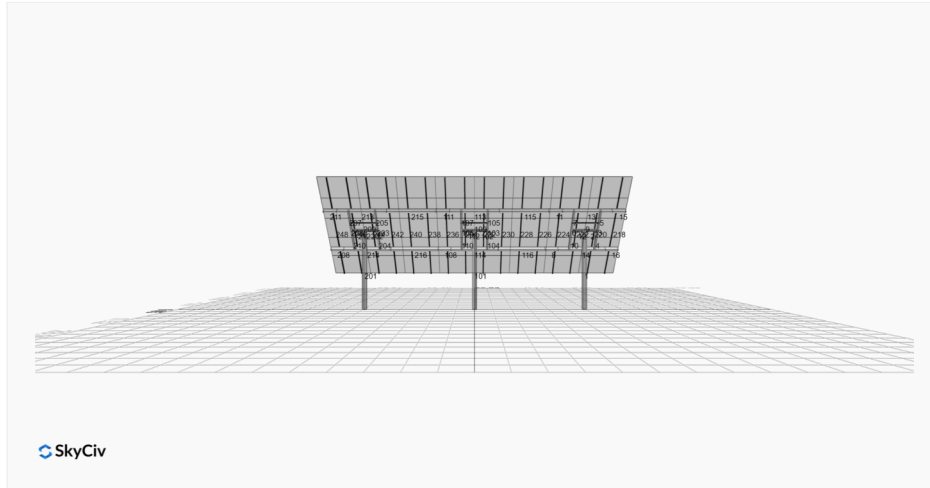


Project Name: MTSOLAR_452BC90C7IEA8 **Date:** Sat Nov 08 2025
Location: 20 Sherry Rd, Harvard, MA 01451, USA **Number of Modules:** 40
Unique ID: 3P-17-8TOP-HD-24-L-5Hx8W-EJ58 **Number of Poles:** 3
Dealer: _____ **Date Sold:** _____



Array Dimensions N/S	18.83 ft
Array Dimensions E/W	45.87 ft
Winter Tilt Angle (Degrees)	50
Front Edge Clearance	5

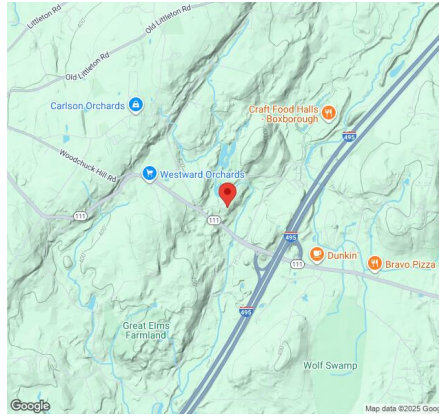
MT Solar Bill of Materials (3P-17-8TOP-HD-24-L-5Hx8W-EJ58)

Part	Short Description	BOM Qty
MTS-PC-8	8IN Pole Cap Assembly	3
MTS-HF-HD	H-Frame Assembly-HD	3
MTS-HD-Wing-24	24IN HD Wing	4
MTS-HD-Splice-57	57IN HD Splice	8
MTS-CLAMP-ANGLE-4PK	Angle Clamp	8

Rail Bill of Materials

Part	Qty
Rails (226in Long)	16x
Rail Attachment	64x
Module Mid Clamp	64x
Module End Clamp	32x
Ground Lug	8x

Site Details:



Site Address: 20 Sherry Rd, Harvard, MA 01451, USA

Array Specifications

Duty Classification:	HD
Module Width:	44.70 in
Module Length:	67.80 in
Number of Rows:	5
Number of Columns:	8
Total Number of Modules:	40
Winter Tilt Angle:	50
Front Edge Clearance:	5
Total Array Height at Tilt:	19.43 ft
Total Frame Length:	45.50 ft
Module Info/Notes:	te
Array Dimensions N/S:	18.83 ft
Array Dimensions E/W:	45.87 ft
Rail Length:	226.00 in
Rail Spacing:	2.87 ft

Support Specifications

Pole Size:	8in Pipe Sch 80
Pole Length above Grade:	12.21 ft
Number of Poles:	3
Pole Spacing:	17 ft

Foundation Specifications

Foundation Type:	rectangular
Foundation Dimensions:	48x48 in
Foundation Depth (below grade):	7.5 ft
Foundation Volume:	120.00 ft ³

