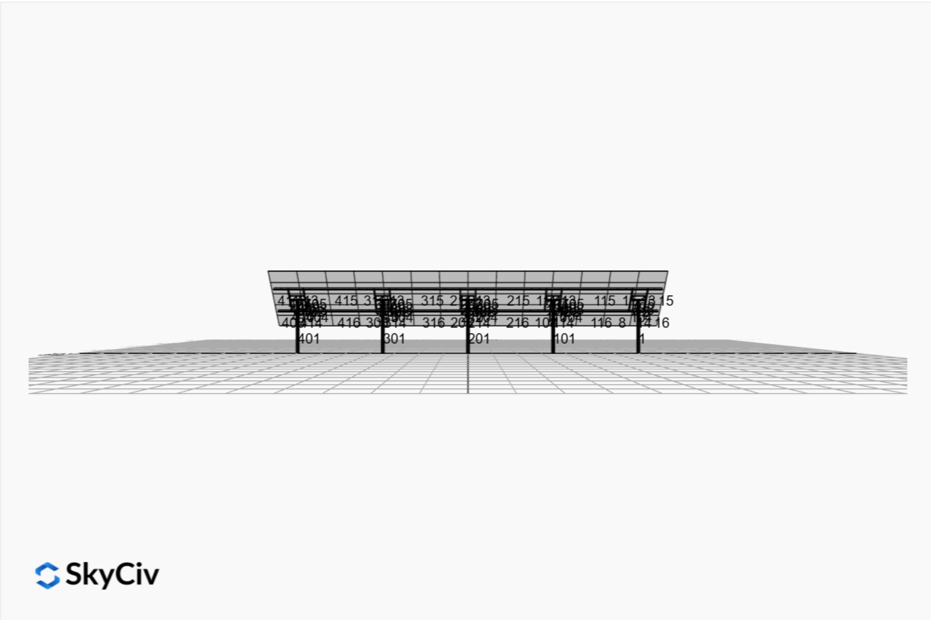
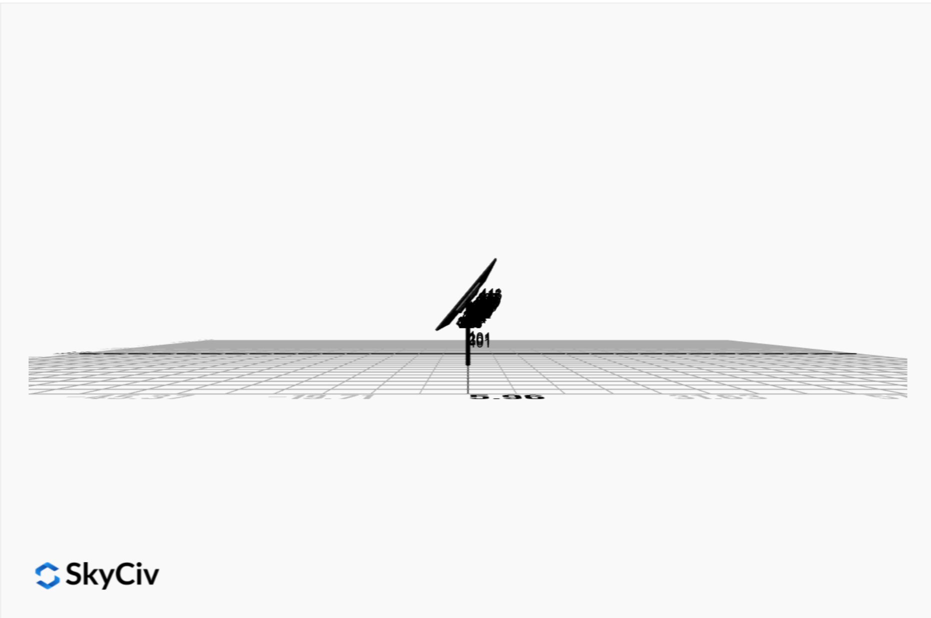
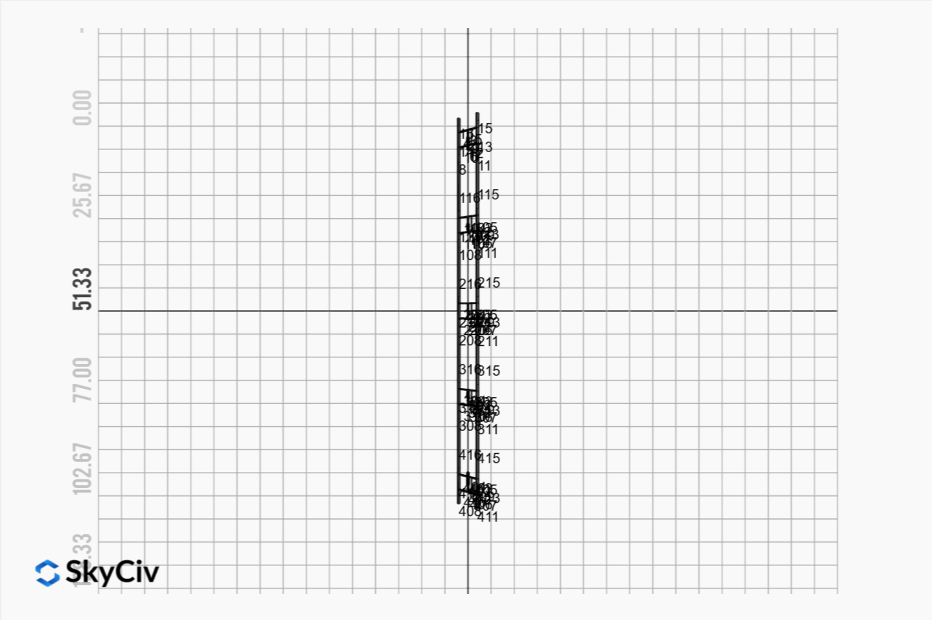
Design Notes:

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



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77.00
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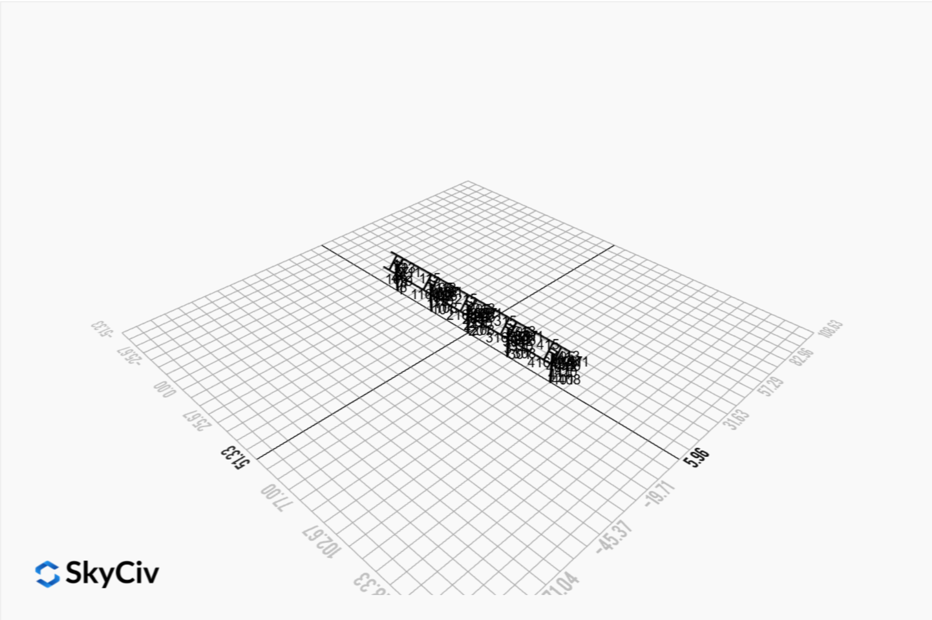
SkyCiv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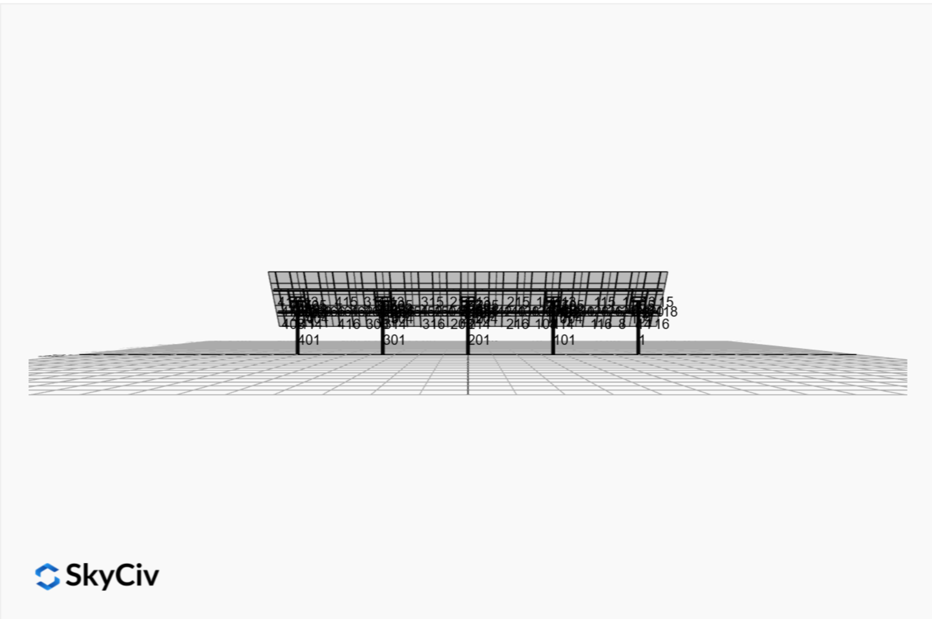
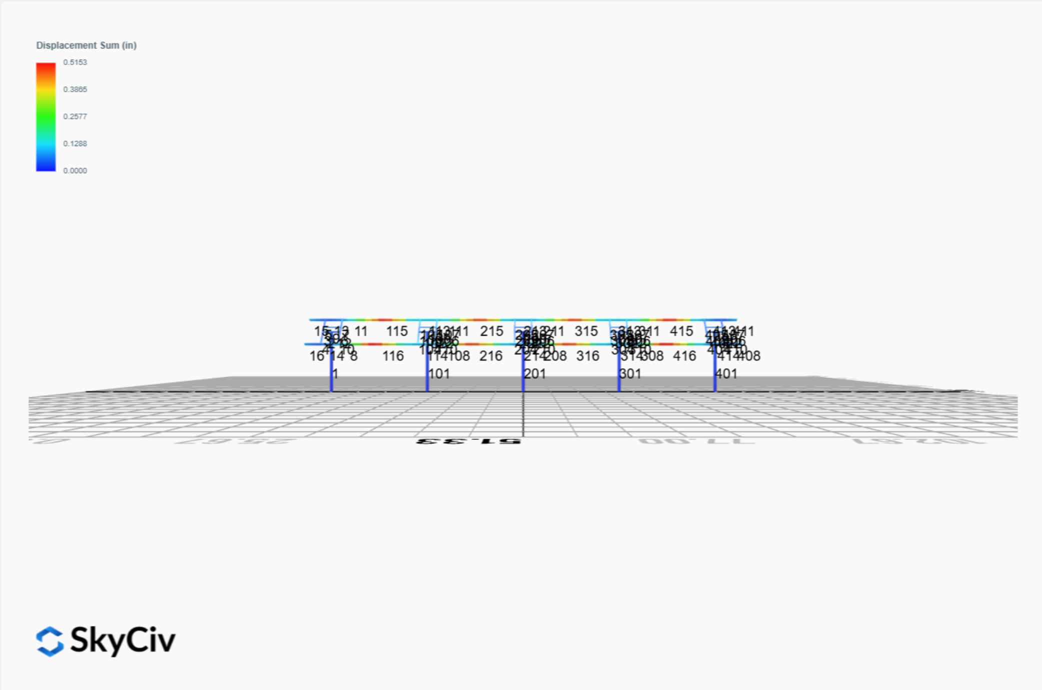
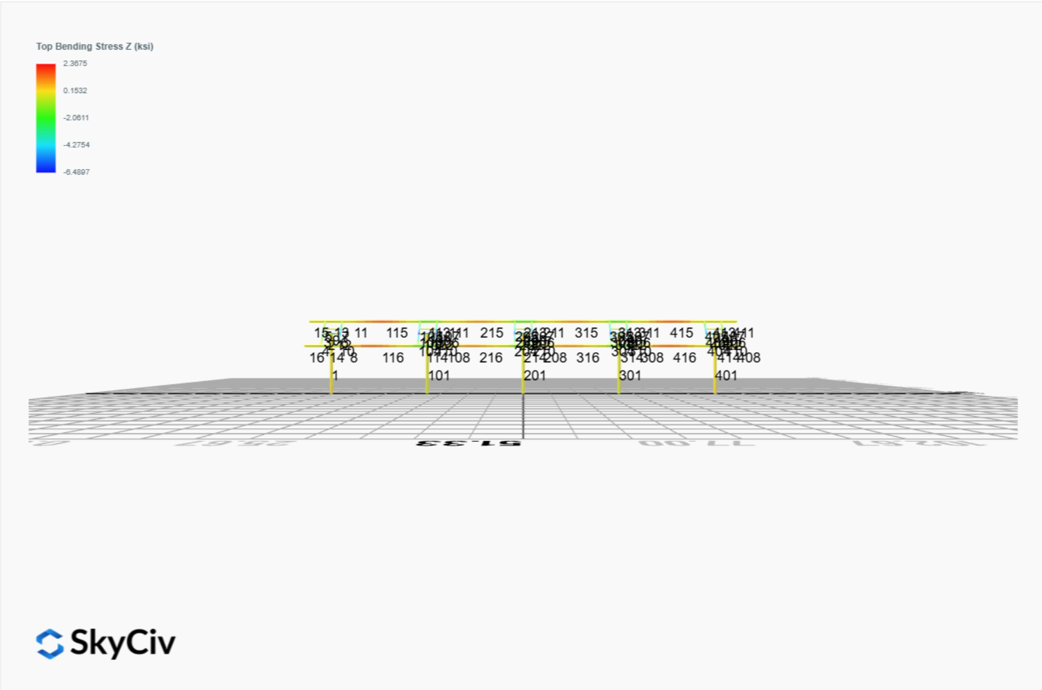
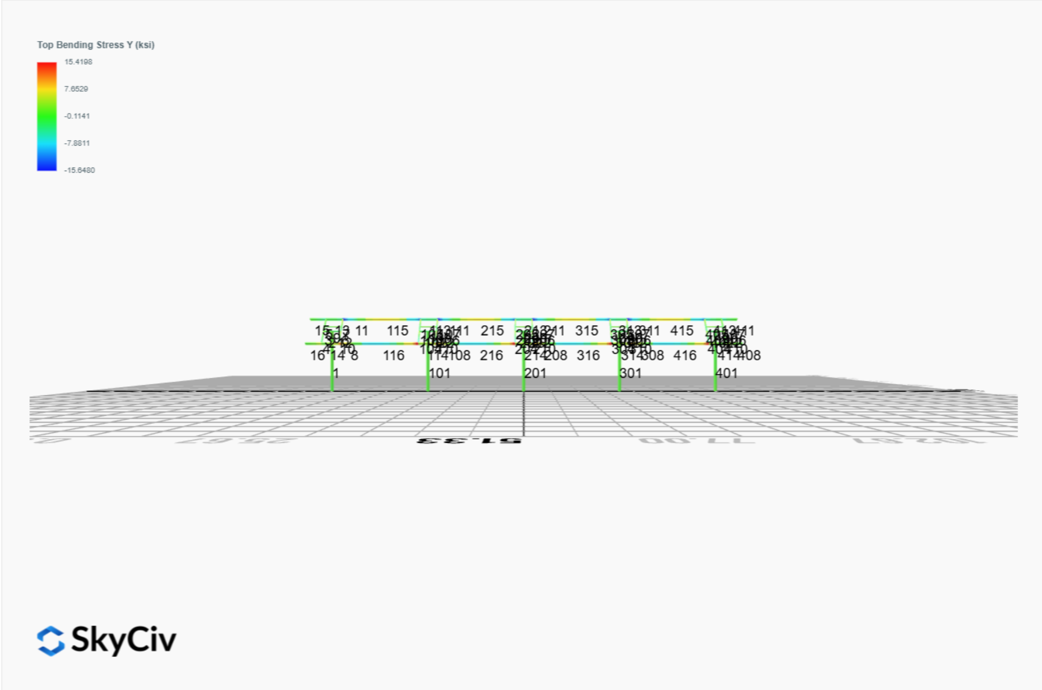

