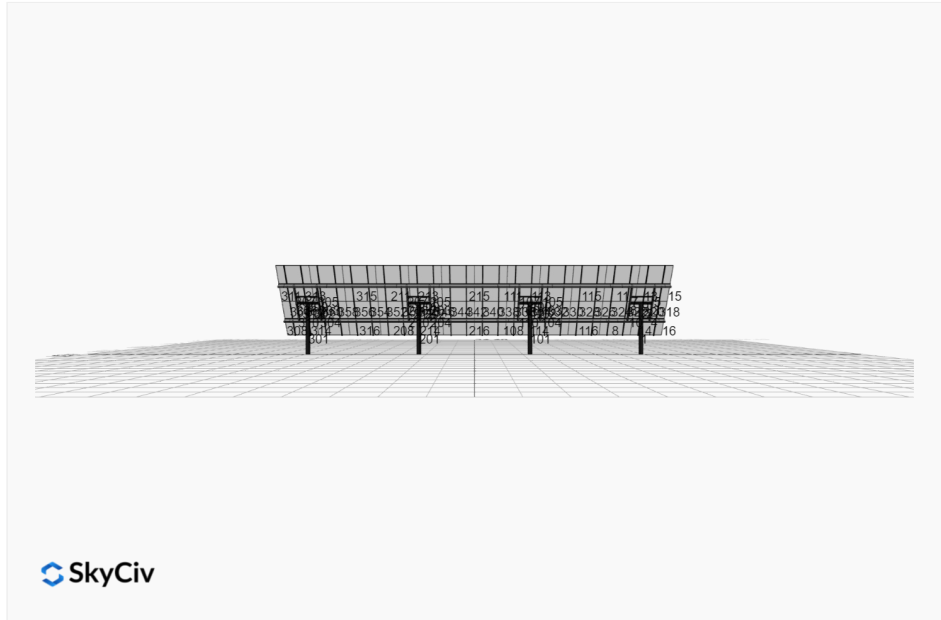


Project Name: Lamar Buffalo Ranch V2 **Date:** Tue Oct 15 2024
Location: VQW8+37, Fossil Forest, WY 82190, USA **Number of Modules:** 48
Unique ID: 4P-19.75-8TOP-XD-12-L-4Hx12W-LIJ **Number of Poles:** 4
Dealer: _____ **Date Sold:** _____



Array Dimensions N/S	15.03 ft
Array Dimensions E/W	68.80 ft
Winter Tilt Angle	55
Front Edge Clearance	2.9 ft

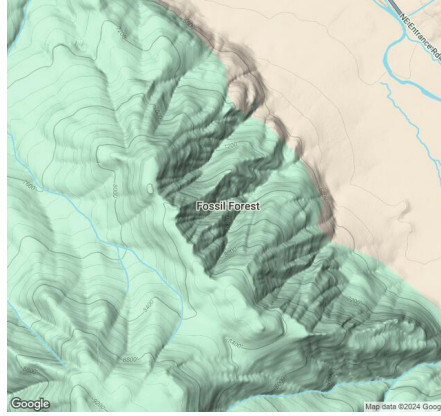
MT Solar Bill of Materials (4P-19.75-8TOP-XD-12-L-4Hx12W-LIJ)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	4
MTS-HF-XD	H-Frame Assembly-XD	4
MTS-XD-Wing-12	12IN XD Wing	4
MTS-XD-Splice-90	90IN XD Splice	6
MTS-XD-Splice-57	57IN XD Splice	6
MTS-CLAMP-HOOK-4PK	Hook Clamp	12

Rail Bill of Materials

Part	Qty
Rails (178in)	24
Rail Attachment	48
Module Mid Clamp	72
Module End Clamp	48
Ground Lug	12

Site Details:



Site Address: VQW8+37, Fossil Forest, WY 82190, USA

Array Specification

Duty Classification:	XD
Module Width:	44.60 in
Module Length:	67.80in
Number of Rows:	4
Number of Columns:	12
Total Number of Modules:	48
Winter Tilt Angle:	55
Front Edge Clearance:	2.9
Total Array Height at Tilt:	15.21 ft
Total Frame Length:	68.75 ft
Frame Weight:	4790 lbs
Array Dimensions N/S:	15.03 ft
Array Dimensions E/W:	68.80 ft
Rail Length:	180.40 in
Rail Spacing:	2.87 ft

Support Specifications

Pole Size:	8in Pipe Sch 40
Pole Length above Grade:	9.06 ft
Number of Poles:	4
Pole Spacing:	19.75 ft

Foundation Specifications

Foundation Type:	Square
Foundation Dimensions:	48 x 48 in
Foundation Depth (below grade):	Pile 1: 5.50 ft Pile 2: 6.00 ft Pile 3: 6.00 ft Pile 4: 5.50 ft
Foundation Volume:	13.630 y ³

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	VQW8+37, Fossil Forest, WY 82190, USA
Wind Speed:	101 mph

Snow Load:

140 psf

Design Disclaimer

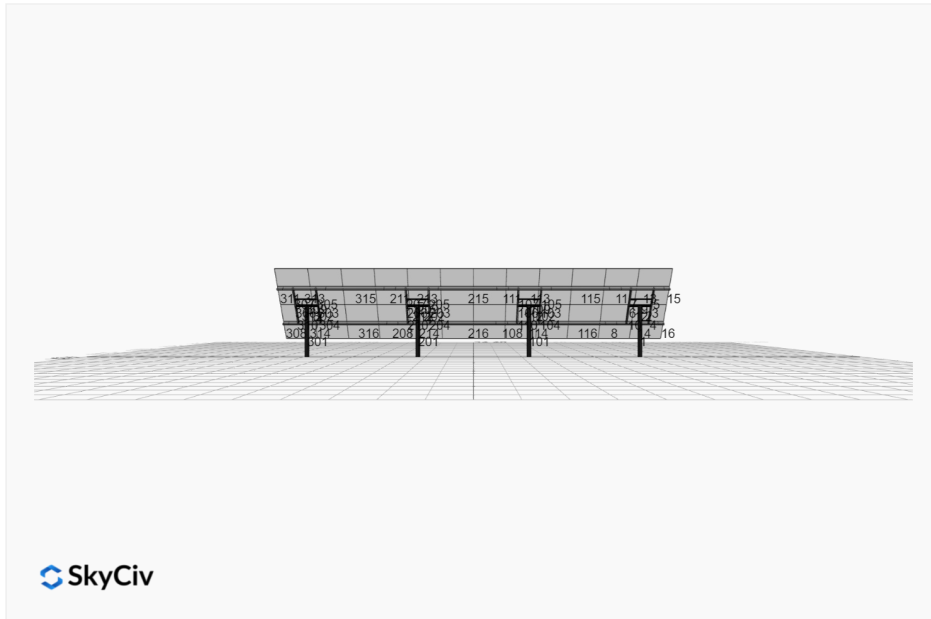
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

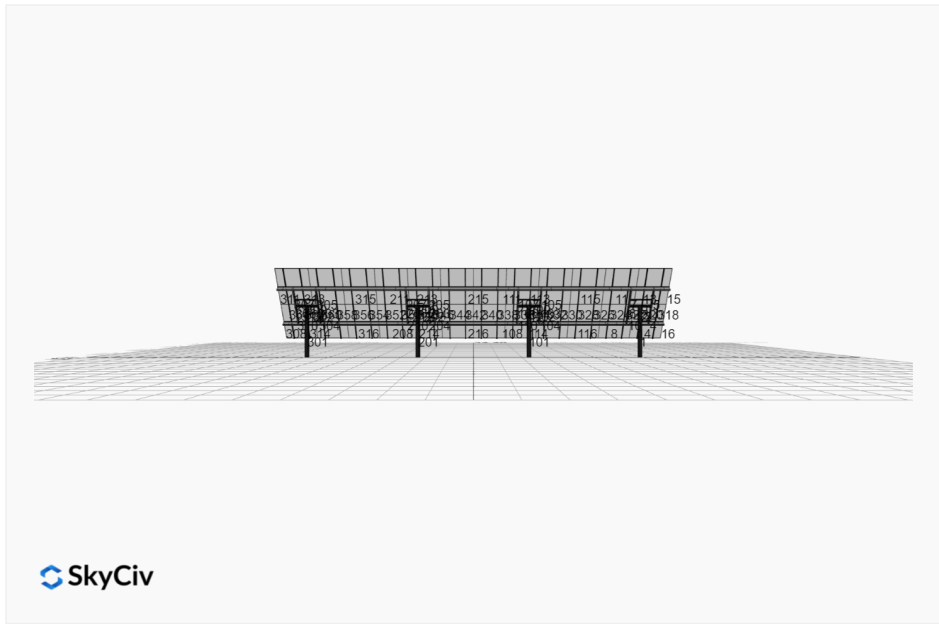
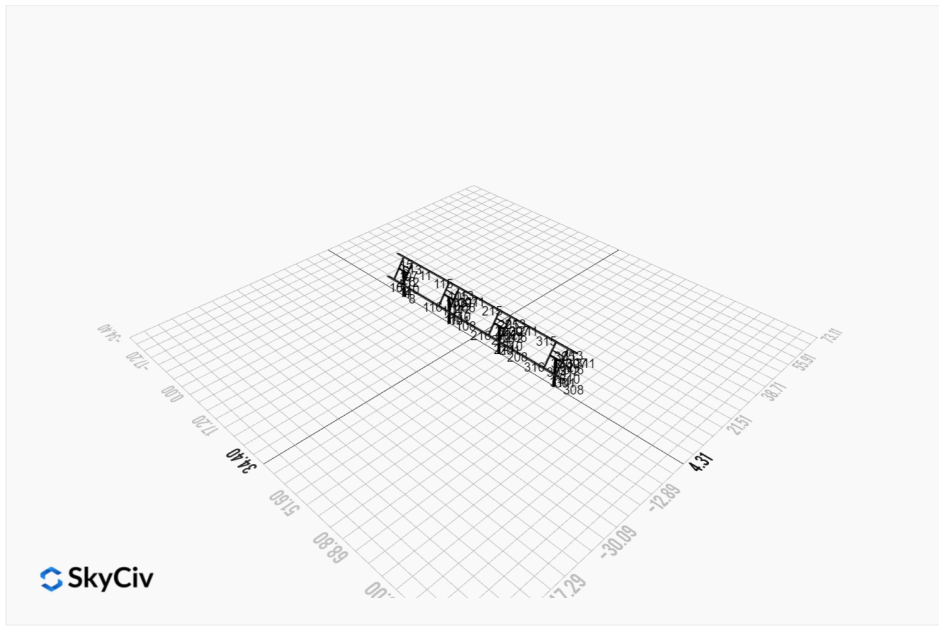
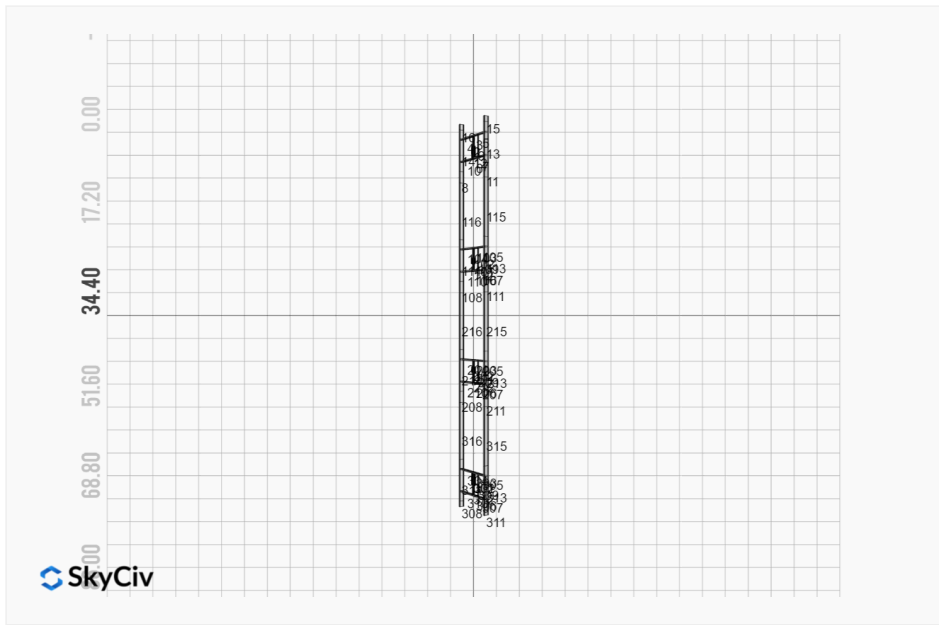
AutoDesigner Input