Site Info

Risk Category:	I
Exposure:	C
Soil Classification:	sand
Site Location:	20 Sherry Rd, Harvard, MA 01451, USA
Wind Speed:	116 mph

Snow Load:

50 psf

Design Disclaimer

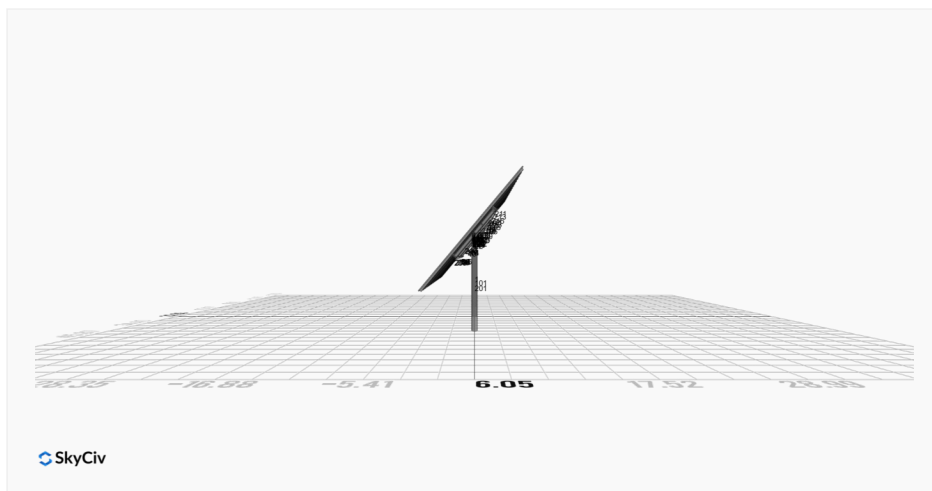
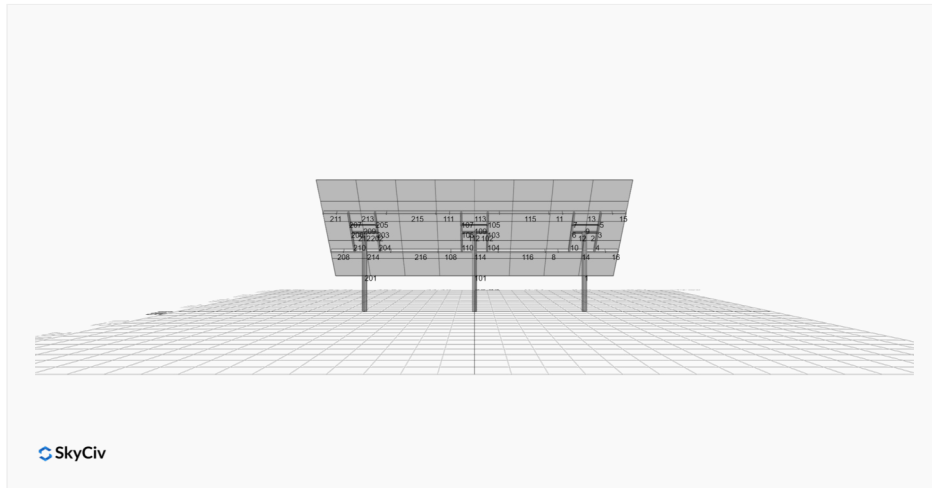
This software should be used for preliminary designs and should not be used as a final design unless reviewed, verified and designed by a qualified structural engineer.