401
301
201
101
1
SkyCiv

FEM Results (Envelope Worst Case for each member)



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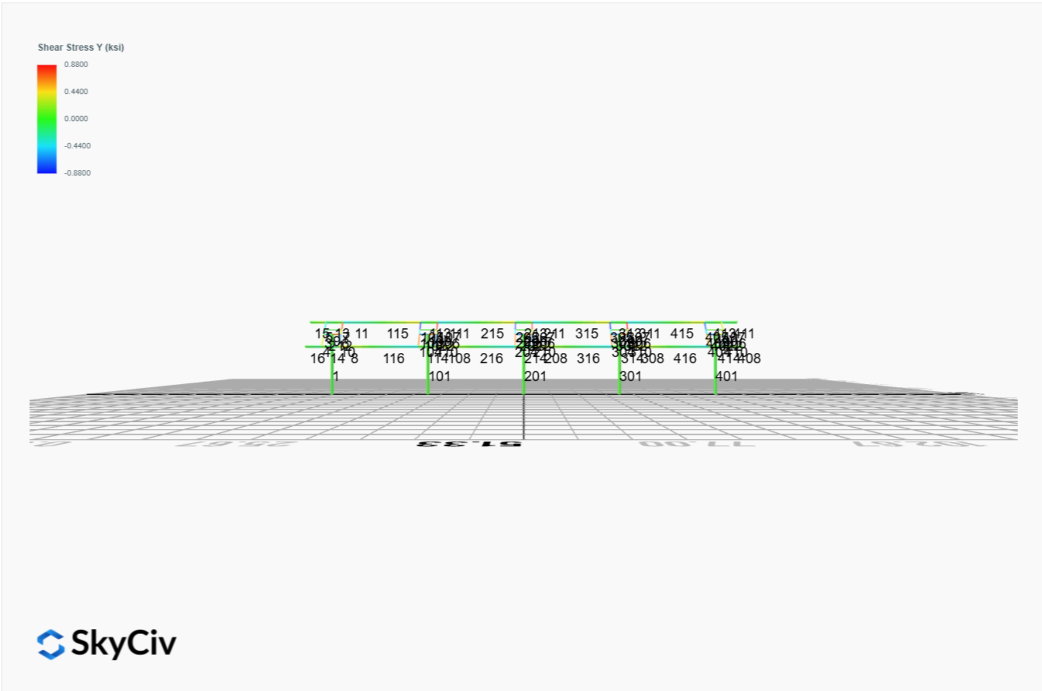
-0.1141
-7.8811
-15.6480
115
215
315
415
116
216
316
416
101
201
301
401
SkyCiv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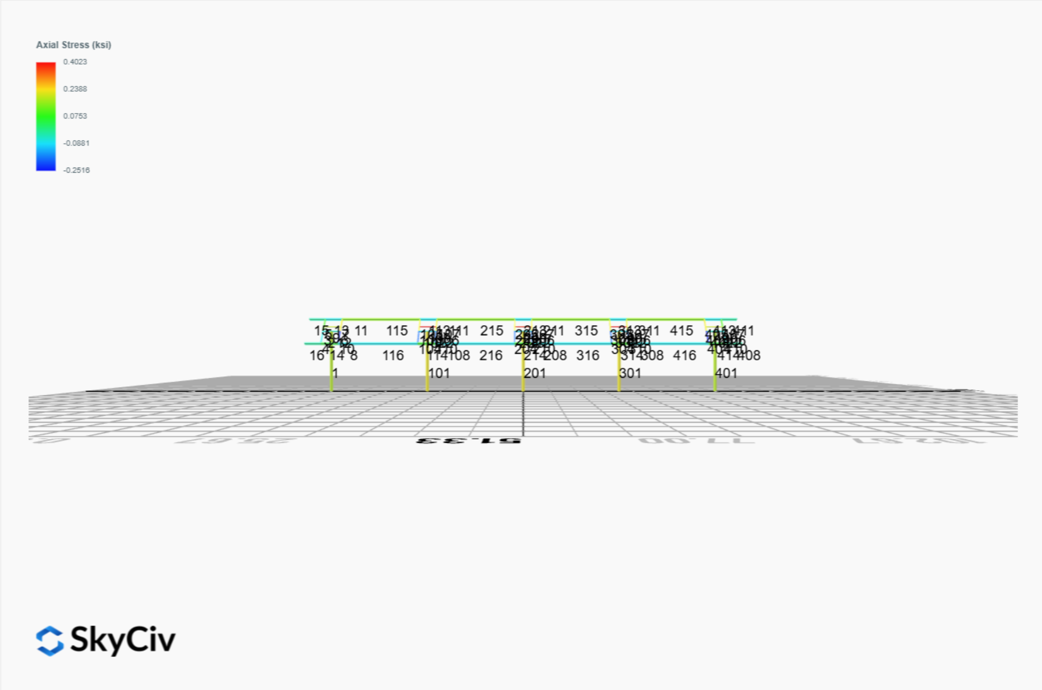
215
315
415
116
216
316
416
101
201
301
401
SkyCiv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115
215
315
415
116
216
316
416
1
101
201
301
401

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	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 2. D + L	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 3. D + (S or Lr or R)	0.0831	4.6881	0.2328	1.0047	-0.4041	-1.1020
ULS: 3. D + (S or Lr or R)	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0716	4.1530	0.2005	0.8654	-0.3480	-0.9469
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 5b. D + 0.7E	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0716	4.1530	0.2005	0.8654	-0.3480	-0.9469
ULS: 8. 0.6D + 0.7E	0.0222	1.5287	0.0622	0.2684	-0.1079	-0.2891
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.8428	4.9168	0.3933	1.6314	-2.0435	40.9101
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.9118	0.1824	-0.1790	-0.7072	1.6417	-40.7713
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0883	5.9297	0.4177	1.7534	-1.7457	30.0970
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0716	4.1530	0.2005	0.8654	-0.3480	-0.9469
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2276	2.3789	-0.0115	-0.0005	1.0182	-31.1640
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0716	4.1530	0.2005	0.8654	-0.3480	-0.9469
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1228	4.3246	0.3209	1.3354	-1.5776	30.5621
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1931	0.7738	-0.1083	-0.4185	1.1863	-30.6989
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0371	2.5479	0.1037	0.4473	-0.1799	-0.4819
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.8576	3.8977	0.3518	1.4525	-1.9715	41.1028
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0222	1.5287	0.0622	0.2684	-0.1079	-0.2891
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.8969	-0.8367	-0.2205	-0.8861	1.7137	-40.5785
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0222	1.5287	0.0622	0.2684	-0.1079	-0.2891

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	8.4568
Shear X	-4.8622
Shear Z	0.6768
Moment X	2.8123
Moment Y (Twist)	3.4638
Moment Z	69.1585

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	5.9297
Shear X	-2.9118
Shear Z	0.4177
Moment X	1.7534
Moment Y (Twist)	2.0435
Moment Z	41.1028

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	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 2. D + L	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 3. D + (S or Lr or R)	-0.0807	6.1199	-0.0144	-0.0659	0.1057	1.0913
ULS: 3. D + (S or Lr or R)	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0695	5.3866	-0.0124	-0.0567	0.0910	0.9420

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 5b. D + 0.7E	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0695	5.3866	-0.0124	-0.0567	0.0910	0.9420
ULS: 8. 0.6D + 0.7E	-0.0216	1.9120	-0.0039	-0.0176	0.0283	0.2964
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.9408	6.5081	0.0146	0.0479	-0.1681	56.1759
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.8749	-0.1396	-0.0235	-0.0906	0.2342	-53.4130
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9981	7.8777	0.0034	0.0012	-0.0704	42.7033
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0695	5.3866	-0.0124	-0.0567	0.0910	0.9420
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8637	2.8919	-0.0252	-0.1026	0.2314	-39.4883
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0695	5.3866	-0.0124	-0.0567	0.0910	0.9420
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9646	5.6777	0.0094	0.0286	-0.1143	42.2554
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8972	0.6919	-0.0192	-0.0753	0.1875	-39.9362
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0360	3.1866	-0.0064	-0.0294	0.0471	0.4940
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.9264	5.2335	0.0172	0.0597	-0.1869	55.9783
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0216	1.9120	-0.0039	-0.0176	0.0283	0.2964
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.8893	-1.4143	-0.0209	-0.0788	0.2154	-53.6106
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0216	1.9120	-0.0039	-0.0176	0.0283	0.2964

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.2829
Shear X	-6.5680
Shear Z	-0.0429
Moment X	-0.1659
Moment Y (Twist)	0.4177
Moment Z	95.3128

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	7.8777
Shear X	-3.9408
Shear Z	-0.0252
Moment X	-0.1026
Moment Y (Twist)	0.2342
Moment Z	56.1759

Reaction Forces for Foundation 3 (Node ID#201), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897
ULS: 2. D + L	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897
ULS: 3. D + (S or Lr or R)	-0.0048	6.0407	0.0000	-0.0001	0.0001	0.1841
ULS: 3. D + (S or Lr or R)	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0042	5.3183	0.0000	-0.0001	0.0001	0.1605
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897
ULS: 5b. D + 0.7E	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0042	5.3183	0.0000	-0.0001	0.0001	0.1605
ULS: 8. 0.6D + 0.7E	-0.0013	1.8907	0.0000	-0.0000	0.0000	0.0538
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.9136	6.4384	0.0000	-0.0000	0.0000	56.3625
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.9073	-0.1335	0.0000	-0.0000	0.0000	-54.2641
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9377	7.7837	0.0000	-0.0001	0.0001	42.3651
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0042	5.3183	0.0000	-0.0001	0.0001	0.1605
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9279	2.8548	0.0000	-0.0001	0.0001	-40.6048
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0042	5.3183	0.0000	-0.0001	0.0001	0.1605
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9357	5.6166	0.0000	-0.0000	0.0000	42.2943
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.9300	0.6877	0.0000	-0.0000	0.0000	-40.6757
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0021	3.1512	0.0000	-0.0000	0.0000	0.0897
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.9127	5.1779	0.0000	-0.0000	0.0000	56.3266
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0013	1.8907	0.0000	-0.0000	0.0000	0.0538
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.9082	-1.3940	0.0000	-0.0000	0.0000	-54.3000
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0013	1.8907	0.0000	-0.0000	0.0000	0.0538

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.1465
Shear X	-6.5256
Shear Z	0.0000
Moment X	-0.0013
Moment Y (Twist)	0.0012
Moment Z	95.6828

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	7.7837
Shear X	-3.9136
Shear Z	0.0000
Moment X	-0.0001
Moment Y (Twist)	0.0001
Moment Z	56.3625

Reaction Forces for Foundation 4 (Node ID#301), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940
ULS: 2. D + L	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940
ULS: 3. D + (S or Lr or R)	-0.0807	6.1199	0.0144	0.0656	-0.1054	1.0913
ULS: 3. D + (S or Lr or R)	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0695	5.3866	0.0124	0.0565	-0.0908	0.9420
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940
ULS: 5b. D + 0.7E	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0695	5.3866	0.0124	0.0565	-0.0908	0.9420
ULS: 8. 0.6D + 0.7E	-0.0216	1.9120	0.0039	0.0176	-0.0282	0.2964
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.9408	6.5081	-0.0146	-0.0480	0.1681	56.1759
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.8749	-0.1396	0.0235	0.0905	-0.2342	-53.4130
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9981	7.8777	-0.0034	-0.0014	0.0706	42.7033
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0695	5.3866	0.0124	0.0565	-0.0908	0.9420
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8637	2.8919	0.0252	0.1024	-0.2311	-39.4883
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0695	5.3866	0.0124	0.0565	-0.0908	0.9420
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.9646	5.6777	-0.0094	-0.0287	0.1143	42.2554
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8972	0.6919	0.0192	0.0752	-0.1874	-39.9362
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0360	3.1866	0.0064	0.0293	-0.0471	0.4940

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.9264	5.2335	-0.0172	-0.0597	0.1870	55.9783
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0216	1.9120	0.0039	0.0176	-0.0282	0.2964
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.8893	-1.4143	0.0209	0.0788	-0.2153	-53.6106
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0216	1.9120	0.0039	0.0176	-0.0282	0.2964

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	11.2829
Shear X	-6.5680
Shear Z	0.0430
Moment X	0.1670
Moment Y (Twist)	0.4181
Moment Z	95.3131

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	7.8777
Shear X	-3.9408
Shear Z	0.0252
Moment X	0.1024
Moment Y (Twist)	0.2342
Moment Z	56.1759

Reaction Forces for Foundation 5 (Node ID#401), (kip, kip-ft)