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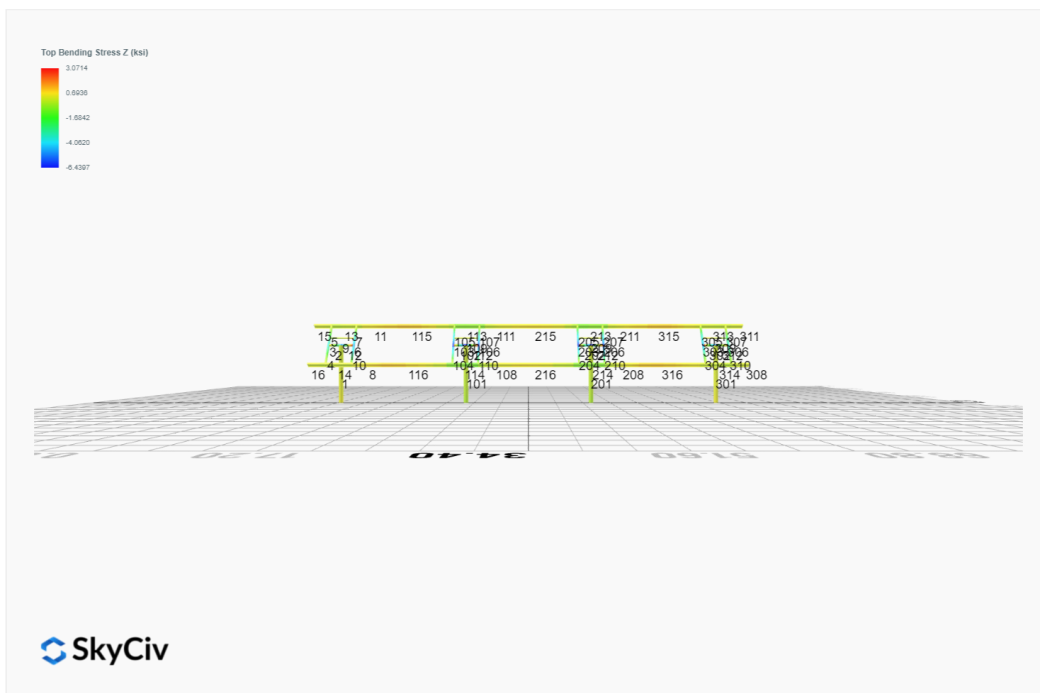
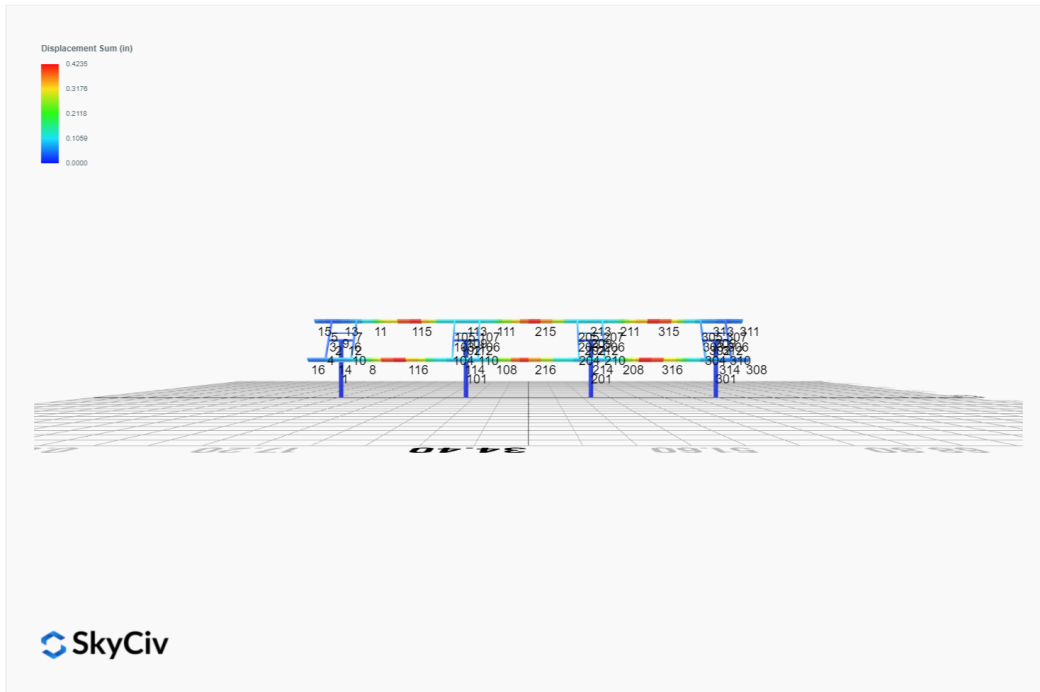
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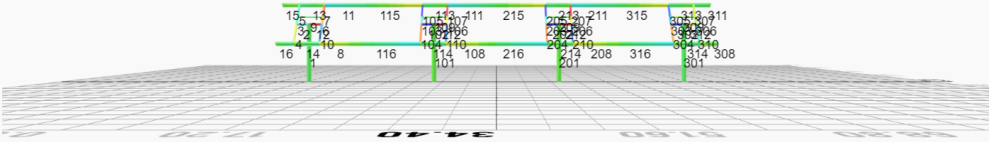
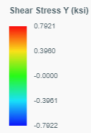
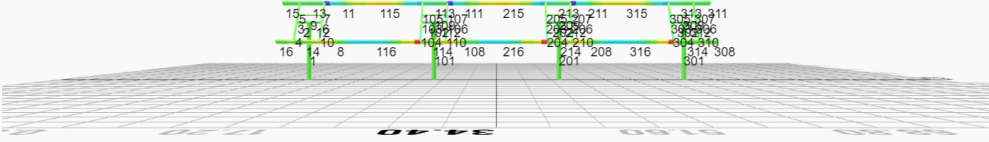
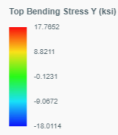
- AISC Deflection checks are set to L/1 due to structure design intent
- Foundation Soil Parameters used in this Autodesign are all estimates, proper geotechnical reports are required to confirm soil profiles
- Wind speeds, snow loads and other site specific results are based on ASCE 7 2016
- Steel frame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

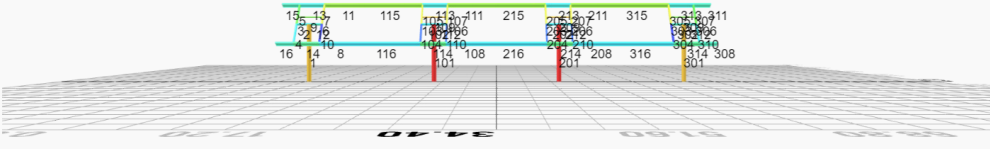




FEM Results (Envelope Worst Case for each member)







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	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 2. D + L	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 3. D + (S or Lr or R)	0.1097	4.7454	0.2810	0.6976	-0.2615	-0.9084
ULS: 3. D + (S or Lr or R)	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0911	4.0312	0.2333	0.5790	-0.2171	-0.7516
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 5b. D + 0.7E	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0911	4.0312	0.2333	0.5790	-0.2171	-0.7516
ULS: 8. 0.6D + 0.7E	0.0212	1.1332	0.0542	0.1340	-0.0503	-0.1688
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7934	3.1503	0.2545	0.5867	-0.9491	16.5634
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8631	0.6278	-0.0726	-0.1370	0.7748	-16.9788
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2805	4.9773	0.3565	0.8515	-0.8661	11.8819
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0911	4.0312	0.2333	0.5790	-0.2171	-0.7516
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4619	3.0855	0.1111	0.3088	0.4269	-13.2748
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0911	4.0312	0.2333	0.5790	-0.2171	-0.7516
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3362	2.8349	0.2135	0.4958	-0.7328	12.3522
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4061	0.9431	-0.0319	-0.0469	0.5602	-12.8045
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0353	1.8887	0.0903	0.2233	-0.0838	-0.2813
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8075	2.3948	0.2184	0.4974	-0.9156	16.6759
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0212	1.1332	0.0542	0.1340	-0.0503	-0.1688
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8489	-0.1277	-0.1087	-0.2263	0.8084	-16.8663
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0212	1.1332	0.0542	0.1340	-0.0503	-0.1688

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.8888
Shear X	-3.1269
Shear Z	0.5547
Moment X	1.3485
Moment Y (Twist)	1.6392
Moment Z	28.7058

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module.
Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	4.9773
Shear X	-1.8631
Shear Z	0.3565
Moment X	0.8515
Moment Y (Twist)	0.9491
Moment Z	16.9788

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	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 2. D + L	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 3. D + (S or Lr or R)	-0.1100	6.4159	-0.0074	-0.0242	0.0229	0.9771
ULS: 3. D + (S or Lr or R)	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0914	5.4188	-0.0062	-0.0201	0.0191	0.8135

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 5b. D + 0.7E	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0914	5.4188	-0.0062	-0.0201	0.0191	0.8135
ULS: 8. 0.6D + 0.7E	-0.0213	1.4564	-0.0014	-0.0047	0.0045	0.1937
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.6548	4.2802	0.0138	0.0247	-0.1030	23.9671
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5849	0.5737	-0.0178	-0.0389	0.1141	-23.0649
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.0559	6.8085	0.0060	0.0043	-0.0638	18.5468
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0914	5.4188	-0.0062	-0.0201	0.0191	0.8135
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8738	4.0286	-0.0177	-0.0434	0.0991	-16.7272
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0914	5.4188	-0.0062	-0.0201	0.0191	0.8135
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9999	3.8170	0.0097	0.0166	-0.0754	18.0560
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9298	1.0371	-0.0140	-0.0312	0.0874	-17.2179
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0354	2.4273	-0.0024	-0.0079	0.0074	0.3228
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.6406	3.3093	0.0147	0.0279	-0.1060	23.8380
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0213	1.4564	-0.0014	-0.0047	0.0045	0.1937
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5990	-0.3972	-0.0169	-0.0358	0.1111	-23.1940
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0213	1.4564	-0.0014	-0.0047	0.0045	0.1937