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 2. D + L	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 3. D + (S or Lr or R)	0.0831	4.6880	-0.2328	-1.0053	0.4043	-1.1017
ULS: 3. D + (S or Lr or R)	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0716	4.1530	-0.2005	-0.8658	0.3482	-0.9468
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 5b. D + 0.7E	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0716	4.1530	-0.2005	-0.8658	0.3482	-0.9468
ULS: 8. 0.6D + 0.7E	0.0222	1.5287	-0.0622	-0.2685	0.1080	-0.2891
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.8428	4.9168	-0.3933	-1.6316	2.0436	40.9101
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.9118	0.1824	0.1790	0.7070	-1.6417	-40.7712
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0883	5.9297	-0.4177	-1.7539	1.7459	30.0972
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0716	4.1530	-0.2005	-0.8658	0.3482	-0.9468
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.2276	2.3789	0.0115	0.0000	-1.0180	-31.1638
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0716	4.1530	-0.2005	-0.8658	0.3482	-0.9468
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.1228	4.3246	-0.3209	-1.3355	1.5777	30.5622
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.1931	0.7738	0.1083	0.4184	-1.1863	-30.6989
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0371	2.5479	-0.1037	-0.4475	0.1800	-0.4818
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.8576	3.8977	-0.3518	-1.4526	1.9716	41.1029
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0222	1.5287	-0.0622	-0.2685	0.1080	-0.2891
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.8969	-0.8367	0.2205	0.8860	-1.7137	-40.5785
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0222	1.5287	-0.0622	-0.2685	0.1080	-0.2891

Worst Case Reactions LRFD

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

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	8.4567
Shear X	-4.8622
Shear Z	-0.6768
Moment X	-2.8144
Moment Y (Twist)	3.4651
Moment Z	69.1598

Result	Value (kip, kip-ft)
Axial	5.9297
Shear X	-2.9118
Shear Z	-0.4177
Moment X	-1.7539
Moment Y (Twist)	2.0436
Moment Z	41.1029

Project Details

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

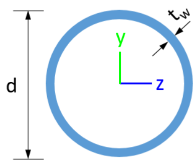
User Name: sales@mtsolar.us
Unit System: imperial

Design Input Information

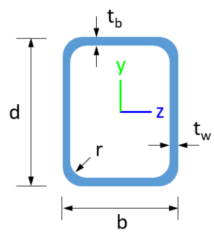
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

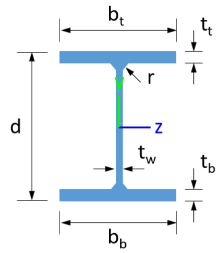
Section Dimensions



ID	Name	d (in)	t_w (in)					
2	2in Pipe Sch 80	2.38	0.22					
5	4in Pipe Sch 80	4.50	0.34					
10	8in Pipe Sch 80	8.63	0.50					



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)		
16	HSS5x3x3/16	5.00	3.00	0.17	0.17	0.17		



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
19	W8x10	7.89	0.17	3.94	3.94	0.20	0.20	0.30

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)

2	2in Pipe Sch 80	1.48	1.74	0.87	0.87	0.00	1.02	1.02
5	4in Pipe Sch 80	4.41	19.22	9.61	9.61	0.00	5.85	5.85
10	8in Pipe Sch 80	12.76	211.43	105.72	105.72	0.00	33.05	33.05
16	HSS5x3x3/16	2.58	8.64	3.85	8.53	0.73	2.96	4.21
19	W8x10	2.96	0.04	2.09	30.80	30.90	1.66	8.87

Member Properties								
Member ID	Section ID	K_zL (ft)	K_yL (ft)	L_b(ft)	C_b	LST	LSC	LD
1	10	29.61	29.61	14.10	-	300	200	1
2	5	1.30	1.30	2.00	-	300	200	1
3	16	0.92	0.92	1.42	1.18,1.17,1.18,1.17,1.18,1.18,1.16,1.17,1.15,1.17,1.16,1.18,1.16,1.18,1.17,1.17,1.22,1.17,1.17,1.18,1.14,1.18,1.16,1.18,1.16,1.18	300	200	1
4	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.73,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
5	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.70,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
6	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.22,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.19	300	200	1
7	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.80,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
8	19	1.33	1.33	2.05	1.36,1.36,1.36,1.37,1.36,1.36,1.37,1.36,1.37,1.36,1.37,1.36,1.37,1.36,1.37,1.37,1.36,1.37,1.37,1.36,1.37,1.36,1.37,1.36,1.37,1.36	300	200	1
9	2	2.60	2.60	4.00	-	300	200	1
10	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.74,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
11	19	1.33	1.33	2.05	1.41,1.41,1.41,1.41,1.41,1.41,1.52,1.41,1.64,1.41,1.53,1.41,1.60,1.41,1.47,1.41,1.03,1.41,1.51,1.41,1.71,1.41,1.54,1.41,1.58,1.41	300	200	1
12	5	1.30	1.30	2.00	-	300	200	1
13	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.17,1.10,1.23,1.10,1.18,1.10,1.21,1.10,1.14,1.10,2.65,1.10,1.16,1.10,1.26,1.10,1.18,1.10,1.20,1.10	300	200	1
14	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.07,1.10,1.09,1.10,1.07,1.10,1.09,1.10,1.08,1.10,1.37,1.10,1.08,1.10,1.11,1.10,1.07,1.10,1.08,1.10	300	200	1
15	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
16	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
101	10	29.61	29.61	14.10	-	300	200	1
102	5	1.30	1.30	2.00	-	300	200	1
103	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18	300	200	1
104	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.70,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
105	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
106	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18	300	200	1
107	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.70,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
108	19	1.33	1.33	2.05	2.23,2.23,2.23,2.23,2.23,2.23,2.26,2.23,2.31,2.23,2.27,2.23,2.29,2.23,2.25,2.23,1.45,2.23,2.26,2.23,2.33,2.23,2.27,2.23,2.29,2.23	300	200	1
109	2	2.60	2.60	4.00	-	300	200	1
110	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.72,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
111	19	1.33	1.33	2.05	2.27,2.27,2.27,2.27,2.27,2.27,2.14,2.27,2.08,2.27,2.13,2.27,2.10,2.27,2.36,2.27,1.23,2.27,2.14,2.27,2.01,2.27,2.13,2.27,2.10,2.27	300	200	1
112	5	1.30	1.30	2.00	-	300	200	1

113	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.07,1.04,1.10,1.04,1.07,1.04,1.09,1.04,1.06,1.04,1.16,1.04,1.07,1.04,1.12,1.04,1.07,1.04,1.09,1.04	300	200	1
114	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.07,1.03,1.05,1.03,1.06,1.03,1.05,1.03,1.10,1.03,1.05,1.03,1.07,1.03,1.05,1.03,1.06,1.03	300	200	1
115	19	8.42	8.42	12.95	1.16,1.16,1.16,1.16,1.16,1.16,1.13,1.16,1.10,1.16,1.12,1.16,1.11,1.16,1.14,1.16,2.25,1.16,1.13,1.16,1.10,1.16,1.12,1.16,1.11,1.16	300	200	1
116	19	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.16,1.17,1.17,1.17,1.55,1.17,1.16,1.17,1.15,1.17,1.16,1.17,1.16,1.17	300	200	1
201	10	29.61	29.61	14.10	-	300	200	1
202	5	1.30	1.30	2.00	-	300	200	1
203	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
204	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.72,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
205	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.70,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
206	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.20,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.18,1.18	300	200	1
207	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.70,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
208	19	1.33	1.33	2.05	2.26,2.26,2.26,2.26,2.26,2.26,2.26,2.26,2.27,2.26,2.26,2.26,2.26,2.26,2.26,2.26,2.12,2.26,2.26,2.26,2.27,2.26,2.26,2.26,2.26,2.26	300	200	1
209	2	2.60	2.60	4.00	-	300	200	1
210	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.72,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
211	19	1.33	1.33	2.05	2.23,2.23,2.23,2.23,2.23,2.23,2.28,2.23,2.33,2.23,2.28,2.23,2.31,2.23,2.25,2.23,1.31,2.23,2.27,2.23,2.36,2.23,2.28,2.23,2.30,2.23	300	200	1
212	5	1.30	1.30	2.00	-	300	200	1
213	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.02,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03	300	200	1
214	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03,1.03	300	200	1
215	19	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.17,1.18,1.18,1.18,3.22,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
216	19	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.23,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17,1.17	300	200	1
301	10	29.61	29.61	14.10	-	300	200	1
302	5	1.30	1.30	2.00	-	300	200	1
303	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18	300	200	1
304	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.72,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
305	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.70,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.67,1.67	300	200	1
306	16	0.92	0.92	1.42	1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.20,1.18,1.18,1.18,1.17,1.18,1.18,1.18,1.17,1.18	300	200	1
307	16	1.52	1.52	2.33	1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.68,1.67,1.67,1.67,1.66,1.67,1.67,1.67,1.66,1.67	300	200	1
308	19	1.33	1.33	2.05	2.34,2.34,2.34,2.34,2.34,2.34,2.14,2.34,2.11,2.34,2.14,2.34,2.12,2.34,2.16,2.34,1.45,2.34,2.15,2.34,2.10,2.34,2.14,2.34,2.13,2.34	300	200	1
309	2	2.60	2.60	4.00	-	300	200	1
310	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.70,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
311	19	1.33	1.33	2.05	2.14,2.14,2.14,2.14,2.14,2.14,1.80,2.14,1.51,2.14,1.76,2.14,1.58,2.14,2.07,2.14,1.24,2.14,1.87,2.14,1.43,2.14,1.74,2.14,1.62,2.14	300	200	1
312	5	1.30	1.30	2.00	-	300	200	1
313	19	4.88	4.00	7.50	1.04,1.04,1.04,1.04,1.04,1.04,1.07,1.04,1.10,1.04,1.07,1.04,1.09,1.04,1.06,1.04,1.16,1.04,1.07,1.04,1.12,1.04,1.07,1.04,1.09,1.04	300	200	1
314	19	4.88	4.00	7.50	1.03,1.03,1.03,1.03,1.03,1.03,1.05,1.03,1.07,1.03,1.05,1.03,1.06,1.03,1.05,1.03,1.09,1.03,1.05,1.03,1.07,1.03,1.05,1.03,1.06,1.03	300	200	1

315	19	8.42	8.42	12.95	1.17,1.17,1.17,1.17,1.17,1.17,1.14,1.17,1.13,1.17,1.14,1.17,1.13,1.17,1.15,1.17,3.44,1.17,1.15,1.17,1.13,1.17,1.14,1.17,1.14,1.17	300	200	1
316	19	8.42	8.42	12.95	1.18,1.18,1.18,1.18,1.18,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18,1.18,1.18,1.84,1.18,1.17,1.18,1.16,1.18,1.17,1.18,1.17,1.18	300	200	1
401	10	29.61	29.61	14.10	-	300	200	1
402	5	1.30	1.30	2.00	-	300	200	1
403	16	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.22,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.19,1.19	300	200	1
404	16	2.44	2.44	3.75	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.74,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68	300	200	1
405	16	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.67,1.68,1.67,1.67,1.80,1.67,1.67,1.68,1.66,1.68,1.67,1.68,1.67,1.68	300	200	1
406	16	0.92	0.92	1.42	1.18,1.17,1.18,1.17,1.18,1.18,1.16,1.17,1.15,1.17,1.16,1.18,1.16,1.18,1.17,1.17,1.22,1.17,1.17,1.18,1.14,1.18,1.16,1.18,1.16,1.18	300	200	1
407	16	1.52	1.52	2.33	1.68,1.68,1.68,1.67,1.68,1.68,1.67,1.68,1.66,1.68,1.67,1.68,1.66,1.68,1.67,1.67,1.70,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
408	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
409	2	2.60	2.60	4.00	-	300	200	1
410	16	2.44	2.44	3.75	1.69,1.68,1.69,1.68,1.69,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.68,1.73,1.68,1.67,1.69,1.65,1.69,1.67,1.69,1.66,1.69	300	200	1
411	19	4.20	4.20	2.00	2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33	300	200	1
412	5	1.30	1.30	2.00	-	300	200	1
413	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.17,1.10,1.23,1.10,1.18,1.10,1.21,1.10,1.14,1.10,2.65,1.10,1.16,1.10,1.26,1.10,1.18,1.10,1.21,1.10	300	200	1
414	19	4.88	4.00	7.50	1.10,1.10,1.10,1.10,1.10,1.10,1.07,1.10,1.09,1.10,1.07,1.10,1.09,1.10,1.08,1.10,1.36,1.10,1.08,1.10,1.10,1.10,1.07,1.10,1.08,1.10	300	200	1
415	19	8.42	8.42	12.95	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.11,1.10,1.10,1.10,1.47,1.10,1.10,1.10,1.12,1.10,1.10,1.10,1.11,1.10	300	200	1
416	19	8.42	8.42	12.95	1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.15,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10,1.10	300	200	1

Member Design Capacity

Member ID	$\Phi_t P_n$ (kip)	$\Phi_c P_n$ (kip)	$\Phi_b M_{zn}$ (k-ft)	$\Phi_b M_{yn}$ (k-ft)	$\Phi_v V_{yn}$ (kip)	$\Phi_v V_{zn}$ (kip)
1	574.32	189.12	123.94	123.94	172.30	172.30
2	198.33	196.72	21.95	21.95	59.50	59.50
3	116.10	115.41	15.79	11.10	42.08	23.28
4	116.10	111.33	15.79	11.10	42.08	23.28
5	116.10	114.23	15.79	11.10	42.08	23.28
6	116.10	115.41	15.79	11.10	42.08	23.28
7	116.10	114.23	15.79	11.10	42.08	23.28
8	133.20	123.95	32.87	6.12	40.24	43.62
9	66.48	58.89	3.82	3.82	19.94	19.94
10	116.10	111.33	15.79	11.10	42.08	23.28
11	133.20	123.95	32.87	6.12	40.24	43.62
12	198.33	196.72	21.95	21.95	59.50	59.50
13	133.20	85.85	25.24	6.12	40.24	43.62
14	133.20	85.85	24.53	6.12	40.24	43.62
15	133.20	102.39	32.87	6.12	40.24	43.62
16	133.20	102.39	32.87	6.12	40.24	43.62
101	574.32	189.12	123.94	123.94	172.30	172.30
102	198.33	196.72	21.95	21.95	59.50	59.50
103	116.10	115.41	15.79	11.10	42.08	23.28

104	116.10	111.33	15.79	11.10	42.08	23.28
105	116.10	114.23	15.79	11.10	42.08	23.28
106	116.10	115.41	15.79	11.10	42.08	23.28
107	116.10	114.23	15.79	11.10	42.08	23.28
108	133.20	123.95	32.87	6.12	40.24	43.62
109	66.48	58.89	3.82	3.82	19.94	19.94
110	116.10	111.33	15.79	11.10	42.08	23.28
111	133.20	123.95	32.87	6.12	40.24	43.62
112	198.33	196.72	21.95	21.95	59.50	59.50
113	133.20	85.85	23.82	6.12	40.24	43.62
114	133.20	85.85	23.71	6.12	40.24	43.62
115	133.20	46.28	11.87	6.12	40.24	43.62
116	133.20	46.28	12.44	6.12	40.24	43.62
201	574.32	189.12	123.94	123.94	172.30	172.30
202	198.33	196.72	21.95	21.95	59.50	59.50
203	116.10	115.41	15.79	11.10	42.08	23.28
204	116.10	111.33	15.79	11.10	42.08	23.28
205	116.10	114.23	15.79	11.10	42.08	23.28
206	116.10	115.41	15.79	11.10	42.08	23.28
207	116.10	114.23	15.79	11.10	42.08	23.28
208	133.20	123.95	32.87	6.12	40.24	43.62
209	66.48	58.89	3.82	3.82	19.94	19.94
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	123.95	32.87	6.12	40.24	43.62
212	198.33	196.72	21.95	21.95	59.50	59.50
213	133.20	85.85	23.36	6.12	40.24	43.62
214	133.20	85.85	23.51	6.12	40.24	43.62
215	133.20	46.28	12.59	6.12	40.24	43.62
216	133.20	46.28	12.70	6.12	40.24	43.62
301	574.32	189.12	123.94	123.94	172.30	172.30
302	198.33	196.72	21.95	21.95	59.50	59.50
303	116.10	115.41	15.79	11.10	42.08	23.28
304	116.10	111.33	15.79	11.10	42.08	23.28
305	116.10	114.23	15.79	11.10	42.08	23.28
306	116.10	115.41	15.79	11.10	42.08	23.28
307	116.10	114.23	15.79	11.10	42.08	23.28
308	133.20	123.95	32.87	6.12	40.24	43.62
309	66.48	58.89	3.82	3.82	19.94	19.94
310	116.10	111.33	15.79	11.10	42.08	23.28
311	133.20	123.95	32.87	6.12	40.24	43.62
312	198.33	196.72	21.95	21.95	59.50	59.50
313	133.20	85.85	23.82	6.12	40.24	43.62
314	133.20	85.85	23.71	6.12	40.24	43.62
315	133.20	46.28	12.20	6.12	40.24	43.62
316	133.20	46.28	12.55	6.12	40.24	43.62
401	574.32	189.12	123.94	123.94	172.30	172.30
402	198.33	196.72	21.95	21.95	59.50	59.50
403	116.10	115.41	15.79	11.10	42.08	23.28
404	116.10	111.33	15.79	11.10	42.08	23.28
405	116.10	114.23	15.79	11.10	42.08	23.28
406	116.10	115.41	15.79	11.10	42.08	23.28
407	116.10	114.23	15.79	11.10	42.08	23.28

407	116.10	114.23	15.79	11.10	42.08	23.28
408	133.20	102.39	32.87	6.12	40.24	43.62
409	66.48	58.89	3.82	3.82	19.94	19.94
410	116.10	111.33	15.79	11.10	42.08	23.28
411	133.20	102.39	32.87	6.12	40.24	43.62
412	198.33	196.72	21.95	21.95	59.50	59.50
413	133.20	85.85	25.24	6.12	40.24	43.62
414	133.20	85.85	24.53	6.12	40.24	43.62
415	133.20	46.28	11.93	6.12	40.24	43.62
416	133.20	46.28	11.90	6.12	40.24	43.62

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	0.045	0.558	0.054	0.028	0.004	0.602	#13	0.617	Not Required	Pass
2	0.004	0.136	0.130	0.039	0.030	0.247	#13	0.035	Not Required	Pass
3	0.006	0.338	0.042	0.031	0.013	0.342	#13	0.045	Not Required	Pass
4	0.005	0.343	0.093	0.034	0.023	0.428	#13	0.120	Not Required	Pass
5	0.005	0.210	0.067	0.034	0.019	0.218	#13	0.074	Not Required	Pass
6	0.013	0.666	0.117	0.069	0.029	0.741	#13	0.045	Not Required	Pass
7	0.014	0.412	0.250	0.066	0.061	0.443	#13	0.074	Not Required	Pass
8	0.007	0.122	0.274	0.042	0.022	0.279	#23	0.095	Not Required	Pass
9	0.012	0.073	0.096	0.006	0.006	0.155	#13	0.204	Not Required	Pass
10	0.015	0.625	0.240	0.062	0.051	0.649	#13	0.080	Not Required	Pass
11	0.008	0.105	0.285	0.045	0.022	0.298	#23	0.095	Not Required	Pass
12	0.003	0.421	0.288	0.090	0.056	0.710	#13	0.053	Not Required	Pass
13	0.011	0.130	0.592	0.056	0.027	0.646	#21	0.286	Not Required	Pass
14	0.007	0.097	0.578	0.052	0.027	0.603	#21	0.190	Not Required	Pass
15	0.000	0.015	0.041	0.012	0.006	0.053	#21	Not Required	Not Required	Pass
16	0.000	0.015	0.041	0.012	0.006	0.053	#21	Not Required	Not Required	Pass
101	0.060	0.769	0.004	0.038	0.000	0.798	#13	0.617	Not Required	Pass
102	0.006	0.366	0.291	0.089	0.053	0.658	#13	0.035	Not Required	Pass
103	0.013	0.660	0.065	0.065	0.002	0.704	#13	0.045	Not Required	Pass
104	0.013	0.692	0.254	0.069	0.052	0.796	#13	0.080	Not Required	Pass
105	0.013	0.409	0.268	0.065	0.068	0.453	#13	0.074	Not Required	Pass
106	0.013	0.691	0.065	0.069	0.004	0.725	#13	0.045	Not Required	Pass
107	0.013	0.429	0.256	0.068	0.066	0.472	#13	0.074	Not Required	Pass
108	0.008	0.067	0.263	0.046	0.022	0.320	#21	0.095	Not Required	Pass
109	0.026	0.048	0.061	0.001	0.000	0.117	#13	0.204	Not Required	Pass
110	0.012	0.693	0.241	0.069	0.050	0.780	#13	0.080	Not Required	Pass
111	0.008	0.051	0.275	0.045	0.022	0.319	#21	0.095	Not Required	Pass
112	0.006	0.379	0.304	0.088	0.057	0.685	#13	0.035	Not Required	Pass
113	0.012	0.226	0.607	0.058	0.027	0.771	#21	0.286	Not Required	Pass
114	0.012	0.272	0.597	0.062	0.027	0.794	#21	0.286	Not Required	Pass
115	0.021	0.544	0.318	0.048	0.022	0.770	#21	0.601	Not Required	Pass
116	0.008	0.531	0.312	0.051	0.022	0.738	#21	0.601	Not Required	Pass
201	0.059	0.772	0.000	0.038	0.000	0.800	#13	0.617	Not Required	Pass
202	0.006	0.370	0.297	0.087	0.055	0.668	#13	0.035	Not Required	Pass
203	0.013	0.685	0.064	0.068	0.002	0.725	#13	0.045	Not Required	Pass
204	0.012	0.671	0.240	0.067	0.050	0.762	#13	0.080	Not Required	Pass
205	0.013	0.425	0.254	0.068	0.065	0.465	#13	0.074	Not Required	Pass

206	0.013	0.685	0.064	0.068	0.002	0.725	#13	0.045	Not Required	Pass
207	0.013	0.425	0.254	0.068	0.065	0.465	#13	0.074	Not Required	Pass
208	0.008	0.068	0.262	0.046	0.022	0.318	#21	0.095	Not Required	Pass
209	0.025	0.043	0.063	0.001	0.000	0.113	#13	0.204	Not Required	Pass
210	0.012	0.671	0.240	0.067	0.050	0.762	#13	0.080	Not Required	Pass
211	0.008	0.067	0.272	0.047	0.022	0.331	#21	0.095	Not Required	Pass
212	0.006	0.370	0.297	0.087	0.055	0.668	#13	0.035	Not Required	Pass
213	0.012	0.268	0.576	0.058	0.027	0.787	#21	0.286	Not Required	Pass
214	0.012	0.271	0.564	0.057	0.027	0.765	#21	0.286	Not Required	Pass
215	0.022	0.397	0.318	0.047	0.022	0.637	#21	0.601	Not Required	Pass
216	0.011	0.371	0.310	0.046	0.022	0.606	#21	0.601	Not Required	Pass
301	0.060	0.769	0.004	0.038	0.000	0.798	#13	0.617	Not Required	Pass
302	0.006	0.378	0.304	0.088	0.057	0.684	#13	0.035	Not Required	Pass
303	0.013	0.691	0.065	0.069	0.004	0.725	#13	0.045	Not Required	Pass
304	0.013	0.693	0.241	0.069	0.050	0.780	#13	0.080	Not Required	Pass
305	0.013	0.429	0.256	0.068	0.066	0.472	#13	0.074	Not Required	Pass
306	0.013	0.660	0.065	0.065	0.002	0.704	#13	0.045	Not Required	Pass
307	0.013	0.409	0.268	0.065	0.068	0.453	#13	0.074	Not Required	Pass
308	0.007	0.060	0.289	0.051	0.022	0.335	#21	0.095	Not Required	Pass
309	0.026	0.048	0.061	0.001	0.000	0.117	#13	0.204	Not Required	Pass
310	0.013	0.692	0.254	0.069	0.052	0.796	#13	0.080	Not Required	Pass
311	0.008	0.087	0.298	0.048	0.022	0.325	#21	0.095	Not Required	Pass
312	0.006	0.366	0.291	0.089	0.053	0.658	#13	0.035	Not Required	Pass
313	0.012	0.226	0.608	0.058	0.027	0.772	#21	0.286	Not Required	Pass
314	0.012	0.272	0.597	0.062	0.027	0.793	#21	0.286	Not Required	Pass
315	0.022	0.398	0.319	0.045	0.022	0.641	#21	0.601	Not Required	Pass
316	0.011	0.367	0.310	0.046	0.022	0.606	#21	0.601	Not Required	Pass
401	0.045	0.558	0.054	0.028	0.004	0.602	#13	0.617	Not Required	Pass
402	0.003	0.421	0.288	0.090	0.056	0.710	#13	0.053	Not Required	Pass
403	0.013	0.666	0.117	0.069	0.029	0.741	#13	0.045	Not Required	Pass
404	0.015	0.625	0.241	0.062	0.051	0.649	#13	0.080	Not Required	Pass
405	0.014	0.412	0.249	0.066	0.061	0.443	#13	0.074	Not Required	Pass
406	0.006	0.338	0.042	0.031	0.013	0.342	#13	0.045	Not Required	Pass
407	0.005	0.210	0.067	0.034	0.019	0.218	#13	0.074	Not Required	Pass
408	0.000	0.015	0.041	0.012	0.006	0.053	#21	Not Required	Not Required	Pass
409	0.012	0.073	0.096	0.006	0.006	0.155	#13	0.204	Not Required	Pass
410	0.005	0.343	0.093	0.035	0.023	0.428	#13	0.120	Not Required	Pass
411	0.000	0.015	0.041	0.012	0.006	0.053	#21	Not Required	Not Required	Pass
412	0.004	0.136	0.130	0.039	0.030	0.247	#13	0.035	Not Required	Pass
413	0.011	0.130	0.592	0.056	0.027	0.646	#21	0.190	Not Required	Pass
414	0.007	0.097	0.579	0.052	0.027	0.604	#21	0.286	Not Required	Pass
415	0.021	0.566	0.319	0.045	0.022	0.775	#21	0.601	Not Required	Pass
416	0.008	0.563	0.308	0.042	0.022	0.756	#21	0.601	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength

A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis
KL	Effective length
C_b	Buckling modification factor (from all load combinations)
L_b	Length between braced points
LST	Limited slenderness for tension
LSC	Limited slenderness for compression
LD	Limited deflection
P_n	Nominal axial strength (tension/comression)
M_n	Nominal flexural strength (about Z/Y axis)
V_n	Nominal shear strength (along Z/Y axis)
P	Design ratio in case of axial force
M_z	Design ratio in case of bending about Z axis
M_y	Design ratio in case of bending about Y axis
V_y	Design ratio in case of shear along Y axis
V_z	Design ratio in case of shear along Z axis
(P,M_z,M_y)	Design ratio in case of axial force and bending action
KL/r	Design ratio in case of section slenderness
δ	Design ratio in case of member deflection
OK	Capacity is provided
NG	Capacity is not provided

REFERENCES	CALCULATIONS	RESULTS

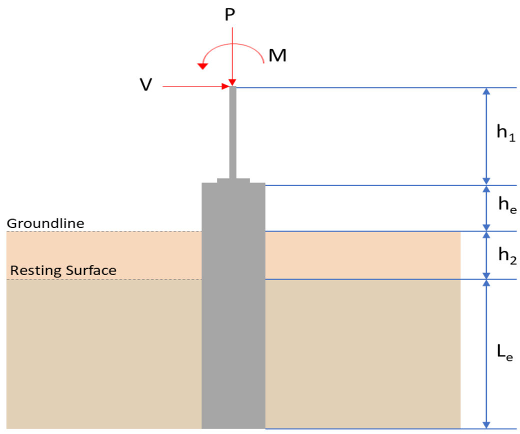
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \mathrm{in}$ - Pile width
$D = 48\ \mathrm{in}$ - Pile depth
$L = 7.5\ \mathrm{ft}$ - Total pile length
$h_1 = 0\ \mathrm{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \mathrm{ft}$ - Depth to resisting surface
$h_e = 0\ \mathrm{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.930	8.457
V_x (kip)	-2.912	-4.862
V_z (kip)	0.418	0.677
M_x (kipft)	1.753	2.812
M_z (kipft)	41.103	69.159

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.912\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.46369\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.103\ \mathrm{kipft}) + ((-2.912\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 6.5451\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 6.9183\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.418\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.066561\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.753\ \mathrm{kipft}) + ((0.418\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.27914\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 3.285\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.9183\ \mathrm{ft}), (3.285\ \mathrm{ft})]$$

$$L_{e,req} = 6.918\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 7.5\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.918\ \mathrm{ft})}{(7.5\ \mathrm{ft})}$$

$$Ratio = 0.9224$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(5.93\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.37063\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.37063\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.18531$$