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.8382
Shear X	-4.4441
Shear Z	-0.0321
Moment X	-0.0713
Moment Y (Twist)	0.1999
Moment Z	40.5283

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	6.8085
Shear X	-2.6548
Shear Z	-0.0178
Moment X	-0.0434
Moment Y (Twist)	0.1141
Moment Z	23.9671

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	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209
ULS: 2. D + L	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209
ULS: 3. D + (S or Lr or R)	-0.1091	6.4145	0.0074	0.0175	-0.0237	0.9710
ULS: 3. D + (S or Lr or R)	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0906	5.4176	0.0061	0.0146	-0.0197	0.8084
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209
ULS: 5b. D + 0.7E	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0906	5.4176	0.0061	0.0146	-0.0197	0.8084
ULS: 8. 0.6D + 0.7E	-0.0211	1.4561	0.0014	0.0034	-0.0046	0.1925
ULS: 5a. D + 0.6W_Wind downforce Case A only	-2.6541	4.2797	-0.0141	-0.0294	0.1008	23.9660
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209
ULS: 5a. D + 0.6W_Wind uplift Case A only	2.5848	0.5733	0.0181	0.0393	-0.1123	-23.0675
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209

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	-2.0549	6.8072	-0.0062	-0.0117	0.0616	18.5423
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0906	5.4176	0.0061	0.0146	-0.0197	0.8084
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.8743	4.0275	0.0180	0.0398	-0.0982	-16.7328
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0906	5.4176	0.0061	0.0146	-0.0197	0.8084
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.9994	3.8165	-0.0100	-0.0206	0.0737	18.0547
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.9298	1.0367	0.0142	0.0309	-0.0861	-17.2204
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0351	2.4268	0.0024	0.0057	-0.0077	0.3209
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-2.6401	3.3090	-0.0150	-0.0317	0.1039	23.8377
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0211	1.4561	0.0014	0.0034	-0.0046	0.1925
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	2.5989	-0.3974	0.0172	0.0370	-0.1092	-23.1958
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0211	1.4561	0.0014	0.0034	-0.0046	0.1925

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	10.8361
Shear X	-4.4429
Shear Z	0.0326
Moment X	0.0707
Moment Y (Twist)	0.1970
Moment Z	40.5259

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	6.8072
Shear X	-2.6541
Shear Z	0.0181
Moment X	0.0398
Moment Y (Twist)	0.1123
Moment Z	23.9660

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	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810
ULS: 2. D + L	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810
ULS: 3. D + (S or Lr or R)	0.1095	4.7454	-0.2810	-0.7045	0.2586	-0.9074
ULS: 3. D + (S or Lr or R)	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0909	4.0312	-0.2333	-0.5848	0.2147	-0.7508
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810
ULS: 5b. D + 0.7E	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0909	4.0312	-0.2333	-0.5848	0.2147	-0.7508
ULS: 8. 0.6D + 0.7E	0.0212	1.1333	-0.0541	-0.1353	0.0497	-0.1686
ULS: 5a. D + 0.6W_Wind downforce Case A only	-1.7934	3.1502	-0.2542	-0.5901	0.9435	16.5619
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810
ULS: 5a. D + 0.6W_Wind uplift Case A only	1.8629	0.6279	0.0723	0.1359	-0.7711	-16.9767
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.2805	4.9773	-0.3563	-0.8582	0.8602	11.8813
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0909	4.0312	-0.2333	-0.5848	0.2147	-0.7508
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4617	3.0856	-0.1114	-0.3137	-0.4258	-13.2726
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0909	4.0312	-0.2333	-0.5848	0.2147	-0.7508
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-1.3362	2.8348	-0.2132	-0.4989	0.7284	12.3512
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	1.4060	0.9431	0.0317	0.0456	-0.5576	-12.8028
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0353	1.8888	-0.0902	-0.2255	0.0829	-0.2810

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-1.8075	2.3947	-0.2181	-0.4999	0.9104	16.6743
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0212	1.1333	-0.0541	-0.1353	0.0497	-0.1686
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	1.8488	-0.1276	0.1084	0.2261	-0.8042	-16.8643
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0212	1.1333	-0.0541	-0.1353	0.0497	-0.1686

Worst Case Reactions LRFD

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

Result	Value (kip, kip-ft)
Axial	7.8888
Shear X	-3.1265
Shear Z	-0.5545
Moment X	-1.3598
Moment Y (Twist)	1.6294
Moment Z	28.7024

Worst Case Reactions ASD

These results are taken from the worst case values in the above table and are used in the Soil Checks in the Foundation Module.
 Note: Worst case values are assumed as downforce wind load cases.

Result	Value (kip, kip-ft)
Axial	4.9773
Shear X	-1.8629
Shear Z	-0.3563
Moment X	-0.8582
Moment Y (Twist)	0.9435
Moment Z	16.9767

Project Details

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

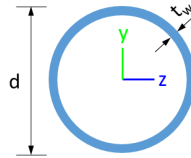


Design Input Information

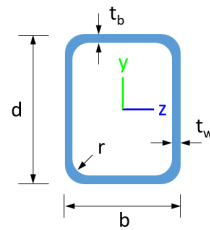
Design Factors			
Φ_t	Φ_c	Φ_b	Φ_v
0.9	0.9	0.9	0.9

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

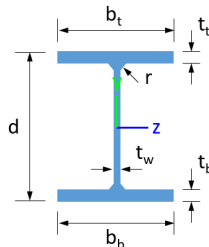
Section Dimensions



ID	Name	d (in)	t_w (in)				
3	2in Pipe Sch 120	2.38	0.25				
6	4in Pipe Sch 120	4.50	0.44				
9	8in Pipe Sch 40	8.63	0.32				



ID	Name	d (in)	b (in)	t_w (in)	t_b (in)	r (in)	
17	HSS5x3x1/4	5.00	3.00	0.23	0.23	0.23	



ID	Name	d (in)	t_w (in)	b_t (in)	b_b (in)	t_t (in)	t_b (in)	r (in)
20	W10x12	9.87	0.19	3.96	3.96	0.21	0.21	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)
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3	2in Pipe Sch 120	1.67	1.91	0.96	0.96	0.00	1.13	1.13
6	4in Pipe Sch 120	5.58	23.29	11.64	11.64	0.00	7.24	7.24
9	8in Pipe Sch 40	8.40	144.98	72.49	72.49	0.00	22.21	22.21
17	HSS5x3x1/4	3.37	11.00	4.81	10.70	0.93	3.77	5.38
20	W10x12	3.54	0.05	2.18	53.80	50.90	1.74	12.60

Member Properties

Member ID	Section ID	K _z L (ft)	K _y L (ft)	L _b (ft)	C _b	LS T	LS C	L D
1	9	19.0 2	19.0 2	9.0 6	-	30 0	20 0	1
2	6	1.30	1.30	2.0 0	-	30 0	20 0	1
3	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.18,1.16,1.18,1.17,1.19,1.16,1.19,1.17,1.17,1.18,1.17,1.17,1.19,1.1 4,1.19,1.17,1.19,1.16,1.19	30 0	20 0	1
4	17	2.44	2.44	3.7 5	1.70,1.69,1.70,1.68,1.69,1.70,1.67,1.69,1.65,1.69,1.67,1.70,1.65,1.70,1.67,1.68,1.69,1.68,1.68,1.70,1.6 3,1.70,1.67,1.70,1.66,1.70	30 0	20 0	1
5	17	1.52	1.52	2.3 3	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.6 4,1.69,1.67,1.69,1.66,1.69	30 0	20 0	1
6	17	0.92	0.92	1.4 2	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.19,1.19,1.19,1.1 7,1.19,1.19,1.19,1.18,1.19	30 0	20 0	1
7	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.6 5,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
8	20	1.33	1.33	2.0 5	1.22,1.22,1.22,1.22,1.22,1.22,1.21,1.22,1.19,1.22,1.21,1.22,1.20,1.22,1.21,1.22,1.24,1.22,1.21,1.22,1.1 9,1.22,1.21,1.22,1.20,1.22	30 0	20 0	1
9	3	2.60	2.60	4.0 0	-	30 0	20 0	1
10	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.69,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.6 4,1.69,1.67,1.69,1.66,1.69	30 0	20 0	1
11	20	1.33	1.33	2.0 5	1.24,1.24,1.24,1.24,1.24,1.24,1.27,1.24,1.32,1.24,1.28,1.24,1.30,1.24,1.26,1.24,1.20,1.24,1.27,1.24,1.3 3,1.24,1.28,1.24,1.29,1.24	30 0	20 0	1
12	6	2.00	1.30	2.0 0	-	30 0	20 0	1
13	20	4.88	4.00	7.5 0	1.48,1.50,1.48,1.51,1.49,1.48,1.32,1.50,1.25,1.50,1.32,1.48,1.29,1.48,1.38,1.51,2.01,1.51,1.33,1.48,1.2 5,1.48,1.31,1.48,1.29,1.48	30 0	20 0	1
14	20	4.88	4.00	7.5 0	1.69,1.72,1.69,1.74,1.70,1.69,1.94,1.72,2.35,1.72,1.96,1.69,2.16,1.69,1.84,1.74,1.42,1.74,1.91,1.69,2.4 4,1.69,1.98,1.69,2.12,1.69	30 0	20 0	1
15	20	2.10	2.10	1.0 0	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.3 3,2.32,2.33,2.33,2.33,2.33	30 0	20 0	1
16	20	2.10	2.10	1.0 0	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.32,2.3 3,2.32,2.33,2.33,2.33,2.33	30 0	20 0	1
101	9	19.0 2	19.0 2	9.0 6	-	30 0	20 0	1
102	6	2.00	1.30	2.0 0	-	30 0	20 0	1
103	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.1 6,1.19,1.18,1.19,1.17,1.19	30 0	20 0	1
104	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.6 4,1.69,1.67,1.69,1.66,1.69	30 0	20 0	1
105	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.6 5,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
106	17	0.92	0.92	1.4 2	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.19,1.1 7,1.19,1.18,1.19,1.18,1.19	30 0	20 0	1
107	17	1.52	1.52	2.3 3	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.6 5,1.68,1.67,1.68,1.66,1.68	30 0	20 0	1
108	20	1.33	1.33	2.0 5	2.12,2.12,2.12,2.12,2.12,2.12,2.10,2.12,2.07,2.12,2.09,2.12,2.08,2.12,2.11,2.12,2.35,2.12,2.10,2.12,2.0 7,2.12,2.09,2.12,2.08,2.12	30 0	20 0	1
109	3	2.60	2.60	4.0 0	-	30 0	20 0	1
110	17	2.44	2.44	3.7 5	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.6 5,1.69,1.67,1.69,1.66,1.69	30 0	20 0	1
111	20	1.33	1.33	2.0 5	2.08,2.08,2.08,2.08,2.08,2.08,1.65,2.08,1.34,2.08,1.60,2.08,1.44,2.08,1.87,2.08,1.98,2.08,1.66,2.08,1.3 3,2.08,1.58,2.08,1.47,2.08	30 0	20 0	1
112	6	1.30	1.30	2.0 0	-	30 0	20 0	1