Status: **PASS**
Ratio: **0.190**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.46369\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5451\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5451\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (6.5451\ \text{kipft/ft})) + (4 \times (-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.1635\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.5451\ \text{kipft/ft})) + (3 \times (-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft}))]^2}{(7.5\ \text{ft})^2 \times [(3 \times (6.5451\ \text{kipft/ft})) + (2 \times (-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft}))]}$$

$$p = 0.26075\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.5451\ \text{kipft/ft})) + ((-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft}))]}{(7.5\ \text{ft})^2}$$

$$s = 1.0253\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.1635\ \text{ft})}{2}$$

$$p_a = 0.38726\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.26075\ \mathrm{kip/ft^2}\right)}{\left(0.38726\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.67333$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$

$$p_s = 1.125\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.0253\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.9114$$

Status: **PASS**
Ratio: **0.910**

Considering z-direction:

$H_o = 0.066561\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.27914\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.27914\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.27914\ \mathrm{kipft/ft})) + (4 \times (0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3399\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.27914\ \mathrm{kipft/ft})) + (3 \times (0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^{\,2}}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.27914\ \mathrm{kipft/ft})) + (2 \times (0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$

$$p = 0.049634\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.27914\ \mathrm{kipft/ft})) + ((0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$

$$s = 0.1128\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3399\ \mathrm{ft})}{2}$$

$$p_a = 0.40049\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.049634\ \mathrm{kip/ft^2}\right)}{\left(0.40049\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.12393$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \text{psf/ft}) \times (7.5\ \text{ft})$$

$$p_s = 1.125\ \text{kip/ft}^2$$

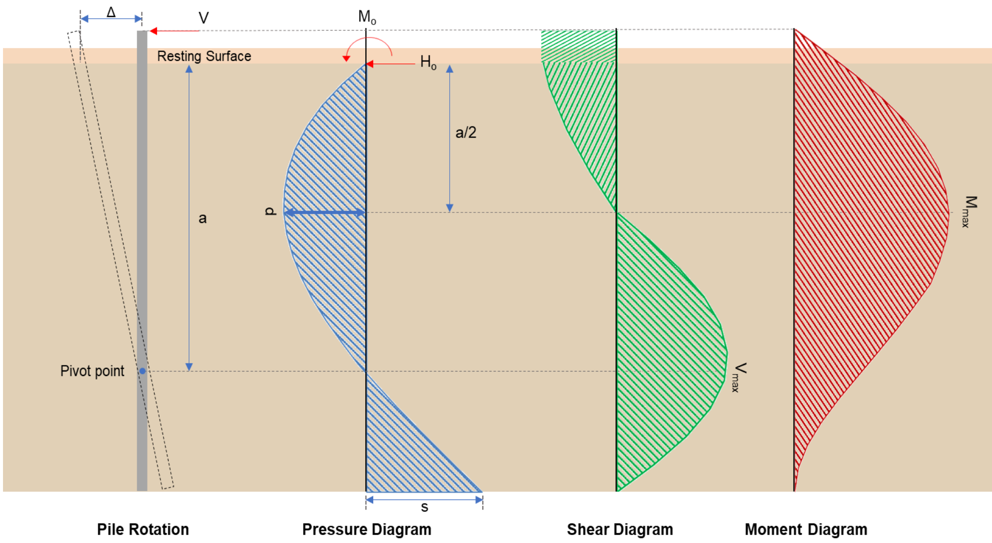
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.1128\ \text{kip/ft}^2\right)}{\left(1.125\ \text{kip/ft}^2\right)}$$

$$Ratio = 0.10027$$

Status: **PASS**
Ratio: **0.100**



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.862\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.7742\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(69.159\ \text{kipft}) + ((-4.862\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 11.013\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.013\ \text{kipft/ft})}{(-0.7742\ \text{kip/ft})}$$

$$E = 14.224\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.013\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.7742\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{}$$

$$a = \frac{}{(6 \times (11.013\ \mathrm{kipft/ft})) + (4 \times (-0.7742\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.1626\ \mathrm{ft}$$

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

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

$$V_{max} = ((-0.7742\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.224\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1626\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.224\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1626\ \mathrm{ft})}{(7.5\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 12.437\ \mathrm{kip}$$

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

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

$$M_{max} = ((-0.7742\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (7.5\ \mathrm{ft})) \times \left[\left(\frac{(14.224\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + \frac{(5.1626\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (14.224\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.1626\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.224\ \mathrm{ft})}{(7.5\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.1626\ \mathrm{ft})}{2 \times (7.5\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 44.526\ \mathrm{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.677\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = 0.1078\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.812\ \mathrm{kipft}) + ((0.677\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.44777\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.44777\ \mathrm{kipft/ft})}{(0.1078\ \mathrm{kip/ft})}$$

$$E = 4.1536\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.44777\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (0.1078\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.44777\ \mathrm{kipft/ft})) + (4 \times (0.1078\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$

$$a = 5.3414\ \mathrm{ft}$$

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

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

$$V_{max} = ((0.1078\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.1536\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.3414\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.1536\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.3414\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.70944\ \text{kip}$$

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

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

$$M_{max} = ((0.1078\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(4.1536\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.3414\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.1536\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.3414\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.1536\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.3414\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.3715\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,
$f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(8.457\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.315\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.315\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(8.457\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0031613$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 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

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.457 \text{ kip} \rightarrow 8457 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(8457 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.61 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.61 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.61 \text{ kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

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

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

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

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

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(737.28 \text{ kip}), (50.894 \text{ kip})\right]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\,\left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((119.61 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.83 \text{ kip}$$

Considering x-direction:

$V_{max} = 12.437 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(12.437\ \text{kip})}{(110.83\ \text{kip})}$$ $$Ratio = 0.11221$$	Status: **PASS** Ratio: **0.110**
	Considering z-direction: $V_{max} = 0.70944\ \text{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.70944\ \text{kip})}{(110.83\ \text{kip})}$$ $$Ratio = 0.0064012$$	Status: **PASS** Ratio: **0.010**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \text{in}) \times (48\ \text{in})^2}{6}$$ $$S_m = 18432\ \text{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f_c')} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f_{ck}'\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \text{ksi}) \times \left(18432\ \text{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \text{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \text{kipft}), (2121.6\ \text{kipft})]$$ $$\phi M_n = 249.6\ \text{kipft}$$ **Considering x-direction:** $M_{max} = 44.526\ \text{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(44.526\ \text{kipft})}{(249.6\ \text{kipft})}$$ $$Ratio = 0.17839$$	Status: **PASS** Ratio: **0.180**
	Considering z-direction: $M_{max} = 2.3715\ \text{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(2.3715 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0095013$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

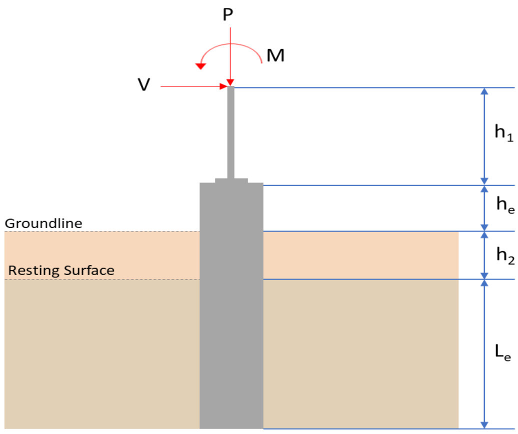
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48\ \text{in}$ - Pile width
$D = 48\ \text{in}$ - Pile depth
$L = 7.5\ \text{ft}$ - Total pile length
$h_1 = 0\ \text{ft}$ - Lateral load height from the top of the pile,
$h_2 = 0\ \text{ft}$ - Depth to resisting surface
$h_e = 0\ \text{ft}$ - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	5.930	8.457
V_x (kip)	-2.912	-4.862
V_z (kip)	-0.418	-0.677
M_x (kipft)	-1.754	-2.814
M_z (kipft)	41.103	69.160

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-2.912\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.46369\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(41.103\ \text{kipft}) + ((-2.912\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 6.5451\ \text{kipft/ft}$$

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:
$L_{e,x} = 6.9183\ \text{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.418\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.066561\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.754\ \text{kipft}) + ((-0.418\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.2793\ \text{kipft/ft}$$

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:
$L_{e,z} = 2.3491\ \text{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(6.9183\ \text{ft}), (2.3491\ \text{ft})]$$

$$L_{e,req} = 6.918\ \text{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (7.5\ \text{ft}) - (0\ \text{ft}) - (0\ \text{ft})$$

$$L_e = 7.5\ \text{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(6.918\ \text{ft})}{(7.5\ \text{ft})}$$

$$Ratio = 0.9224$$

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

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

$$q = \frac{(5.93\ \text{kip})}{(16\ \text{ft}^2)}$$

$$q = 0.37063\ \text{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.37063\ \text{kip/ft}^2\right)}{(2000\ \text{psf})}$$

$$Ratio = 0.18531$$

Status: **PASS**
Ratio: **0.190**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(7.5\ \text{ft})}{(48\ \text{in})}$$

$$L/D = 1.875$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.46369\ \text{kip/ft}$ - Lateral force per length of pile,
$M_o = 6.5451\ \text{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.5451\ \text{kipft/ft}) \times (7.5\ \text{ft})) + \left(3 \times (-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft})^2\right)}{(6 \times (6.5451\ \text{kipft/ft})) + (4 \times (-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft}))}$$

$$a = 5.1635\ \text{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (6.5451\ \text{kipft/ft})) + (3 \times (-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft}))]^2}{(7.5\ \text{ft})^2 \times [(3 \times (6.5451\ \text{kipft/ft})) + (2 \times (-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft}))]}$$

$$p = 0.26075\ \text{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (6.5451\ \text{kipft/ft})) + ((-0.46369\ \text{kip/ft}) \times (7.5\ \text{ft}))]}{(7.5\ \text{ft})^2}$$

$$s = 1.0253\ \text{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \text{psf/ft}) \times \frac{(5.1635\ \text{ft})}{2}$$

$$p_a = 0.38726\ \text{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.26075\ \mathrm{kip/ft^2}\right)}{\left(0.38726\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.67333$$	Status: **PASS** Ratio: **0.670**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\, L_e$$ $$p_s = (150\ \mathrm{psf/ft}) \times (7.5\ \mathrm{ft})$$ $$p_s = 1.125\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.0253\ \mathrm{kip/ft^2}\right)}{\left(1.125\ \mathrm{kip/ft^2}\right)}$$ $$Ratio = 0.9114$$	Status: **PASS** Ratio: **0.910**
	Considering z-direction: $H_o = -0.066561\ \mathrm{kip/ft}$ - Lateral force per length of pile, $M_o = 0.2793\ \mathrm{kipft/ft}$ - Overturning moment per length of pile, a - Distance from resting surface to pivot point, $$a = \frac{(4\, M_o\, L_e) + \left(3\, H_o\, L_e^2\right)}{(6\, M_o) + (4\, H_o\, L_e)}$$ $$a = \frac{(4 \times (0.2793\ \mathrm{kipft/ft}) \times (7.5\ \mathrm{ft})) + \left(3 \times (-0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft})^2\right)}{(6 \times (0.2793\ \mathrm{kipft/ft})) + (4 \times (-0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))}$$ $$a = 5.3398\ \mathrm{ft}$$ p - Earth pressure against the pile at distance a/2 from resting surface, $$p = \frac{0.75\, [(4\, M_o) + (3\, H_o\, L_e)]^2}{L_e^2\, [(3\, M_o) + (2\, H_o\, L_e)]}$$ $$p = \frac{0.75 \times [(4 \times (0.2793\ \mathrm{kipft/ft})) + (3 \times (-0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]^2}{(7.5\ \mathrm{ft})^2 \times [(3 \times (0.2793\ \mathrm{kipft/ft})) + (2 \times (-0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}$$ $$p = -0.012021\ \mathrm{kip/ft^2}$$ s - Earth pressure against the pile at distance L_e, $$s = \frac{6\, [(2\, M_o) + (H_o\, L_e)]}{L_e^2}$$ $$s = \frac{6 \times [(2 \times (0.2793\ \mathrm{kipft/ft})) + ((-0.066561\ \mathrm{kip/ft}) \times (7.5\ \mathrm{ft}))]}{(7.5\ \mathrm{ft})^2}$$ $$s = 0.0063355\ \mathrm{kip/ft^2}$$ **Check lateral soil pressure capacity:** p_a - Allowable lateral soil pressure at depth a/2, $$p_a = R\, \frac{a}{2}$$ $$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.3398\ \mathrm{ft})}{2}$$ $$p_a = 0.40049\ \mathrm{kip/ft^2}$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(-0.012021\ \mathrm{kip/ft^2}\right)}{\left(0.40049\ \mathrm{kip/ft^2}\right)}$$	

$$Ratio = -0.030017$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150 \text{ psf/ft}) \times (7.5 \text{ ft})$$

$$p_s = 1.125 \text{ kip/ft}^2$$

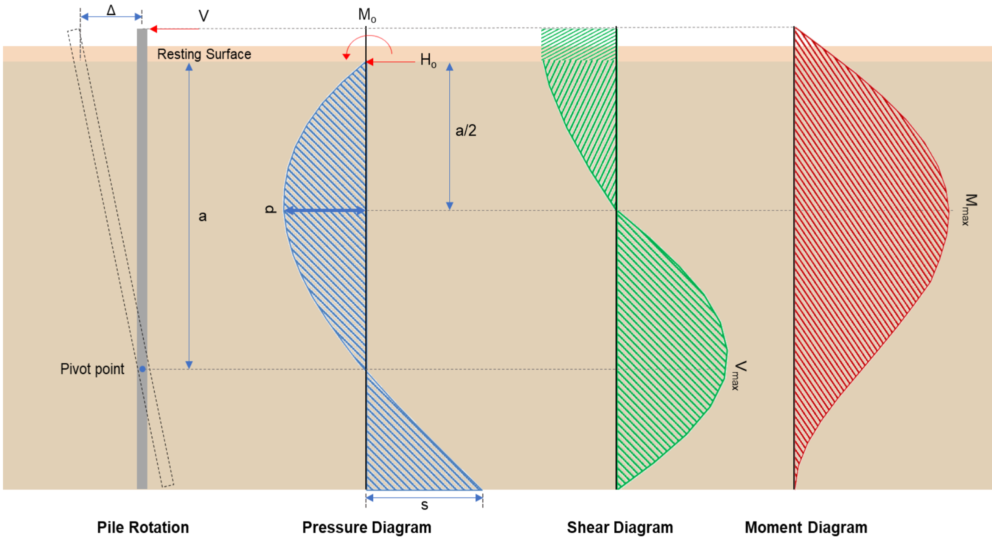
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0063355 \text{ kip/ft}^2\right)}{\left(1.125 \text{ kip/ft}^2\right)}$$

$$Ratio = 0.0056315$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.862 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.7742 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(69.16 \text{ kipft}) + ((-4.862 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 11.013 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(11.013 \text{ kipft/ft})}{(-0.7742 \text{ kip/ft})}$$

$$E = 14.225 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (11.013 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.7742 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (11.013 \text{ kipft/ft})) + (4 \times (-0.7742 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.1626 \text{ ft}$$

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

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

$$V_{max} = ((-0.7742 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.225 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.1626 \text{ ft})}{(7.5 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.225 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.1626 \text{ ft})}{(7.5 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 12.437 \text{ kip}$$

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

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

$$M_{max} = ((-0.7742 \text{ kip/ft}) \times (48 \text{ in}) \times (7.5 \text{ ft})) \times \left[\left(\frac{(14.225 \text{ ft})}{(7.5 \text{ ft})} + \frac{(5.1626 \text{ ft})}{2 \times (7.5 \text{ ft})}\right) - \left[\left(\frac{4 \times (14.225 \text{ ft})}{(7.5 \text{ ft})} + 3\right) \times \left(\frac{(5.1626 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.225 \text{ ft})}{(7.5 \text{ ft})} + 2\right) \times \left(\frac{(5.1626 \text{ ft})}{2 \times (7.5 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 44.527 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.677 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.1078 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(2.814 \text{ kipft}) + ((-0.677 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.44809 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.44809 \text{ kipft/ft})}{(-0.1078 \text{ kip/ft})}$$

$$E = 4.1566 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.44809 \text{ kipft/ft}) \times (7.5 \text{ ft})) + \left(3 \times (-0.1078 \text{ kip/ft}) \times (7.5 \text{ ft})^2\right)}{(6 \times (0.44809 \text{ kipft/ft})) + (4 \times (-0.1078 \text{ kip/ft}) \times (7.5 \text{ ft}))}$$

$$a = 5.3413 \text{ ft}$$

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

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

$$V_{max} = ((-0.1078\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (4.1566\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.3413\ \text{ft})}{(7.5\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (4.1566\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.3413\ \text{ft})}{(7.5\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.70974\ \text{kip}$$

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

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

$$M_{max} = ((-0.1078\ \text{kip/ft}) \times (48\ \text{in}) \times (7.5\ \text{ft})) \times \left[\left(\frac{(4.1566\ \text{ft})}{(7.5\ \text{ft})} + \frac{(5.3413\ \text{ft})}{2 \times (7.5\ \text{ft})}\right) - \left[\left(\frac{4 \times (4.1566\ \text{ft})}{(7.5\ \text{ft})} + 3\right) \times \left(\frac{(5.3413\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (4.1566\ \text{ft})}{(7.5\ \text{ft})} + 2\right) \times \left(\frac{(5.3413\ \text{ft})}{2 \times (7.5\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 2.3726\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,
$f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(8.457\ \text{kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5\ \text{ksi}) \times (2304\ \text{in}^2))}{(60\ \text{ksi}) - (0.85 \times (2.5\ \text{ksi}))}, (0.08 \times (2304\ \text{in}^2))\right]$$

$$A_{st,required} = -84.315\ \text{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.315\ \text{in}^2), (0.0018 \times (2304\ \text{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[(2304\text{ in}^2) - (4.2951\text{ in}^2)\right]\right) + \left((60\text{ ksi}) \times (4.2951\text{ in}^2)\right)\right]$$

$$\phi P_N = 2675.2\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(8.457\text{ kip})}{(2675.2\text{ kip})}$$

$$Ratio = 0.0031613$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 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

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\text{ psi})} \times (48\text{ in}) \times (38.4\text{ in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 8.457 \text{ kip} \rightarrow 8457 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(8457 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.61 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.61 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.61 \text{ kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

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

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

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

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

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(737.28 \text{ kip}), (50.894 \text{ kip})\right]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.61 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.83 \text{ kip}$$

Considering x-direction:

$V_{max} = 12.437 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(12.437\ \mathrm{kip})}{(110.83\ \mathrm{kip})}$$

$$Ratio = 0.11222$$

Status: **PASS**
Ratio: **0.110**

Considering z-direction:

$V_{max} = 0.70974\ \mathrm{kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.70974\ \mathrm{kip})}{(110.83\ \mathrm{kip})}$$

$$Ratio = 0.0064039$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b\, D^2}{6}$$

$$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$

$$S_m = 18432\ \mathrm{in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$

$$\phi M_{n,1} = 249.600kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$

$$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$

$$\phi M_n = 249.6\ \mathrm{kipft}$$

Considering x-direction:

$M_{max} = 44.527\ \mathrm{kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(44.527\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$

$$Ratio = 0.17839$$

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

Considering z-direction:

$M_{max} = 2.3726\ \mathrm{kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(2.3726 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.0095058$$	Status: **PASS** Ratio: **0.010**

REFERENCES	CALCULATIONS	RESULTS

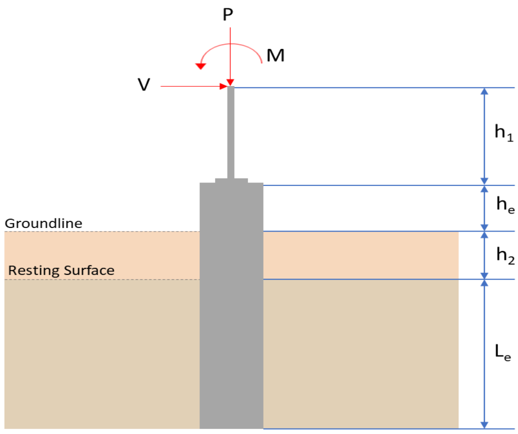
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 8.25$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.878	11.283
V_x (kip)	-3.941	-6.568
V_z (kip)	-0.025	-0.043
M_x (kipft)	-0.103	-0.166
M_z (kipft)	56.176	95.313

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.941\text{ kip})}{1.57 \times (48\text{ in})}$$

$$H_o = -0.62755\text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(56.176\ \mathrm{kipft}) + ((-3.941\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 8.9452\ \mathrm{kipft/ft}$$

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:
$L_{e,x} = 7.5546\ \mathrm{ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.025\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -0.0039809\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.103\ \mathrm{kipft}) + ((-0.025\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 0.016401\ \mathrm{kipft/ft}$$

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:
$L_{e,z} = 1.0221\ \mathrm{ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.5546\ \mathrm{ft}), (1.0221\ \mathrm{ft})]$$

$$L_{e,req} = 7.555\ \mathrm{ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25\ \mathrm{ft}) - (0\ \mathrm{ft}) - (0\ \mathrm{ft})$$

$$L_e = 8.25\ \mathrm{ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.555\ \mathrm{ft})}{(8.25\ \mathrm{ft})}$$

$$Ratio = 0.91576$$

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

End-bearing Capacity (ASD)

A - Pile cross-section area

$$A = b\,D$$

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

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

q - End-bearing pressure

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

$$q = \frac{(7.878\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.49238\ \mathrm{kip/ft}^2$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.49238\ \mathrm{kip/ft}^2)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.24619$$

Status: **PASS**
Ratio: **0.250**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.62755\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9452\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.9452\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (8.9452\ \mathrm{kipft/ft})) + (4 \times (-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.6914\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.9452\ \mathrm{kipft/ft})) + (3 \times (-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^2}{(8.25\ \mathrm{ft})^2 \times [(3 \times (8.9452\ \mathrm{kipft/ft})) + (2 \times (-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.27414\ \mathrm{kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.9452\ \mathrm{kipft/ft})) + ((-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 1.1207\ \mathrm{kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.6914\ \mathrm{ft})}{2}$$

$$p_a = 0.42686\ \mathrm{kip/ft}^2$$

$Ratio$ - Lateral soil capacity

	$$Ratio = \frac{p}{p_a}$$ $$Ratio = \frac{\left(0.27414 \text{ kip/ft}^2\right)}{\left(0.42686 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.64224$$	Status: **PASS** Ratio: **0.640**
	p_s - Allowable lateral soil pressure at depth L_e, $$p_s = R\,L_e$$ $$p_s = (150 \text{ psf/ft}) \times (8.25 \text{ ft})$$ $$p_s = 1.2375 \text{ kip/ft}^2$$ $Ratio$ - Lateral soil capacity $$Ratio = \frac{s}{p_s}$$ $$Ratio = \frac{\left(1.1207 \text{ kip/ft}^2\right)}{\left(1.2375 \text{ kip/ft}^2\right)}$$ $$Ratio = 0.90563$$	Status: **PASS** Ratio: **0.910**

Considering z-direction:

$H_o = -0.0039809 \text{ kip/ft}$ - Lateral force per length of pile,
$M_o = 0.016401 \text{ kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.016401 \text{ kipft/ft}) \times (8.25 \text{ ft})) + \left(3 \times (-0.0039809 \text{ kip/ft}) \times (8.25 \text{ ft})^2\right)}{(6 \times (0.016401 \text{ kipft/ft})) + (4 \times (-0.0039809 \text{ kip/ft}) \times (8.25 \text{ ft}))}$$

$$a = 5.8931 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.016401 \text{ kipft/ft})) + (3 \times (-0.0039809 \text{ kip/ft}) \times (8.25 \text{ ft}))]^2}{(8.25 \text{ ft})^2 \times [(3 \times (0.016401 \text{ kipft/ft})) + (2 \times (-0.0039809 \text{ kip/ft}) \times (8.25 \text{ ft}))]}$$

$$p = -0.00072468 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.016401 \text{ kipft/ft})) + ((-0.0039809 \text{ kip/ft}) \times (8.25 \text{ ft}))]}{(8.25 \text{ ft})^2}$$

$$s = -3.5093 \times 10^{-6} \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(5.8931 \text{ ft})}{2}$$

$$p_a = 0.44198 \text{ kip/ft}^2$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-0.00072468 \text{ kip/ft}^2\right)}{\left(0.44198 \text{ kip/ft}^2\right)}$$

$$Ratio = -0.0016396$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

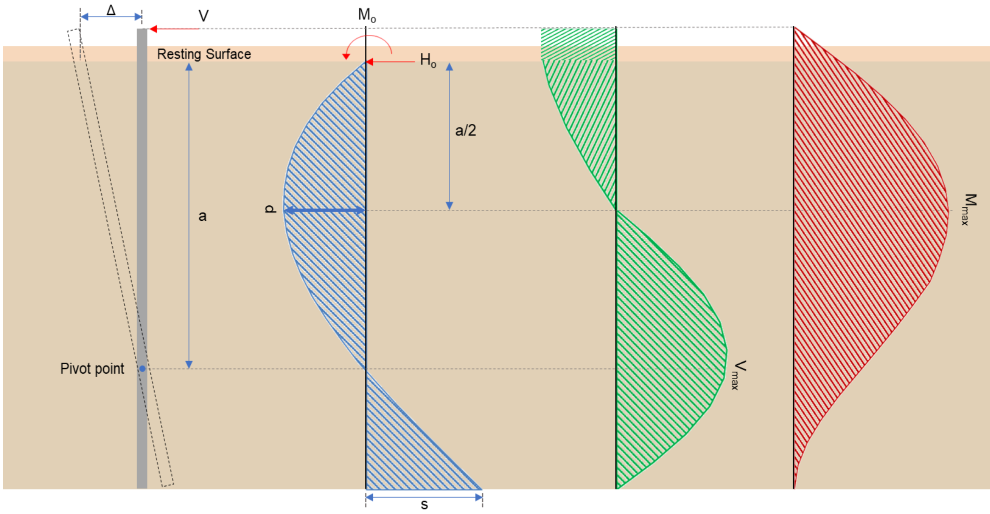
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(-3.5093{\times}10^{-6}\ \mathrm{kip/ft^2}\right)}{(1.2375\ \mathrm{kip/ft^2})}$$

$$Ratio = -2.8358{\times}10^{-6}$$

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



Pile Rotation | Pressure Diagram | Shear Diagram | Moment Diagram

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.568\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.0459\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(95.313\ \mathrm{kipft}) + ((-6.568\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.177\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.177\ \mathrm{kipft/ft})}{(-1.0459\ \mathrm{kip/ft})}$$

$$E = 14.512\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.177\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.0459\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{\ldots}$$

$$a = \frac{}{(6 \times (15.177\ \text{kipft/ft})) + (4 \times (-1.0459\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.689\ \text{ft}$$

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

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

$$V_{max} = ((-1.0459\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.512\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.689\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.512\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.689\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.781\ \text{kip}$$

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

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

$$M_{max} = ((-1.0459\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(14.512\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.689\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.512\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.689\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.512\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.689\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 61.961\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.043\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -0.0068471\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.166\ \text{kipft}) + ((-0.043\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.026433\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.026433\ \text{kipft/ft})}{(-0.0068471\ \text{kip/ft})}$$

$$E = 3.8605\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.026433\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-0.0068471\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.026433\ \text{kipft/ft})) + (4 \times (-0.0068471\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.904\ \text{ft}$$

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

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

$$V_{max} = ((-0.0068471 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.8605 \text{ ft})}{(8.25 \text{ ft})} + 3\right) \times \left(\frac{(5.904 \text{ ft})}{(8.25 \text{ ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.8605 \text{ ft})}{(8.25 \text{ ft})} + 2\right) \times \left(\frac{(5.904 \text{ ft})}{(8.25 \text{ ft})}\right)^3\right]\right]$$

$$V_{max} = 0.040945 \text{ kip}$$

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

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

$$M_{max} = ((-0.0068471 \text{ kip/ft}) \times (48 \text{ in}) \times (8.25 \text{ ft})) \times \left[\left(\frac{(3.8605 \text{ ft})}{(8.25 \text{ ft})} + \frac{(5.904 \text{ ft})}{2 \times (8.25 \text{ ft})}\right) - \left[\left(\frac{4 \times (3.8605 \text{ ft})}{(8.25 \text{ ft})} + 3\right) \times \left(\frac{(5.904 \text{ ft})}{2 \times (8.25 \text{ ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.8605 \text{ ft})}{(8.25 \text{ ft})} + 2\right) \times \left(\frac{(5.904 \text{ ft})}{2 \times (8.25 \text{ ft})}\right)^4\right]\right]$$

$$M_{max} = 0.14876 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5 \text{ ksi}$ - Concrete strength,
$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.283 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2))\right]$$

$$A_{st,required} = -84.221 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.221 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.283\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0042177$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 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

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.283 \text{ kip} \rightarrow 11283 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11283 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 120 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (120 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 120 \text{ kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

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

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

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

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

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(737.28 \text{ kip}), (50.894 \text{ kip})\right]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi\,\left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((120 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.07 \text{ kip}$$