113	20	4.88	4.00	7.50	1.07,1.08,1.07,1.08,1.07,1.07,1.10,1.08,1.20,1.08,1.11,1.07,1.14,1.07,1.09,1.08,1.05,1.08,1.10,1.07,1.34,1.07,1.11,1.07,1.13,1.07	300	200	1
114	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.10,1.07,1.08,1.07,1.09,1.07,1.07,1.07,1.05,1.07,1.08,1.07,1.10,1.07,1.08,1.07,1.09,1.07	300	200	1
115	20	10.20	10.20	10.20	1.15,1.15,1.15,1.14,1.15,1.15,1.10,1.15,1.08,1.15,1.10,1.15,1.09,1.15,1.12,1.14,1.23,1.14,1.10,1.15,1.08,1.15,1.10,1.15,1.09,1.15	300	200	1
116	20	10.20	10.20	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.16,1.17,1.18,1.17,1.16,1.17,1.16,1.17,1.16,1.17	300	200	1
201	9	19.02	19.02	9.06	-	300	200	1
202	6	1.30	1.30	2.00	-	300	200	1
203	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.18,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.18,1.19,1.18,1.18,1.18,1.18,1.18,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
204	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
205	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
206	17	0.92	0.92	1.42	1.19,1.18,1.19,1.18,1.19,1.19,1.18,1.18,1.17,1.18,1.18,1.19,1.17,1.19,1.18,1.18,1.18,1.18,1.18,1.19,1.16,1.19,1.18,1.19,1.17,1.19	300	200	1
207	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.67,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
208	20	1.33	1.33	2.05	1.86,1.87,1.86,1.87,1.86,1.86,1.78,1.87,1.67,1.87,1.77,1.86,1.72,1.86,1.82,1.87,2.07,1.87,1.78,1.86,1.67,1.86,1.76,1.86,1.73,1.86	300	200	1
209	3	2.60	2.60	4.00	-	300	200	1
210	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.66,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
211	20	1.33	1.33	2.05	1.68,1.68,1.68,1.68,1.68,1.68,1.43,1.68,1.24,1.68,1.40,1.68,1.31,1.68,1.52,1.68,2.31,1.68,1.43,1.68,1.23,1.68,1.39,1.68,1.33,1.68	300	200	1
212	6	2.00	1.30	2.00	-	300	200	1
213	20	4.88	4.00	7.50	1.07,1.07,1.07,1.08,1.07,1.07,1.10,1.07,1.20,1.07,1.11,1.07,1.14,1.07,1.09,1.08,1.05,1.08,1.10,1.07,1.32,1.07,1.11,1.07,1.13,1.07	300	200	1
214	20	4.88	4.00	7.50	1.07,1.07,1.07,1.07,1.07,1.07,1.08,1.07,1.10,1.07,1.08,1.07,1.09,1.07,1.07,1.07,1.05,1.07,1.08,1.07,1.10,1.07,1.08,1.07,1.09,1.07	300	200	1
215	20	10.20	10.20	10.20	1.17,1.17,1.17,1.17,1.17,1.17,1.14,1.17,1.10,1.17,1.13,1.17,1.12,1.17,1.15,1.17,1.30,1.17,1.14,1.17,1.10,1.17,1.13,1.17,1.12,1.17	300	200	1
216	20	10.20	10.20	10.20	1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19,1.19,1.19,1.21,1.19,1.18,1.19,1.17,1.19,1.18,1.19,1.18,1.19	300	200	1
301	9	19.02	19.02	9.06	-	300	200	1
302	6	2.00	1.30	2.00	-	300	200	1
303	17	0.92	0.92	1.42	1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.18,1.19,1.19,1.19,1.18,1.19,1.18,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19,1.19	300	200	1
304	17	2.44	2.44	3.75	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
305	17	1.52	1.52	2.33	1.68,1.67,1.68,1.67,1.68,1.68,1.67,1.67,1.66,1.67,1.67,1.68,1.66,1.68,1.67,1.67,1.67,1.67,1.67,1.68,1.65,1.68,1.67,1.68,1.66,1.68	300	200	1
306	17	0.92	0.92	1.42	1.19,1.18,1.19,1.17,1.18,1.19,1.17,1.18,1.16,1.18,1.17,1.19,1.16,1.19,1.17,1.17,1.18,1.17,1.17,1.19,1.14,1.19,1.17,1.19,1.16,1.19	300	200	1
307	17	1.52	1.52	2.33	1.69,1.68,1.69,1.67,1.68,1.69,1.67,1.68,1.65,1.68,1.67,1.69,1.66,1.69,1.67,1.67,1.68,1.67,1.67,1.69,1.64,1.69,1.67,1.69,1.66,1.69	300	200	1
308	20	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.32,2.33	300	200	1
309	3	2.60	2.60	4.00	-	300	200	1
310	17	2.44	2.44	3.75	1.70,1.69,1.70,1.68,1.69,1.70,1.67,1.69,1.65,1.69,1.67,1.70,1.65,1.70,1.67,1.68,1.69,1.68,1.68,1.70,1.63,1.70,1.67,1.70,1.66,1.70	300	200	1
311	20	2.10	2.10	1.00	2.33,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.33,2.33,2.33,2.32,2.33,2.32,2.33,2.32,2.33,2.33,2.33,2.32,2.33	300	200	1
312	6	1.30	1.30	2.00	-	300	200	1
313	20	4.88	4.00	7.50	1.49,1.51,1.49,1.52,1.50,1.49,1.33,1.51,1.26,1.51,1.32,1.49,1.29,1.49,1.38,1.52,2.03,1.52,1.33,1.49,1.25,1.49,1.31,1.49,1.29,1.49	300	200	1
314	20	4.88	4.00	7.50	1.70,1.73,1.70,1.75,1.71,1.70,1.95,1.73,2.37,1.73,1.98,1.70,2.18,1.70,1.85,1.75,1.43,1.75,1.93,1.70,2.46,1.70,1.99,1.70,2.14,1.70	300	200	1

212	251.01	240.00	27.10	27.10	75.30	75.30
213	159.30	97.43	32.09	6.46	56.26	44.91
214	159.30	97.43	32.20	6.46	56.26	44.91
215	159.30	32.87	21.23	6.46	56.26	44.91
216	159.30	32.87	22.53	6.46	56.26	44.91
301	377.97	243.10	83.29	83.29	113.39	113.39
302	251.01	246.00	27.16	27.16	75.30	75.30
303	151.65	150.70	20.17	14.14	54.12	28.95
304	151.65	145.15	20.17	14.14	54.12	28.95
305	151.65	149.10	20.17	14.14	54.12	28.95
306	151.65	150.70	20.17	14.14	54.12	28.95
307	151.65	149.10	20.17	14.14	54.12	28.95
308	159.30	137.23	46.90	6.46	56.26	44.91
309	75.10	66.32	4.25	4.25	22.53	22.53
310	151.65	145.15	20.17	14.14	54.12	28.95
311	159.30	137.23	46.90	6.46	56.26	44.91
312	251.01	248.88	27.16	27.16	75.30	75.30
313	159.30	97.43	38.23	6.46	56.26	44.91
314	159.30	97.43	43.68	6.46	56.26	44.91
315	159.30	32.87	20.70	6.46	56.26	44.91
316	159.30	32.87	20.75	6.46	56.26	44.91

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	0.032	0.345	0.044	0.028	0.005	0.357	#13	0.388	Not Required	Pass
2	0.002	0.131	0.078	0.033	0.018	0.182	#21	0.054	Not Required	Pass
3	0.006	0.200	0.025	0.019	0.005	0.208	#21	0.046	Not Required	Pass
4	0.005	0.200	0.058	0.020	0.014	0.257	#21	0.082	Not Required	Pass
5	0.005	0.124	0.031	0.020	0.009	0.133	#21	0.076	Not Required	Pass
6	0.012	0.321	0.124	0.033	0.036	0.440	#21	0.046	Not Required	Pass
7	0.013	0.199	0.201	0.032	0.050	0.236	#21	0.076	Not Required	Pass
8	0.006	0.073	0.210	0.018	0.024	0.235	#21	0.102	Not Required	Pass
9	0.006	0.043	0.071	0.005	0.005	0.096	#21	0.206	Not Required	Pass
10	0.013	0.298	0.187	0.030	0.041	0.406	#21	0.082	Not Required	Pass
11	0.008	0.068	0.220	0.020	0.024	0.243	#21	0.102	Not Required	Pass
12	0.001	0.266	0.138	0.068	0.027	0.357	#21	0.083	Not Required	Pass
13	0.012	0.031	0.559	0.026	0.031	0.570	#21	0.306	Not Required	Pass
14	0.006	0.038	0.545	0.024	0.031	0.553	#23	0.204	Not Required	Pass
15	0.000	0.002	0.014	0.003	0.004	0.016	#21	Not Required	Not Required	Pass
16	0.000	0.002	0.014	0.003	0.004	0.016	#21	Not Required	Not Required	Pass
101	0.045	0.487	0.003	0.039	0.000	0.504	#13	0.388	Not Required	Pass
102	0.004	0.277	0.161	0.070	0.029	0.395	#21	0.055	Not Required	Pass
103	0.012	0.361	0.074	0.036	0.010	0.441	#21	0.046	Not Required	Pass
104	0.012	0.374	0.199	0.037	0.043	0.508	#21	0.082	Not Required	Pass
105	0.012	0.224	0.209	0.035	0.054	0.278	#21	0.076	Not Required	Pass
106	0.012	0.374	0.074	0.037	0.010	0.447	#21	0.046	Not Required	Pass
107	0.012	0.232	0.205	0.037	0.053	0.283	#21	0.076	Not Required	Pass
108	0.006	0.024	0.208	0.021	0.024	0.230	#21	0.102	Not Required	Pass
109	0.019	0.020	0.038	0.001	0.000	0.060	#21	0.206	Not Required	Pass
110	0.012	0.375	0.195	0.037	0.043	0.504	#21	0.082	Not Required	Pass