Considering x-direction:

$V_{max} = 15.781 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(15.781\ \mathrm{kip})}{(111.07\ \mathrm{kip})}$$ $$Ratio = 0.14207$$	Status: **PASS** Ratio: **0.140**
	Considering z-direction: $V_{max} = 0.040945\ \mathrm{kip}$ - Maximum shear force in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{V_{max}}{\phi V_n}$$ $$Ratio = \frac{(0.040945\ \mathrm{kip})}{(111.07\ \mathrm{kip})}$$ $$Ratio = 0.00036862$$	Status: **PASS** Ratio: **0.000**
14.5.2.1b	**Flexural Strength (ACI 318-19, LRFD)** S_m - Section modulus $$S_m = \frac{b\,D^2}{6}$$ $$S_m = \frac{(48\ \mathrm{in}) \times (48\ \mathrm{in})^2}{6}$$ $$S_m = 18432\ \mathrm{in}^3$$ $\lambda = 1$ - Concrete modification factor (Normal concrete), Allowable flexural strength: M_n shall be the lesser of: $\phi M_{n,1}$ $$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{(f'_c)} \times S_m$$ $$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$ $$\phi M_{n,1} = 249.600kipft$$ $\phi M_{n,2}$ $$\phi M_{n,2} = \phi\ 0.85\ f'_{ck}\ S_m$$ $$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5\ \mathrm{ksi}) \times \left(18432\ \mathrm{in}^3\right)$$ $$\phi M_{n,2} = 2121.6\ \mathrm{kipft}$$ Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6\ \mathrm{kipft}), (2121.6\ \mathrm{kipft})]$$ $$\phi M_n = 249.6\ \mathrm{kipft}$$ **Considering x-direction:** $M_{max} = 61.961\ \mathrm{kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(61.961\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.24824$$	Status: **PASS** Ratio: **0.250**
	Considering z-direction: $M_{max} = 0.14876\ \mathrm{kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$	

	$$Ratio = \frac{(0.14876\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.000596$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

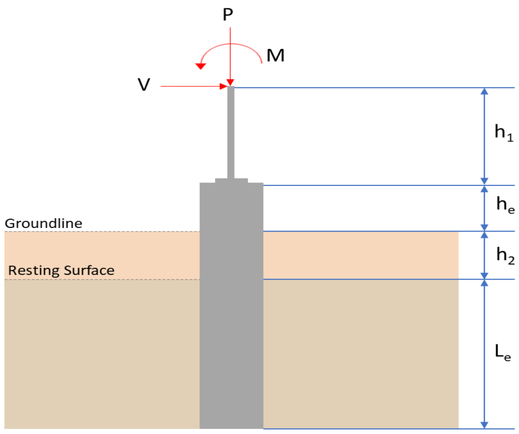
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 8.25$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.784	11.147
V_x (kip)	-3.914	-6.526
V_z (kip)	0.000	0.000
M_x (kipft)	0.000	-0.001
M_z (kipft)	56.362	95.683

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.914 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.62325 \text{ kip/ft}$$

	M_o - Moment per length of pile, $$M_o = \frac{M_z + (V_x\, H)}{1.57\, D}$$ $$M_o = \frac{(56.362 \text{ kipft}) + ((-3.914 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$ $$M_o = 8.9748 \text{ kipft/ft}$$ 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: $L_{e,x} = 7.5753 \text{ ft}$ - Required depth in x-direction, **Considering z-direction:** $L_{e,z} = 0 \text{ ft}$ - Required depth in z-direction, **Minimum embedded depth required:** $L_{e,req}$ - Depth of pile required, $$L_{e,req} = MAX[L_{e,x}, L_{e,z}]$$ $$L_{e,req} = MAX[(7.5753 \text{ ft}), (0 \text{ ft})]$$ $$L_{e,req} = 7.575 \text{ ft}$$ L_e - Actual embedded length of pile, $$L_e = L - h_e - h_2$$ $$L_e = (8.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$ $$L_e = 8.25 \text{ ft}$$ $Ratio$ - Embedded depth $$Ratio = \frac{L_{e,req}}{L_e}$$ $$Ratio = \frac{(7.575 \text{ ft})}{(8.25 \text{ ft})}$$ $$Ratio = 0.91818$$	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 $$q = \frac{P_v}{A}$$ $$q = \frac{(7.784 \text{ kip})}{(16 \text{ ft}^2)}$$ $$q = 0.4865 \text{ kip/ft}^2$$ **Check bearing capacity ratio:** $Ratio$ - Capacity $$Ratio = \frac{q}{q_a}$$ $$Ratio = \frac{(0.4865 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$ $$Ratio = 0.24325$$	Status: **PASS** Ratio: **0.240**
Czerniak	**Lateral Soil Pressure (ASD):** L/D - Length to least lateral dimension ratio,	

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

$$L/D = \frac{(8.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.62325\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9748\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.9748\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.62325\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (8.9748\ \mathrm{kipft/ft})) + (4 \times (-0.62325\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.69\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.9748\ \mathrm{kipft/ft})) + (3 \times (-0.62325\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\ 2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (8.9748\ \mathrm{kipft/ft})) + (2 \times (-0.62325\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.27757\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.9748\ \mathrm{kipft/ft})) + ((-0.62325\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 1.1291\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.69\ \mathrm{ft})}{2}$$

$$p_a = 0.42675\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27757\ \mathrm{kip/ft^2}\right)}{\left(0.42675\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.65044$$

Status: **PASS**
Ratio: **0.650**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\, L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

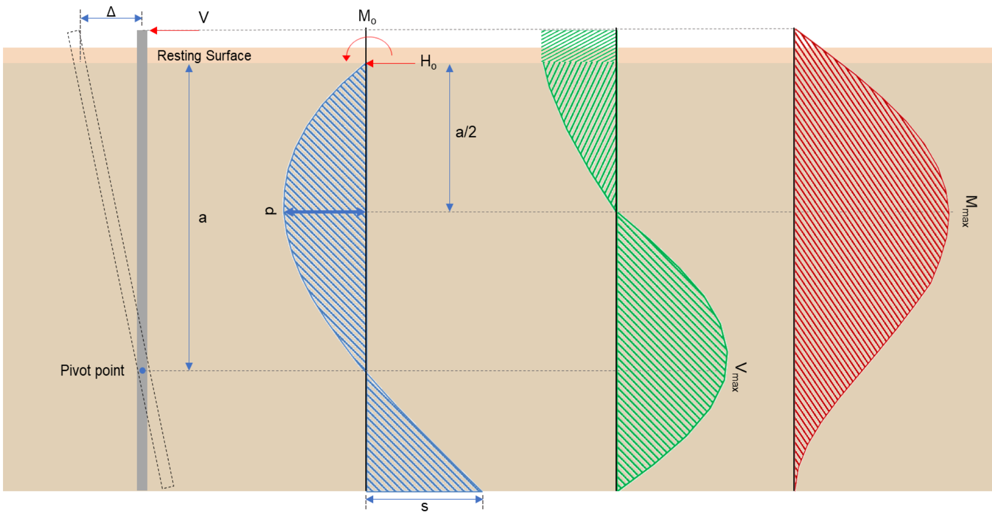
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1291\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.91238$$

Status: **PASS**
Ratio: **0.910**



Pile Rotation **Pressure Diagram** **Shear Diagram** **Moment Diagram**

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.526\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = -1.0392\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(95.683\ \text{kipft}) + ((-6.526\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 15.236\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.236\ \text{kipft/ft})}{(-1.0392\ \text{kip/ft})}$$

$$E = 14.662\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.236\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (-1.0392\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (15.236\ \text{kipft/ft})) + (4 \times (-1.0392\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.6875\ \text{ft}$$

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

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

$$V_{max} = ((-1.0392\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.662\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6875\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.662\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6875\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.814\ \text{kip}$$

$$V_{max} = 15.814\ \text{kip}$$

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

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

$$M_{max} = ((-1.0392\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(14.662\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.6875\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.662\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.6875\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.662\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.6875\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 62.117\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.001\ \text{kipft}) + ((0\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.00015924\ \text{kipft/ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.00015924\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (0\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.00015924\ \text{kipft/ft})) + (4 \times (0\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.5\ \text{ft}$$

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

$$V_{max} = 12 \left(\frac{M_o\, b}{L_e}\right) \left(\frac{a}{L_e} - 1\right) \left(\frac{a}{L_e}\right)^2$$

$$V_{max} = 12 \times \left(\frac{(0.00015924\ \text{kipft/ft}) \times (48\ \text{in})}{(8.25\ \text{ft})}\right) \times \left(\frac{(5.5\ \text{ft})}{(8.25\ \text{ft})} - 1\right) \times \left(\frac{(5.5\ \text{ft})}{(8.25\ \text{ft})}\right)^2$$

$$V_{max} = 0.00013725\ \text{kip}$$

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

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

$$M_{max} = ((0.00015924\ \text{kipft/ft}) \times (48\ \text{in})) \times \left[1 - \left(4 \times \frac{(5.5\ \text{ft})}{2 \times (8.25\ \text{ft})}^3\right) + \left(3 \times \frac{(5.5\ \text{ft})}{2 \times (8.25\ \text{ft})}^4\right)\right]$$

$$M_{max} = 0.00056617\ \text{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \text{ksi}$ - Concrete strength,
$f_{yk} = 60\ \text{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 — $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304\ \text{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

22.4.2.2, 10.6.1.1 — $A_{st,required}$

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

$$A_{st,required} = Min\left[\frac{\frac{(11.147\text{ kip})}{(0.65)\times(0.8)} - \left(0.85 \times (2.5\text{ ksi}) \times \left(2304\text{ in}^2\right)\right)}{(60\text{ ksi}) - (0.85 \times (2.5\text{ ksi}))}, \left(0.08 \times \left(2304\text{ in}^2\right)\right)\right]$$

$$A_{st,required} = -84.226\text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[\left(-84.226\text{ in}^2\right), \left(0.0018 \times \left(2304\text{ in}^2\right)\right)\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

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

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\text{ ksi}) \times \left[\left(2304\text{ in}^2\right) - \left(4.2951\text{ in}^2\right)\right]\right) + \left((60\text{ ksi}) \times \left(4.2951\text{ in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\text{ kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.147 \text{ kip})}{(2675.2 \text{ kip})}$$

$$Ratio = 0.0041668$$

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

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 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

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 11.147 \text{ kip} \rightarrow 11147 \text{ lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi})} + \frac{(11147 \text{ lbf})}{6 \times (2304 \text{ in}^2)}\right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.97 \text{ kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21 \text{ kip}), (119.97 \text{ kip}), (348.89 \text{ kip})\right]$$

$$V_c = 119.97 \text{ kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{s,a} = 737.28 \text{ kip}$$

A_v - Ties rebar area,

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

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

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

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

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

$$V_{s,b} = \frac{2 \times \left(0.11045 \text{ in}^2\right) \times (60 \text{ ksi}) \times (38.4 \text{ in})}{(10 \text{ in})}$$

$$V_{s,b} = 50.894 \text{ kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(737.28 \text{ kip}), (50.894 \text{ kip})\right]$$

$$V_s = 50.894 \text{ kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

$$\phi V_n = \phi \, \left(V_c + V_s\right)$$

$$\phi V_n = (0.65) \times ((119.97 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.06 \text{ kip}$$

Considering x-direction:

$V_{max} = 15.814 \text{ kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.814 \text{ kip})}{(111.06 \text{ kip})}$$

$$Ratio = 0.14239$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b \, D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5 ksi)} \times 18432.001 in^3$$

$$\phi M_{n,1} = 249.600 kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

	Therefore, ϕM_n - Allowable flexural strength, $$\phi M_n = MIN[\phi M_{n,1}, \phi M_{n,2}]$$ $$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$ $$\phi M_n = 249.6 \text{ kipft}$$ **Considering x-direction:** $M_{max} = 62.117 \text{ kipft}$ - Maximum moment in the x-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(62.117 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 0.24887$$	Status: **PASS** Ratio: **0.250**
	Considering z-direction: $M_{max} = 0.00056617 \text{ kipft}$ - Maximum moment in the z-direction, $Ratio$ - Capacity $$Ratio = \frac{M_{max}}{\phi M_n}$$ $$Ratio = \frac{(0.00056617 \text{ kipft})}{(249.6 \text{ kipft})}$$ $$Ratio = 2.2683 \times 10^{-6}$$	Status: **PASS** Ratio: **0.000**

REFERENCES	CALCULATIONS	RESULTS

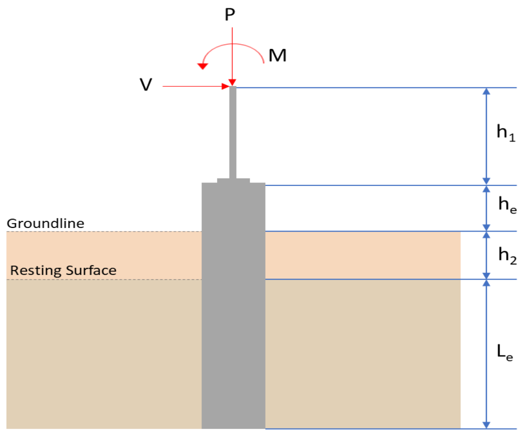
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular
$b = 48$ in - Pile width
$D = 48$ in - Pile depth
$L = 8.25$ ft - Total pile length
$h_1 = 0$ ft - Lateral load height from the top of the pile,
$h_2 = 0$ ft - Depth to resisting surface
$h_e = 0$ ft - Length of pile above the ground

Tabulation of Soil Parameters

Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000

Tabulation of Loads

Load Component	ASD	LRFD
P (kip)	7.878	11.283
V_x (kip)	-3.941	-6.568
V_z (kip)	0.025	0.043
M_x (kipft)	0.102	0.167
M_z (kipft)	56.176	95.313

Material Properties

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

Required depth to resist lateral loads (ASD)

H - Point of application of the lateral load

$$H = h_1 + h_2 + h_e$$

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

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

Considering x-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.941 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.62755 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(56.176 \text{ kipft}) + ((-3.941 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 8.9452 \text{ kipft/ft}$$

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:
$L_{e,x} = 7.5546 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.025 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0039809 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.102 \text{ kipft}) + ((0.025 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.016242 \text{ kipft/ft}$$

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:
$L_{e,z} = 1.164 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = MAX[(7.5546 \text{ ft}), (1.164 \text{ ft})]$$

$$L_{e,req} = 7.555 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (8.25 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 8.25 \text{ ft}$$

$Ratio$ - Embedded depth

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

$$Ratio = \frac{(7.555 \text{ ft})}{(8.25 \text{ ft})}$$

$$Ratio = 0.91576$$

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

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

$$q = \frac{(7.878\ \mathrm{kip})}{(16\ \mathrm{ft}^2)}$$

$$q = 0.49238\ \mathrm{kip/ft^2}$$

Check bearing capacity ratio:

$Ratio$ - Capacity

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

$$Ratio = \frac{\left(0.49238\ \mathrm{kip/ft^2}\right)}{(2000\ \mathrm{psf})}$$

$$Ratio = 0.24619$$

Status: **PASS**
Ratio: **0.250**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(8.25\ \mathrm{ft})}{(48\ \mathrm{in})}$$

$$L/D = 2.0625$$

Since L/D $\leq$ 10,

Pile is short.

Considering x-direction:

$H_o = -0.62755\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 8.9452\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (8.9452\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (8.9452\ \mathrm{kipft/ft})) + (4 \times (-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.6914\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (8.9452\ \mathrm{kipft/ft})) + (3 \times (-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\ 2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (8.9452\ \mathrm{kipft/ft})) + (2 \times (-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.27414\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (8.9452\ \mathrm{kipft/ft})) + ((-0.62755\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 1.1207\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.6914\ \mathrm{ft})}{2}$$

$$p_a = 0.42686\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.27414\ \mathrm{kip/ft^2}\right)}{\left(0.42686\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.64224$$

Status: **PASS**
Ratio: **0.640**

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(1.1207\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.90563$$

Status: **PASS**
Ratio: **0.910**

Considering z-direction:

$H_o = 0.0039809\ \mathrm{kip/ft}$ - Lateral force per length of pile,
$M_o = 0.016242\ \mathrm{kipft/ft}$ - Overturning moment per length of pile,
a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.016242\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (0.0039809\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{(6 \times (0.016242\ \mathrm{kipft/ft})) + (4 \times (0.0039809\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))}$$

$$a = 5.8947\ \mathrm{ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.016242\ \mathrm{kipft/ft})) + (3 \times (0.0039809\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]^{\,2}}{(8.25\ \mathrm{ft})^2 \times [(3 \times (0.016242\ \mathrm{kipft/ft})) + (2 \times (0.0039809\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}$$

$$p = 0.0025745\ \mathrm{kip/ft^2}$$

s - Earth pressure against the pile at distance L_e,

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

$$s = \frac{6 \times [(2 \times (0.016242\ \mathrm{kipft/ft})) + ((0.0039809\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft}))]}{(8.25\ \mathrm{ft})^2}$$

$$s = 0.0057588\ \mathrm{kip/ft^2}$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150\ \mathrm{psf/ft}) \times \frac{(5.8947\ \mathrm{ft})}{2}$$

$$p_a = 0.4421\ \mathrm{kip/ft^2}$$

$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0025745\ \mathrm{kip/ft^2}\right)}{\left(0.4421\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0058234$$

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

p_s - Allowable lateral soil pressure at depth L_e,

$$p_s = R\,L_e$$

$$p_s = (150\ \mathrm{psf/ft}) \times (8.25\ \mathrm{ft})$$

$$p_s = 1.2375\ \mathrm{kip/ft^2}$$

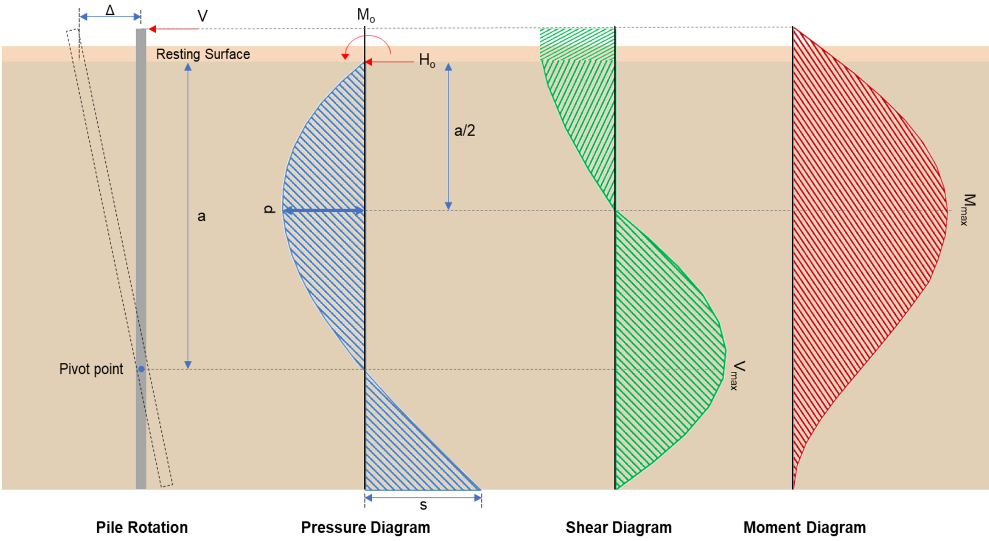
$Ratio$ - Lateral soil capacity

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

$$Ratio = \frac{\left(0.0057588\ \mathrm{kip/ft^2}\right)}{\left(1.2375\ \mathrm{kip/ft^2}\right)}$$

$$Ratio = 0.0046536$$

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-6.568\ \mathrm{kip})}{1.57 \times (48\ \mathrm{in})}$$

$$H_o = -1.0459\ \mathrm{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(95.313\ \mathrm{kipft}) + ((-6.568\ \mathrm{kip}) \times (0\ \mathrm{ft}))}{1.57 \times (48\ \mathrm{in})}$$

$$M_o = 15.177\ \mathrm{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(15.177\ \mathrm{kipft/ft})}{(-1.0459\ \mathrm{kip/ft})}$$

$$E = 14.512\ \mathrm{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (15.177\ \mathrm{kipft/ft}) \times (8.25\ \mathrm{ft})) + \left(3 \times (-1.0459\ \mathrm{kip/ft}) \times (8.25\ \mathrm{ft})^2\right)}{}$$

$$a = \frac{\ldots}{(6 \times (15.177\ \text{kipft/ft})) + (4 \times (-1.0459\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.689\ \text{ft}$$

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

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

$$V_{max} = ((-1.0459\ \text{kip/ft}) \times (48\ \text{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (14.512\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.689\ \text{ft})}{(8.25\ \text{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (14.512\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.689\ \text{ft})}{(8.25\ \text{ft})}\right)^3\right]\right]$$

$$V_{max} = 15.781\ \text{kip}$$

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

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

$$M_{max} = ((-1.0459\ \text{kip/ft}) \times (48\ \text{in}) \times (8.25\ \text{ft})) \times \left[\left(\frac{(14.512\ \text{ft})}{(8.25\ \text{ft})} + \frac{(5.689\ \text{ft})}{2 \times (8.25\ \text{ft})}\right) - \left[\left(\frac{4 \times (14.512\ \text{ft})}{(8.25\ \text{ft})} + 3\right) \times \left(\frac{(5.689\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^3\right] + \left[\left(\frac{3 \times (14.512\ \text{ft})}{(8.25\ \text{ft})} + 2\right) \times \left(\frac{(5.689\ \text{ft})}{2 \times (8.25\ \text{ft})}\right)^4\right]\right]$$

$$M_{max} = 61.961\ \text{kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.043\ \text{kip})}{1.57 \times (48\ \text{in})}$$

$$H_o = 0.0068471\ \text{kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.167\ \text{kipft}) + ((0.043\ \text{kip}) \times (0\ \text{ft}))}{1.57 \times (48\ \text{in})}$$

$$M_o = 0.026592\ \text{kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.026592\ \text{kipft/ft})}{(0.0068471\ \text{kip/ft})}$$

$$E = 3.8837\ \text{ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.026592\ \text{kipft/ft}) \times (8.25\ \text{ft})) + \left(3 \times (0.0068471\ \text{kip/ft}) \times (8.25\ \text{ft})^2\right)}{(6 \times (0.026592\ \text{kipft/ft})) + (4 \times (0.0068471\ \text{kip/ft}) \times (8.25\ \text{ft}))}$$

$$a = 5.903\ \text{ft}$$

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

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

$$V_{max} = ((0.0068471\ \mathrm{kip/ft}) \times (48\ \mathrm{in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (3.8837\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.903\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^2\right] + \left[4 \times \left(\frac{3 \times (3.8837\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.903\ \mathrm{ft})}{(8.25\ \mathrm{ft})}\right)^3\right]\right]$$

$$V_{max} = 0.04108\ \mathrm{kip}$$

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

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

$$M_{max} = ((0.0068471\ \mathrm{kip/ft}) \times (48\ \mathrm{in}) \times (8.25\ \mathrm{ft})) \times \left[\left(\frac{(3.8837\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + \frac{(5.903\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right) - \left[\left(\frac{4 \times (3.8837\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 3\right) \times \left(\frac{(5.903\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^3\right] + \left[\left(\frac{3 \times (3.8837\ \mathrm{ft})}{(8.25\ \mathrm{ft})} + 2\right) \times \left(\frac{(5.903\ \mathrm{ft})}{2 \times (8.25\ \mathrm{ft})}\right)^4\right]\right]$$

$$M_{max} = 0.14932\ \mathrm{kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

$f'_{ck} = 2.5\ \mathrm{ksi}$ - Concrete strength,
$f_{yk} = 60\ \mathrm{ksi}$ - Longitudinal reinforcement strength,
$\phi = 0.65$ - Reduction factor for axial strength,
Table 22.4.2.1 $\alpha = 0.8$ - Alpha factor for axial strength,
$A_g = 2304\ \mathrm{in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

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

$$A_{st,required} = Min\left[\frac{\frac{(11.283\ \mathrm{kip})}{(0.65)\times(0.8)} - (0.85 \times (2.5\ \mathrm{ksi}) \times (2304\ \mathrm{in}^2))}{(60\ \mathrm{ksi}) - (0.85 \times (2.5\ \mathrm{ksi}))}, (0.08 \times (2304\ \mathrm{in}^2))\right]$$

$$A_{st,required} = -84.221\ \mathrm{in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = Max\left[(-84.221\ \mathrm{in}^2), (0.0018 \times (2304\ \mathrm{in}^2))\right]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

$Ratio$ - Capacity

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

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

$$Ratio = 0.96556$$

Status: PASS
Ratio: 0.970

25.2.3 s_{rebar} - Minimum spacing of reinforcement,

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

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

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

Ties:

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

25.7.2.1 s_{ties} - Maximum spacing of ties,

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

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

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

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

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

$$\phi P_N = (0.65) \times 0.80 \times \left[\left(0.85 \times (2.5\ \text{ksi}) \times \left[\left(2304\ \text{in}^2\right) - \left(4.2951\ \text{in}^2\right)\right]\right) + \left((60\ \text{ksi}) \times \left(4.2951\ \text{in}^2\right)\right)\right]$$

$$\phi P_N = 2675.2\ \text{kip}$$

$Ratio$ - Capacity

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

$$Ratio = \frac{(11.283\ \text{kip})}{(2675.2\ \text{kip})}$$

$$Ratio = 0.0042177$$

Status: PASS
Ratio: 0.000

Shear Strength (ACI 318-19, LRFD)

Parameters:

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

22.5.2.2 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

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

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

$$\lambda_s = 0.64282$$

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

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

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

$$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

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

The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5\ \text{ksi} \rightarrow 2500\ \text{psi}$, $P = 11.283\ \text{kip} \rightarrow 11283\ \text{lbf}$,

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

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500\ \text{psi})} + \frac{(11283\ \text{lbf})}{6 \times (2304\ \text{in}^2)}\right] \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{c,a} = 120\ \text{kip}$$

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

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = Min\left[(296.21\ \text{kip}), (120\ \text{kip}), (348.89\ \text{kip})\right]$$

$$V_c = 120\ \text{kip}$$

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

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

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

$$V_{s,a} = 8 \times \sqrt{(2500\ \text{psi})} \times (48\ \text{in}) \times (38.4\ \text{in})$$

$$V_{s,a} = 737.28\ \text{kip}$$

A_v - Ties rebar area,

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

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

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

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

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

$$V_{s,b} = \frac{2 \times \left(0.11045\ \text{in}^2\right) \times (60\ \text{ksi}) \times (38.4\ \text{in})}{(10\ \text{in})}$$

$$V_{s,b} = 50.894\ \text{kip}$$

V_s - Governing shear strength of steel

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

$$V_s = MIN\left[(737.28\ \text{kip}), (50.894\ \text{kip})\right]$$

$$V_s = 50.894\ \text{kip}$$

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((120\ \text{kip}) + (50.894\ \text{kip}))$$

$$\phi V_n = 111.07\ \text{kip}$$

Considering x-direction:

$V_{max} = 15.781\ \text{kip}$ - Maximum shear force in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(15.781 \text{ kip})}{(111.07 \text{ kip})}$$

$$Ratio = 0.14207$$

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

Considering z-direction:

$V_{max} = 0.04108 \text{ kip}$ - Maximum shear force in the z-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(0.04108 \text{ kip})}{(111.07 \text{ kip})}$$

$$Ratio = 0.00036984$$

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

Flexural Strength (ACI 318-19, LRFD)

S_m - Section modulus

$$S_m = \frac{b\,D^2}{6}$$

$$S_m = \frac{(48 \text{ in}) \times (48 \text{ in})^2}{6}$$

$$S_m = 18432 \text{ in}^3$$

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

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

$$\phi M_{n,1} = 0.65 \times 5 \times 1 \times \sqrt{(2.5ksi)} \times 18432.001in^3$$

$$\phi M_{n,1} = 249.600kipft$$

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

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

$$\phi M_{n,2} = (0.65) \times 0.85 \times (2.5 \text{ ksi}) \times \left(18432 \text{ in}^3\right)$$

$$\phi M_{n,2} = 2121.6 \text{ kipft}$$

Therefore,
ϕM_n - Allowable flexural strength,

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

$$\phi M_n = MIN[(249.6 \text{ kipft}), (2121.6 \text{ kipft})]$$

$$\phi M_n = 249.6 \text{ kipft}$$

Considering x-direction:

$M_{max} = 61.961 \text{ kipft}$ - Maximum moment in the x-direction,
$Ratio$ - Capacity

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

$$Ratio = \frac{(61.961 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.24824$$

Status: **PASS**
Ratio: **0.250**

Considering z-direction:

$M_{max} = 0.14932 \text{ kipft}$ - Maximum moment in the z-direction,
$Ratio$ - Capacity

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

	$$Ratio = \frac{(0.14932\ \mathrm{kipft})}{(249.6\ \mathrm{kipft})}$$ $$Ratio = 0.00059822$$	Status: **PASS** Ratio: **0.000**