111	0.008	0.040	0.217	0.021	0.024	0.233	#23	0.102	Not Required	Pass
112	0.004	0.278	0.168	0.070	0.030	0.399	#21	0.036	Not Required	Pass
113	0.012	0.094	0.567	0.028	0.031	0.645	#21	0.306	Not Required	Pass
114	0.006	0.115	0.556	0.030	0.031	0.650	#21	0.306	Not Required	Pass
115	0.036	0.202	0.301	0.022	0.024	0.513	#21	0.780	Not Required	Pass
116	0.006	0.195	0.294	0.024	0.024	0.476	#21	0.780	Not Required	Pass
201	0.045	0.487	0.003	0.039	0.000	0.504	#13	0.388	Not Required	Pass
202	0.004	0.278	0.167	0.070	0.030	0.399	#21	0.036	Not Required	Pass
203	0.012	0.375	0.074	0.037	0.010	0.447	#21	0.046	Not Required	Pass
204	0.012	0.375	0.195	0.037	0.043	0.504	#21	0.082	Not Required	Pass
205	0.012	0.233	0.205	0.037	0.053	0.284	#21	0.076	Not Required	Pass
206	0.012	0.361	0.074	0.036	0.010	0.441	#21	0.046	Not Required	Pass
207	0.012	0.224	0.209	0.035	0.054	0.278	#21	0.076	Not Required	Pass
208	0.006	0.043	0.218	0.024	0.024	0.229	#21	0.102	Not Required	Pass
209	0.019	0.020	0.038	0.001	0.000	0.060	#21	0.206	Not Required	Pass
210	0.012	0.374	0.199	0.037	0.043	0.508	#21	0.082	Not Required	Pass
211	0.008	0.057	0.227	0.022	0.024	0.234	#21	0.102	Not Required	Pass
212	0.004	0.277	0.161	0.070	0.029	0.395	#21	0.055	Not Required	Pass
213	0.012	0.094	0.567	0.028	0.031	0.644	#21	0.306	Not Required	Pass
214	0.006	0.115	0.556	0.030	0.031	0.650	#21	0.306	Not Required	Pass
215	0.037	0.154	0.307	0.021	0.024	0.466	#21	0.780	Not Required	Pass
216	0.006	0.119	0.300	0.021	0.024	0.417	#21	0.780	Not Required	Pass
301	0.032	0.345	0.044	0.028	0.005	0.358	#13	0.388	Not Required	Pass
302	0.001	0.265	0.138	0.068	0.027	0.357	#21	0.083	Not Required	Pass
303	0.012	0.321	0.124	0.033	0.036	0.440	#21	0.046	Not Required	Pass
304	0.013	0.298	0.187	0.030	0.041	0.406	#21	0.082	Not Required	Pass
305	0.013	0.199	0.201	0.032	0.050	0.236	#21	0.076	Not Required	Pass
306	0.006	0.200	0.025	0.019	0.005	0.208	#21	0.046	Not Required	Pass
307	0.005	0.124	0.031	0.020	0.009	0.133	#21	0.076	Not Required	Pass
308	0.000	0.002	0.014	0.003	0.004	0.016	#21	Not Required	Not Required	Pass
309	0.006	0.043	0.071	0.005	0.005	0.096	#21	0.206	Not Required	Pass
310	0.005	0.201	0.058	0.020	0.014	0.258	#21	0.082	Not Required	Pass
311	0.000	0.002	0.014	0.003	0.004	0.016	#21	Not Required	Not Required	Pass
312	0.002	0.131	0.078	0.033	0.018	0.183	#21	0.054	Not Required	Pass
313	0.012	0.031	0.559	0.026	0.031	0.570	#21	0.204	Not Required	Pass
314	0.006	0.038	0.545	0.024	0.031	0.553	#23	0.306	Not Required	Pass
315	0.036	0.214	0.301	0.020	0.024	0.521	#21	0.780	Not Required	Pass
316	0.006	0.211	0.294	0.018	0.024	0.490	#21	0.780	Not Required	Pass

Definitions

Φ_t	Safety factor for tensile
Φ_c	Safety factor for compression
Φ_b	Safety factor for flexure
Φ_v	Safety factor for shear
E	Modulus of elasticity
F_y	Specified minimum yield stress
F_u	Specified minimum tensile strength
A	Cross-sectional area
J	Torsional constant
I_{yp}	Moment of inertia about the Y axes
I_{zp}	Moment of inertia about the Z axes
I_w	Warping constant
S_{yp}	Plastic section modulus about the Y axis
S_{zp}	Plastic section modulus about the Z axis

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

REFERENCES	CALCULATIONS	RESULTS
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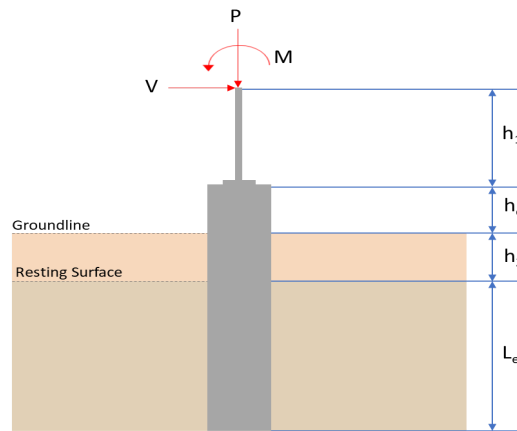
SkyCiv Foundation Design

Pile Foundation

Design Information :

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

Pile Input



Geometry

Pile shape: rectangular

$b = 48$ in - Pile width

$D = 48$ in - Pile depth

$L = 5.5$ ft - Total pile length

$h_1 = 0$ 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)	4.977	7.889
V_x (kip)	-1.863	-3.127
V_z (kip)	0.357	0.555
M_x (kipft)	0.852	1.348
M_z (kipft)	16.979	28.706

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,

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

$$H_o = \frac{(-1.863 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.29666 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.979 \text{ kipft}) + ((-1.863 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.7037 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$$

Solving the cubic equation:

$L_{e,x} = 5.0246 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.357 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.056847 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.852 \text{ kipft}) + ((0.357 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.13567 \text{ kipft/ft}$$

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:

$L_{e,z} = 2.7204 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(5.0246 \text{ ft}), (2.7204 \text{ ft})]$$

$$L_{e,req} = 5.025 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

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

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(5.025 \text{ ft})}{(5.5 \text{ ft})}$$

$$\text{Ratio} = 0.91364$$

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

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

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

$$q = \frac{(4.977 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.31106 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.31106 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.15553$$

Status: **PASS**
Ratio: **0.160**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.29666 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 2.7037 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.7037 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.7037 \text{ kipft/ft})) + (4 \times (-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7982 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.7037 \text{ kipft/ft})) + (3 \times (-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.7037 \text{ kipft/ft})) + (2 \times (-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.17923 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (2.7037 \text{ kipft/ft})) + ((-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.7489 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7982 \text{ ft})}{2}$$

$$p_a = 0.28486 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.17923 \text{ kip/ft}^2)}{(0.28486 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.62918$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.7489 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$\text{Ratio} = 0.90776$$

Status: **PASS**
Ratio: **0.630**

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

Considering z-direction:

$H_o = 0.056847 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.13567 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.13567 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.056847 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.13567 \text{ kipft/ft})) + (4 \times (0.056847 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9443 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.13567 \text{ kipft/ft})) + (3 \times (0.056847 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 [(3 \times (0.13567 \text{ kipft/ft})) + (2 \times (0.056847 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.052653 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.13567 \text{ kipft/ft})) + ((0.056847 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.11583 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9443 \text{ ft})}{2}$$

$$p_a = 0.29582 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$\text{Ratio} = \frac{(0.052653 \text{ kip/ft}^2)}{(0.29582 \text{ kip/ft}^2)}$$

$$Ratio = 0.17799$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.11583 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = 0.1404$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.127 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.49793 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.706 \text{ kipft}) + ((-3.127 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.571 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.571 \text{ kipft/ft})}{(-0.49793 \text{ kip/ft})}$$

$$E = 9.18 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.571 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.49793 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.571 \text{ kipft/ft})) + (4 \times (-0.49793 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = \frac{(6 \times (4.571 \text{ kipft/ft})) + (4 \times (-0.49793 \text{ kip/ft}) \times (5.5 \text{ ft}))}{}$$

$$a = 3.7975 \text{ ft}$$

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

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

$$V_{max} = ((-0.49793 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.18 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7975 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (9.18 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7975 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.196 \text{ kip}$$

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

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

$$M_{max} = ((-0.49793 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(9.18 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7975 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (9.18 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7975 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (9.18 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7975 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 18.795 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.555 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.088376 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.348 \text{ kipft}) + ((0.555 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.21465 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.21465 \text{ kipft/ft})}{(0.088376 \text{ kip/ft})}$$

$$E = 2.4288 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.21465 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (0.088376 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.21465 \text{ kipft/ft})) + (4 \times (0.088376 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9424 \text{ ft}$$

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

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

$$V_{max} = ((0.088376 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4288 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9424 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (2.4288 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9424 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.51221 \text{ kip}$$

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

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

$$M_{max} = ((0.088376 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(2.4288 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9424 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (2.4288 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9424 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.4288 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9424 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.2355 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.889 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.334 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.334 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(7.889 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.002949$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.889 \text{ kip} \rightarrow 7889 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(7889 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.54 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.54 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.54 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.54 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.78 \text{ kip}$$

Considering x-direction:

$V_{max} = 7.196 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(7.196 \text{ kip})}{(110.78 \text{ kip})}$$

$$Ratio = 0.064958$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.51221 \text{ kip}$ - Maximum shear force in the z-direction,
Ratio - Capacity

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

$$Ratio = \frac{(0.51221 \text{ kip})}{(110.78 \text{ kip})}$$

$$Ratio = 0.0046237$$

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:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

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

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

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 18.795 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(18.795 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0753$$

Status: **PASS**
Ratio: **0.080**

Considering z-direction:

$M_{max} = 1.2355 \text{ kipft}$ - Maximum moment in the z-direction,

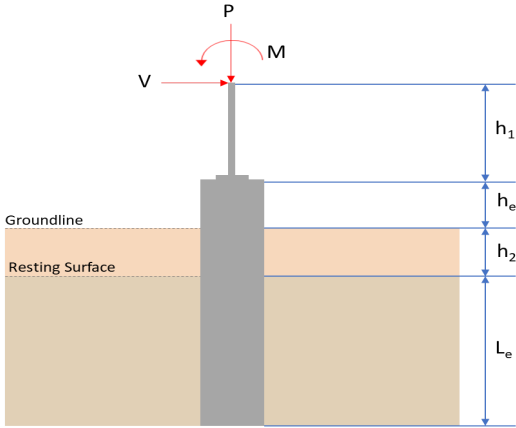
Ratio - Capacity

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

$$Ratio = \frac{(1.2355 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0049497$$

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

REFERENCES	CALCULATIONS	RESULTS																										
	<p>SkyCiv Foundation Design Pile Foundation</p> <p>Design Information : Design code : IBC 2021 (International Building Code) Unit System : Imperial</p>																											
	<p>Pile Input</p>  <p>Geometry</p> <p>Pile shape: rectangular $b = 48$ in - Pile width $D = 48$ in - Pile depth $L = 5.5$ 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</p> <p>Tabulation of Soil Parameters</p> <table border="1"> <thead> <tr> <th>Layer</th> <th>Label</th> <th>Allowable Bearing Pressure (q_a) (psf)</th> <th>Allowable Lateral Pressure (R) (psf/ft)</th> </tr> </thead> <tbody> <tr> <td>1</td> <td>Sand, silty sand, clayey sand, silty gravel & clayey gravel</td> <td>2000.000</td> <td>150.000</td> </tr> </tbody> </table> <p>Tabulation of Loads</p> <table border="1"> <thead> <tr> <th>Load Component</th> <th>ASD</th> <th>LRFD</th> </tr> </thead> <tbody> <tr> <td>P (kip)</td> <td>4.977</td> <td>7.889</td> </tr> <tr> <td>V_x (kip)</td> <td>-1.863</td> <td>-3.127</td> </tr> <tr> <td>V_z (kip)</td> <td>-0.356</td> <td>-0.554</td> </tr> <tr> <td>M_x (kipft)</td> <td>-0.858</td> <td>-1.360</td> </tr> <tr> <td>M_z (kipft)</td> <td>16.977</td> <td>28.702</td> </tr> </tbody> </table> <p>Material Properties</p> <p>$f'_{ck} = 2.5$ ksi - Concrete strength.</p>	Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)	1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000	Load Component	ASD	LRFD	P (kip)	4.977	7.889	V_x (kip)	-1.863	-3.127	V_z (kip)	-0.356	-0.554	M_x (kipft)	-0.858	-1.360	M_z (kipft)	16.977	28.702	
Layer	Label	Allowable Bearing Pressure (q_a) (psf)	Allowable Lateral Pressure (R) (psf/ft)																									
1	Sand, silty sand, clayey sand, silty gravel & clayey gravel	2000.000	150.000																									
Load Component	ASD	LRFD																										
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V_x (kip)	-1.863	-3.127																										
V_z (kip)	-0.356	-0.554																										
M_x (kipft)	-0.858	-1.360																										
M_z (kipft)	16.977	28.702																										
	<p>Required depth to resist lateral loads (ASD)</p> <p>H - Point of application of the lateral load</p> $H = h_1 + h_2 + h_e$ $H = (0 \text{ ft}) + (0 \text{ ft}) + (0 \text{ ft})$ $H = 0 \text{ ft}$ <p>Considering x-direction:</p> <p>H_o - Lateral force per length of pile,</p> $H_o = \frac{V_x}{1.57 D}$ $H_o = \frac{(-1.863 \text{ kip})}{1.57 \times (48 \text{ in})}$ $H_o = -0.29666 \text{ kip/ft}$																											

M_o - Moment per length of pile,

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

$$M_o = \frac{(16.977 \text{ kipft}) + ((-1.863 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 2.7033 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$$

Solving the cubic equation:

$L_{e,x} = 5.0244 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.356 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.056688 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.858 \text{ kipft}) + ((-0.356 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.13662 \text{ kipft/ft}$$

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:

$L_{e,z} = 1.7192 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(5.0244 \text{ ft}), (1.7192 \text{ ft})]$$

$$L_{e,req} = 5.024 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (5.5 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

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

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(5.024 \text{ ft})}{(5.5 \text{ ft})}$$

$$\text{Ratio} = 0.91345$$

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

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

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

$$q = \frac{(4.977 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.31106 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.31106 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.15553$$

Status: **PASS**
Ratio: **0.160**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

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

$$L/D = 1.375$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.29666 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 2.7033 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (2.7033 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (2.7033 \text{ kipft/ft})) + (4 \times (-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7982 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (2.7033 \text{ kipft/ft})) + (3 \times (-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (2.7033 \text{ kipft/ft})) + (2 \times (-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = 0.17919 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (2.7033 \text{ kipft/ft})) + ((-0.29666 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = 0.74878 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.7982 \text{ ft})}{2}$$

$$p_a = 0.28486 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.17919 \text{ kip/ft}^2)}{(0.28486 \text{ kip/ft}^2)}$$

$$Ratio = 0.62903$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.74878 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = 0.90761$$

Status: **PASS**
Ratio: **0.630**

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

Considering z-direction:

$H_o = -0.056688 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.13662 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.13662 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.056688 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.13662 \text{ kipft/ft})) + (4 \times (-0.056688 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9432 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.13662 \text{ kipft/ft})) + (3 \times (-0.056688 \text{ kip/ft}) \times (5.5 \text{ ft}))]^2}{(5.5 \text{ ft})^2 \times [(3 \times (0.13662 \text{ kipft/ft})) + (2 \times (-0.056688 \text{ kip/ft}) \times (5.5 \text{ ft}))]}$$

$$p = -0.017543 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.13662 \text{ kipft/ft})) + ((-0.056688 \text{ kip/ft}) \times (5.5 \text{ ft}))]}{(5.5 \text{ ft})^2}$$

$$s = -0.0076433 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(3.9432 \text{ ft})}{2}$$

$$p_a = 0.29574 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.017543 \text{ kip/ft}^2)}{(0.29574 \text{ kip/ft}^2)}$$

$$Ratio = -0.05932$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

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

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

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.0076433 \text{ kip/ft}^2)}{(0.825 \text{ kip/ft}^2)}$$

$$Ratio = -0.0092646$$

Status: **PASS**
Ratio: **-0.060**

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-3.127 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.49793 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(28.702 \text{ kipft}) + ((-3.127 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 4.5704 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(4.5704 \text{ kipft/ft})}{(-0.49793 \text{ kip/ft})}$$

$$E = 9.1788 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (4.5704 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.49793 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (4.5704 \text{ kipft/ft})) + (4 \times (-0.49793 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = \frac{(6 \times (4.5704 \text{ kipft/ft})) + (4 \times (-0.49793 \text{ kip/ft}) \times (5.5 \text{ ft}))}{(6 \times (4.5704 \text{ kipft/ft})) + (4 \times (-0.49793 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.7975 \text{ ft}$$

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

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

$$V_{max} = ((-0.49793 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.1788 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7975 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (9.1788 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7975 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 7.1952 \text{ kip}$$

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

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

$$M_{max} = ((-0.49793 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(9.1788 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.7975 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) - \left[\left(\frac{4 \times (9.1788 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.7975 \text{ ft})}{(2 \times (5.5 \text{ ft}))} \right)^3 \right] + \left[\left(\frac{3 \times (9.1788 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.7975 \text{ ft})}{(2 \times (5.5 \text{ ft}))} \right)^4 \right] \right]$$

$$M_{max} = 18.793 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.554 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.088217 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(1.36 \text{ kipft}) + ((-0.554 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.21656 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.21656 \text{ kipft/ft})}{(-0.088217 \text{ kip/ft})}$$

$$E = 2.4549 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.21656 \text{ kipft/ft}) \times (5.5 \text{ ft})) + (3 \times (-0.088217 \text{ kip/ft}) \times (5.5 \text{ ft})^2)}{(6 \times (0.21656 \text{ kipft/ft})) + (4 \times (-0.088217 \text{ kip/ft}) \times (5.5 \text{ ft}))}$$

$$a = 3.9412 \text{ ft}$$

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

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

$$V_{max} = ((-0.088217 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.4549 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9412 \text{ ft})}{(5.5 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (2.4549 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9412 \text{ ft})}{(5.5 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.51421 \text{ kip}$$

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

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

$$M_{max} = ((-0.088217 \text{ kip/ft}) \times (48 \text{ in}) \times (5.5 \text{ ft})) \times \left[\left(\frac{(2.4549 \text{ ft})}{(5.5 \text{ ft})} + \frac{(3.9412 \text{ ft})}{2 \times (5.5 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (2.4549 \text{ ft})}{(5.5 \text{ ft})} + 3 \right) \times \left(\frac{(3.9412 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.4549 \text{ ft})}{(5.5 \text{ ft})} + 2 \right) \times \left(\frac{(3.9412 \text{ ft})}{2 \times (5.5 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 1.2412 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(7.889 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.334 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.334 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Max[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Max[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(7.889 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.002949$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 7.889 \text{ kip} \rightarrow 7889 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(7889 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.54 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.54 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.54 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.54 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 110.78 \text{ kip}$$

Considering x-direction:

$V_{max} = 7.1952 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(7.1952 \text{ kip})}{(110.78 \text{ kip})}$$

$$Ratio = 0.06495$$

Status: **PASS**
Ratio: **0.060**

Considering z-direction:

$V_{max} = 0.51421 \text{ kip}$ - Maximum shear force in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(0.51421 \text{ kip})}{(110.78 \text{ kip})}$$

$$Ratio = 0.0046417$$

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:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

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

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

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 18.793 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(18.793 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.075291$$

Status: **PASS**
Ratio: **0.080**

Considering z-direction:

$M_{max} = 1.2412 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$Ratio = \frac{(1.2412 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.0049729$$

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

REFERENCES	CALCULATIONS	RESULTS
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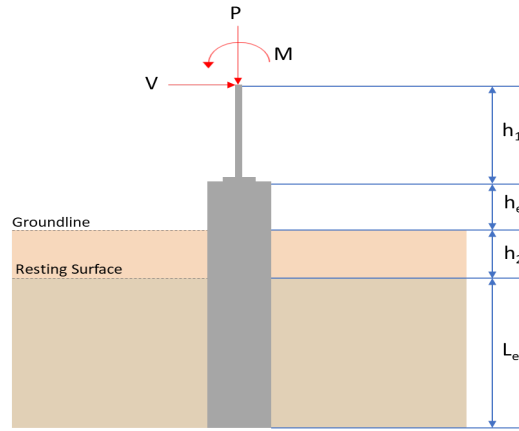
SkyCiv Foundation Design

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

$L = 6$ 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)	6.808	10.838
V_x (kip)	-2.655	-4.444
V_z (kip)	-0.018	-0.032
M_x (kipft)	-0.043	-0.071
M_z (kipft)	23.967	40.528

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,

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

$$H_o = \frac{(-2.655 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.42277 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.967 \text{ kipft}) + ((-2.655 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.8164 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_x^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$$

Solving the cubic equation:

$L_{e,x} = 5.495 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.018 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0028662 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.043 \text{ kipft}) + ((-0.018 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0068471 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_z^3 - \left(14.14 \times \frac{H_o \times L_z}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$$

Solving the cubic equation:

$L_{e,z} = 0.74837 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(5.495 \text{ ft}), (0.74837 \text{ ft})]$$

$$L_{e,req} = 5.495 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(5.495 \text{ ft})}{(6 \text{ ft})}$$

$$\text{Ratio} = 0.91583$$

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

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

$$q = \frac{(6.808 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.4255 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.4255 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.21275$$

Status: **PASS**
Ratio: **0.210**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.5$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.42277 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 3.8164 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.8164 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.42277 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (3.8164 \text{ kipft/ft})) + (4 \times (-0.42277 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1535 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.8164 \text{ kipft/ft})) + (3 \times (-0.42277 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (3.8164 \text{ kipft/ft})) + (2 \times (-0.42277 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = 0.19151 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (3.8164 \text{ kipft/ft})) + ((-0.42277 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.84936 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.1535 \text{ ft})}{2}$$

$$p_a = 0.31151 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.19151 \text{ kip/ft}^2)}{(0.31151 \text{ kip/ft}^2)}$$

$$Ratio = 0.61476$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6 \text{ ft})$$

$$p_s = 0.9 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.84936 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.94374$$

Status: **PASS**
Ratio: **0.610**

Status: **PASS**
Ratio: **0.940**

Considering z-direction:

$H_o = -0.0028662 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.0068471 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0068471 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.0028662 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (0.0068471 \text{ kipft/ft})) + (4 \times (-0.0028662 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.313 \text{ ft}$$

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

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

$$p = \frac{0.75 [(4 \times (0.0068471 \text{ kipft/ft})) + (3 \times (-0.0028662 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (0.0068471 \text{ kipft/ft})) + (2 \times (-0.0028662 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = -0.00088098 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.0068471 \text{ kipft/ft})) + ((-0.0028662 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = -0.00058386 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.313 \text{ ft})}{2}$$

$$p_a = 0.32348 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.00088098 \text{ kip/ft}^2)}{(0.32348 \text{ kip/ft}^2)}$$

$$Ratio = -0.0027235$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6 \text{ ft})$$

$$p_s = 0.9 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(-0.00058386 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = -0.00064874$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.444 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.70764 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(40.528 \text{ kipft}) + ((-4.444 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.4535 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.4535 \text{ kipft/ft})}{(-0.70764 \text{ kip/ft})}$$

$$E = 9.1197 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.4535 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.70764 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (6.4535 \text{ kipft/ft})) + (4 \times (-0.70764 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = \frac{(-0.70764 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (6.4535 \text{ kipft/ft})) + (4 \times (-0.70764 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1524 \text{ ft}$$

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

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

$$V_{max} = ((-0.70764 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.1197 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.1524 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (9.1197 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.1524 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.4794 \text{ kip}$$

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

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

$$M_{max} = ((-0.70764 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[\left(\frac{(9.1197 \text{ ft})}{(6 \text{ ft})} + \frac{(4.1524 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[\left(\frac{4 \times (9.1197 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.1524 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (9.1197 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.1524 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 26.899 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-0.032 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.0050955 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.071 \text{ kipft}) + ((-0.032 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.011306 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.011306 \text{ kipft/ft})}{(-0.0050955 \text{ kip/ft})}$$

$$E = 2.2188 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011306 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.0050955 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (0.011306 \text{ kipft/ft})) + (4 \times (-0.0050955 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.3216 \text{ ft}$$

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

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

$$V_{max} = ((-0.0050955 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.2188 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.3216 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (2.2188 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.3216 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.02698 \text{ kip}$$

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

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

$$M_{max} = ((-0.0050955 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[\left(\frac{(2.2188 \text{ ft})}{(6 \text{ ft})} + \frac{(4.3216 \text{ ft})}{2 \times (6 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (2.2188 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.3216 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.2188 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.3216 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.070076 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\left(\frac{10.838 \text{ kip}}{(0.65) \times (0.8)} \right) - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.236 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.236 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = Min[1.5, (1.5 d_{bar})]$</p> <p>$s_{rebar} = Min[1.5, (1.5 \times (0.625 \text{ in}))]$</p> <p>$s_{rebar} = 1.5 \text{ in}$</p> <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10: Use #3(0.375 in)</p> <p>$s_{ties} = Min[(16 d_{bar}), (48 d_{ties}), Min(D, b)]$</p> <p>$s_{ties} = Min[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), Min((48 \text{ in}), (48 \text{ in}))]$</p> <p>$s_{ties} = 10 \text{ in}$</p> <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> <p style="text-align: center;">$\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_y A_{st})]$</p> <p style="text-align: center;">$\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$</p> <p style="text-align: center;">$\phi P_N = 2675.2 \text{ kip}$</p> <p>Ratio - Capacity</p> <p style="text-align: center;">$Ratio = \frac{P}{\phi P_N}$</p> <p style="text-align: center;">$Ratio = \frac{(10.838 \text{ kip})}{(2675.2 \text{ kip})}$</p> <p style="text-align: center;">$Ratio = 0.0040513$</p>	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> <p style="text-align: center;">$d = 0.80 D$</p> <p style="text-align: center;">$d = 0.80 \times (48 \text{ in})$</p> <p style="text-align: center;">$d = 38.4 \text{ in}$</p> <p>λ_s - size effect modification factor</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = MIN \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$</p> <p style="text-align: center;">$\lambda_s = 0.64282$</p> <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> <p style="text-align: center;">$V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$</p> <p style="text-align: center;">$V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$</p>	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.838 \text{ kip} \rightarrow 10838 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(10838 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.93 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.93 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.93 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.93 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.04 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.4794 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(9.4794 \text{ kip})}{(111.04 \text{ kip})}$$

$$Ratio = 0.085372$$

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

Considering z-direction:

$V_{max} = 0.02698 \text{ kip}$ - Maximum shear force in the z-direction,
Ratio - Capacity

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

$$Ratio = \frac{(0.02698 \text{ kip})}{(111.04 \text{ kip})}$$

$$Ratio = 0.00024299$$

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:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

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

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

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_c \times S_m$$

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 26.899 \text{ kipft}$ - Maximum moment in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(26.899 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.10777$$

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

Considering z-direction:

$M_{max} = 0.070076 \text{ kipft}$ - Maximum moment in the z-direction,

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.070076 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00028075$$

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

REFERENCES	CALCULATIONS	RESULTS
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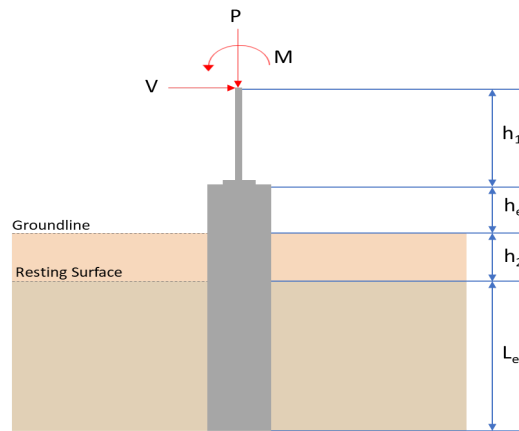
SkyCiv Foundation Design

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

$L = 6$ 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)	6.807	10.836
V_x (kip)	-2.654	-4.443
V_z (kip)	0.018	0.033
M_x (kipft)	0.040	0.071
M_z (kipft)	23.966	40.526

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,

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

$$H_o = \frac{(-2.654 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.42261 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(23.966 \text{ kipft}) + ((-2.654 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 3.8162 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_e^3 - \left(14.14 \times \frac{H_o \times L_x}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$$

Solving the cubic equation:

$L_{e,x} = 5.4954 \text{ ft}$ - Required depth in x-direction,

Considering z-direction:

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.018 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0028662 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.04 \text{ kipft}) + ((0.018 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.0063694 \text{ kipft/ft}$$

Required depth of embedment in earth:

$$L_e^3 - \left(14.14 \times \frac{H_o \times L_z}{R} \right) - \left(18.85 \times \frac{M_o}{R} \right) = 0$$

Solving the cubic equation:

$L_{e,z} = 0.87043 \text{ ft}$ - Required depth in z-direction,

Minimum embedded depth required:

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

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

$$L_{e,req} = \text{MAX}[(5.4954 \text{ ft}), (0.87043 \text{ ft})]$$

$$L_{e,req} = 5.495 \text{ ft}$$

L_e - Actual embedded length of pile,

$$L_e = L - h_e - h_2$$

$$L_e = (6 \text{ ft}) - (0 \text{ ft}) - (0 \text{ ft})$$

$$L_e = 6 \text{ ft}$$

Ratio - Embedded depth

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

$$\text{Ratio} = \frac{(5.495 \text{ ft})}{(6 \text{ ft})}$$

$$\text{Ratio} = 0.91583$$

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

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

$$q = \frac{(6.807 \text{ kip})}{(16 \text{ ft}^2)}$$

$$q = 0.42544 \text{ kip/ft}^2$$

Check bearing capacity ratio:

Ratio - Capacity

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

$$\text{Ratio} = \frac{(0.42544 \text{ kip/ft}^2)}{(2000 \text{ psf})}$$

$$\text{Ratio} = 0.21272$$

Status: **PASS**
Ratio: **0.210**

Czerniak

Lateral Soil Pressure (ASD):

L/D - Length to least lateral dimension ratio,

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

$$L/D = \frac{(6 \text{ ft})}{(48 \text{ in})}$$

$$L/D = 1.5$$

Since $L/D \leq 10$,

Pile is short.

Considering x-direction:

$H_o = -0.42261 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 3.8162 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (3.8162 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.42261 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (3.8162 \text{ kipft/ft})) + (4 \times (-0.42261 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1535 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (3.8162 \text{ kipft/ft})) + (3 \times (-0.42261 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (3.8162 \text{ kipft/ft})) + (2 \times (-0.42261 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = 0.19158 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (3.8162 \text{ kipft/ft})) + ((-0.42261 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.84947 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.1535 \text{ ft})}{2}$$

$$p_a = 0.31151 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.19158 \text{ kip/ft}^2)}{(0.31151 \text{ kip/ft}^2)}$$

$$Ratio = 0.61499$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6 \text{ ft})$$

$$p_s = 0.9 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.84947 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.94385$$

Status: **PASS**
Ratio: **0.610**

Status: **PASS**
Ratio: **0.940**

Considering z-direction:

$H_o = 0.0028662 \text{ kip/ft}$ - Lateral force per length of pile,

$M_o = 0.0063694 \text{ kipft/ft}$ - Overturning moment per length of pile,

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.0063694 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (0.0028662 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (0.0063694 \text{ kipft/ft})) + (4 \times (0.0028662 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.3214 \text{ ft}$$

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

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

$$p = \frac{0.75 \times [(4 \times (0.0063694 \text{ kipft/ft})) + (3 \times (0.0028662 \text{ kip/ft}) \times (6 \text{ ft}))]^2}{(6 \text{ ft})^2 \times [(3 \times (0.0063694 \text{ kipft/ft})) + (2 \times (0.0028662 \text{ kip/ft}) \times (6 \text{ ft}))]}$$

$$p = 0.0023129 \text{ kip/ft}^2$$

s - Earth pressure against the pile at distance L_e ,

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

$$s = \frac{6 \times [(2 \times (0.0063694 \text{ kipft/ft})) + ((0.0028662 \text{ kip/ft}) \times (6 \text{ ft}))]}{(6 \text{ ft})^2}$$

$$s = 0.0049894 \text{ kip/ft}^2$$

Check lateral soil pressure capacity:

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

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

$$p_a = (150 \text{ psf/ft}) \times \frac{(4.3214 \text{ ft})}{2}$$

$$p_a = 0.32411 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0023129 \text{ kip/ft}^2)}{(0.32411 \text{ kip/ft}^2)}$$

$$Ratio = 0.0071361$$

p_s - Allowable lateral soil pressure at depth L_e ,

$$p_s = R L_e$$

$$p_s = (150 \text{ psf/ft}) \times (6 \text{ ft})$$

$$p_s = 0.9 \text{ kip/ft}^2$$

Ratio - Lateral soil capacity

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

$$Ratio = \frac{(0.0049894 \text{ kip/ft}^2)}{(0.9 \text{ kip/ft}^2)}$$

$$Ratio = 0.0055438$$

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

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



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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(-4.443 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = -0.70748 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(40.526 \text{ kipft}) + ((-4.443 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 6.4532 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(6.4532 \text{ kipft/ft})}{(-0.70748 \text{ kip/ft})}$$

$$E = 9.1213 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (6.4532 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (-0.70748 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (6.4532 \text{ kipft/ft})) + (4 \times (-0.70748 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = \frac{(-0.70748 \text{ kip/ft}) \times (48 \text{ in})}{(6 \times (6.4532 \text{ kipft/ft})) + (4 \times (-0.70748 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.1524 \text{ ft}$$

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

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

$$V_{max} = ((-0.70748 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (9.1213 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.1524 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] + \left[4 \times \left(\frac{3 \times (9.1213 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.1524 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 9.4786 \text{ kip}$$

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

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

$$M_{max} = ((-0.70748 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[\left(\frac{(9.1213 \text{ ft})}{(6 \text{ ft})} + \frac{(4.1524 \text{ ft})}{2 \times (6 \text{ ft})} \right) - \left[\left(\frac{4 \times (9.1213 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.1524 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (9.1213 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.1524 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 26.897 \text{ kipft}$$

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

H_o - Lateral force per length of pile,

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

$$H_o = \frac{(0.033 \text{ kip})}{1.57 \times (48 \text{ in})}$$

$$H_o = 0.0052548 \text{ kip/ft}$$

M_o - Moment per length of pile,

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

$$M_o = \frac{(0.071 \text{ kipft}) + ((0.033 \text{ kip}) \times (0 \text{ ft}))}{1.57 \times (48 \text{ in})}$$

$$M_o = 0.011306 \text{ kipft/ft}$$

E - Distance from lateral load to resisting surface,

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

$$E = \frac{(0.011306 \text{ kipft/ft})}{(0.0052548 \text{ kip/ft})}$$

$$E = 2.1515 \text{ ft}$$

a - Distance from resting surface to pivot point,

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

$$a = \frac{(4 \times (0.011306 \text{ kipft/ft}) \times (6 \text{ ft})) + (3 \times (0.0052548 \text{ kip/ft}) \times (6 \text{ ft})^2)}{(6 \times (0.011306 \text{ kipft/ft})) + (4 \times (0.0052548 \text{ kip/ft}) \times (6 \text{ ft}))}$$

$$a = 4.3251 \text{ ft}$$

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

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

$$V_{max} = ((0.0052548 \text{ kip/ft}) \times (48 \text{ in})) \times \left[1 - \left[3 \times \left(\frac{4 \times (2.1515 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.3251 \text{ ft})}{(6 \text{ ft})} \right)^2 \right] \right. \\ \left. + \left[4 \times \left(\frac{3 \times (2.1515 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.3251 \text{ ft})}{(6 \text{ ft})} \right)^3 \right] \right]$$

$$V_{max} = 0.027414 \text{ kip}$$

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

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

$$M_{max} = ((0.0052548 \text{ kip/ft}) \times (48 \text{ in}) \times (6 \text{ ft})) \times \left[\left(\frac{(2.1515 \text{ ft})}{(6 \text{ ft})} + \frac{(4.3251 \text{ ft})}{2 \times (6 \text{ ft})} \right) \right. \\ \left. - \left[\left(\frac{4 \times (2.1515 \text{ ft})}{(6 \text{ ft})} + 3 \right) \times \left(\frac{(4.3251 \text{ ft})}{2 \times (6 \text{ ft})} \right)^3 \right] + \left[\left(\frac{3 \times (2.1515 \text{ ft})}{(6 \text{ ft})} + 2 \right) \times \left(\frac{(4.3251 \text{ ft})}{2 \times (6 \text{ ft})} \right)^4 \right] \right]$$

$$M_{max} = 0.07104 \text{ kipft}$$

Minimum Reinforcement Check (LRFD)

Parameters:

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

$f_{yk} = 60 \text{ ksi}$ - Longitudinal reinforcement strength,

$\phi = 0.65$ - Reduction factor for axial strength,

$\alpha = 0.8$ - Alpha factor for axial strength,

$A_g = 2304 \text{ in}^2$ - Gross area of concrete,

Longitudinal reinforcement:

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

$A_{st,required}$

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

$$A_{st,required} = \text{Min} \left[\frac{\frac{(10.836 \text{ kip})}{(0.65) \times (0.8)} - (0.85 \times (2.5 \text{ ksi}) \times (2304 \text{ in}^2))}{(60 \text{ ksi}) - (0.85 \times (2.5 \text{ ksi}))}, (0.08 \times (2304 \text{ in}^2)) \right]$$

$$A_{st,required} = -84.236 \text{ in}^2$$

A_{min} - Governing minimum reinforcement area,

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

$$A_{min} = \text{Max} [(-84.236 \text{ in}^2), (0.0018 \times (2304 \text{ in}^2))]$$

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

n_{rebar} - Required number of reinforcement,

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

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

$$n_{rebar} = 14$$

A_{st} - Actual total reinforcement area,

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

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

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

Ratio - Capacity

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

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

Table 22.4.2.1

22.4.2.2, 10.6.1.1

<p>25.2.3</p> <p>25.7.2.2</p> <p>25.7.2.1</p>	<p style="text-align: center;">$Ratio = 0.96556$</p> <p>$s_{rebar} = \text{Min spacing of reinforcement,}$</p> $s_{rebar} = \text{Max}[1.5, (1.5 d_{bar})]$ $s_{rebar} = \text{Max}[1.5, (1.5 \times (0.625 \text{ in}))]$ $s_{rebar} = 1.5 \text{ in}$ <p>Ties:</p> <p>Since longitudinal reinforcement is \leq No. 10ø: Use #3(0.375 in)</p> <p>s_{ties} - Maximum spacing of ties,</p> $s_{ties} = \text{Min}[(16 d_{bar}), (48 d_{ties}), \text{Min}(D, b)]$ $s_{ties} = \text{Min}[(16 \times (0.625 \text{ in})), (48 \times (0.375 \text{ in})), \text{Min}((48 \text{ in}), (48 \text{ in}))]$ $s_{ties} = 10 \text{ in}$ <p>Summary:</p> <p style="text-align: center;">Main reinforcement: 14 - #5 (0.625 in) Ties: #3(0.375 in) - 10 in</p>	<p>Status: PASS Ratio: 0.970</p>
<p>22.4.2.2</p>	<p>Axial Compression Strength (ACI 318-19, LRFD)</p> <p>ϕP_N - Allowable axial compressive strength</p> $\phi P_N = \phi 0.80 [(0.85 f'_{ck} [A_g - A_{st}]) + (f_{yk} A_{st})]$ $\phi P_N = (0.65) \times 0.80 \times [(0.85 \times (2.5 \text{ ksi}) \times [(2304 \text{ in}^2) - (4.2951 \text{ in}^2)]) + ((60 \text{ ksi}) \times (4.2951 \text{ in}^2))]$ $\phi P_N = 2675.2 \text{ kip}$ <p><i>Ratio</i> - Capacity</p> $Ratio = \frac{P}{\phi P_N}$ $Ratio = \frac{(10.836 \text{ kip})}{(2675.2 \text{ kip})}$ $Ratio = 0.0040506$	<p>Status: PASS Ratio: 0.000</p>
<p>22.5.2.2</p> <p>22.5.5.1.3</p> <p>22.5.5.1.1</p>	<p>Shear Strength (ACI 318-19, LRFD)</p> <p>Parameters:</p> <p>$b_w = 48 \text{ in}$ - Effective width, d - Effective depth</p> $d = 0.80 D$ $d = 0.80 \times (48 \text{ in})$ $d = 38.4 \text{ in}$ <p>λ_s - size effect modification factor</p> $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{d}{10}}}, 1 \right]$ $\lambda_s = \text{MIN} \left[\sqrt{\frac{2}{1 + \frac{(38.4 \text{ in})}{10}}}, 1 \right]$ $\lambda_s = 0.64282$ <p>The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$,</p> <p>$V_{c,max}$ - Max shear strength of concrete</p> $V_{c,max} = 5 \lambda_s \sqrt{f'_{ck}} b_w d$ $V_{c,max} = 5 \times (0.64282) \times \sqrt{(2500 \text{ psi})} \times (48 \text{ in}) \times (38.4 \text{ in})$	

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

22.5.5.1.1(a) The following variables were converted to be consistent with empirical formula $f'_{ck} = 2.5 \text{ ksi} \rightarrow 2500 \text{ psi}$, $P = 10.836 \text{ kip} \rightarrow 10836 \text{ lbf}$,
 $V_{c,a}$ - Shear strength of concrete (a)

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

$$V_{c,a} = \left[2 \times (0.64282) \times \sqrt{(2500 \text{ psi}) + \frac{(10836 \text{ lbf})}{6 \times (2304 \text{ in}^2)}} \right] \times (48 \text{ in}) \times (38.4 \text{ in})$$

$$V_{c,a} = 119.93 \text{ kip}$$

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

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

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

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

V_c - Governing shear strength of concrete

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

$$V_c = \text{Min}[(296.21 \text{ kip}), (119.93 \text{ kip}), (348.89 \text{ kip})]$$

$$V_c = 119.93 \text{ kip}$$

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

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

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

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

A_v - Ties rebar area,

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

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

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

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

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

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

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

V_s - Governing shear strength of steel

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

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

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

22.5.1.1 ϕV_n - Allowable shear strength

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

$$\phi V_n = (0.65) \times ((119.93 \text{ kip}) + (50.894 \text{ kip}))$$

$$\phi V_n = 111.04 \text{ kip}$$

Considering x-direction:

$V_{max} = 9.4786 \text{ kip}$ - Maximum shear force in the x-direction,

Ratio - Capacity

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

$$Ratio = \frac{(9.4786 \text{ kip})}{(111.04 \text{ kip})}$$

$$Ratio = 0.085365$$

Considering z-direction:

$V_{max} = 0.027414 \text{ kip}$ - Maximum shear force in the z-direction,

$Ratio$ - Capacity

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

$$Ratio = \frac{(0.027414 \text{ kip})}{(111.04 \text{ kip})}$$

$$Ratio = 0.00024689$$

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

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:

$\phi M_{n,1}$

$$\phi M_{n,1} = \phi \times 5 \times \lambda \times \sqrt{f'_c} \times S_m$$

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

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

14.5.2.1b

$\phi M_{n,2}$

$$\phi M_{n,2} = \phi \times 0.85 \times f'_{ck} \times S_m$$

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

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

Therefore,

ϕM_n - Allowable flexural strength,

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

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

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

Considering x-direction:

$M_{max} = 26.897 \text{ kipft}$ - Maximum moment in the x-direction,

$Ratio$ - Capacity

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

$$Ratio = \frac{(26.897 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$Ratio = 0.10776$$

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

Considering z-direction:

$M_{max} = 0.07104 \text{ kipft}$ - Maximum moment in the z-direction,

$Ratio$ - Capacity

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

$$\text{Ratio} = \frac{(0.07104 \text{ kipft})}{(249.6 \text{ kipft})}$$

$$\text{Ratio} = 0.00028461$$

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