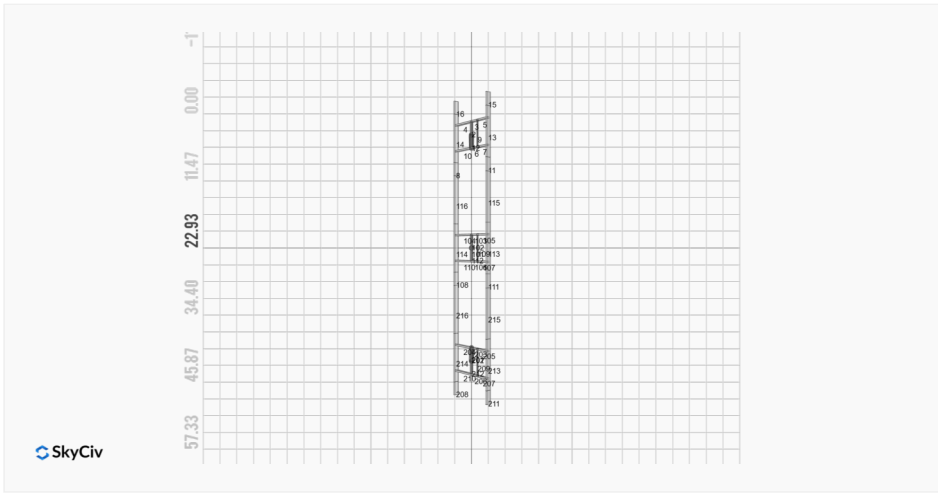
AutoDesigner Input

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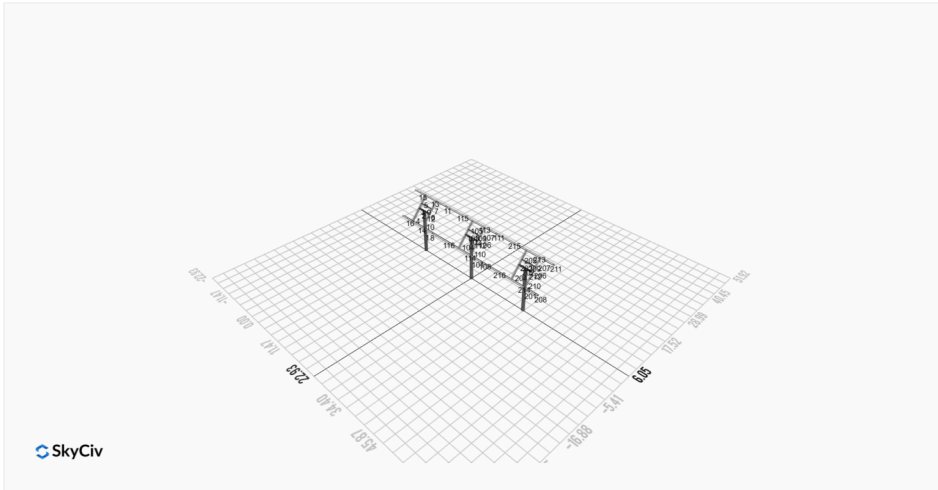
Design Notes:

- Deflection checks are set to L/1 due to manufacturer structural design intent
- Foundation Soil Parameters used in this Autodesigned 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 7-16
- Steel frame design checks are based on AISC 360-16 LRFD
- Design / analysis of fixings and connections are not carried out by this module.
- Impacts of eccentrically applied, partial or pattern loading are not considered by this module.
- Foundation Design and Sizing is approximate only

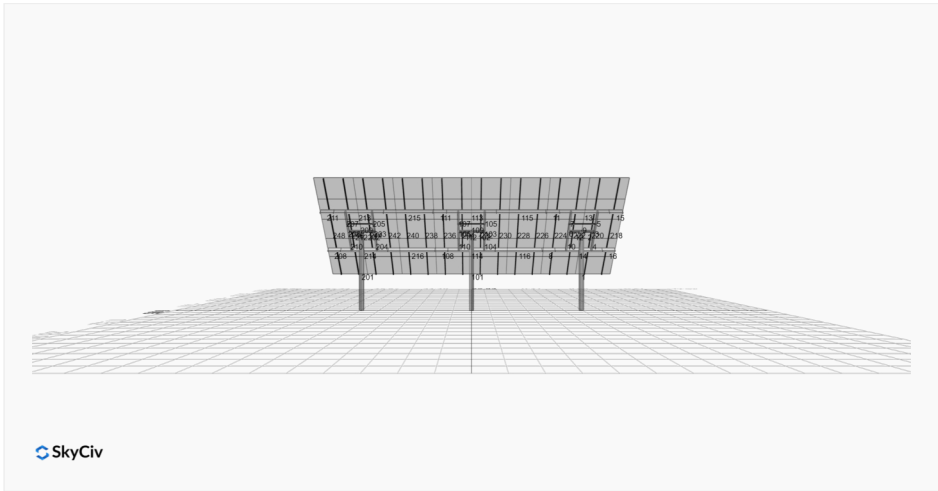




SkyCiv

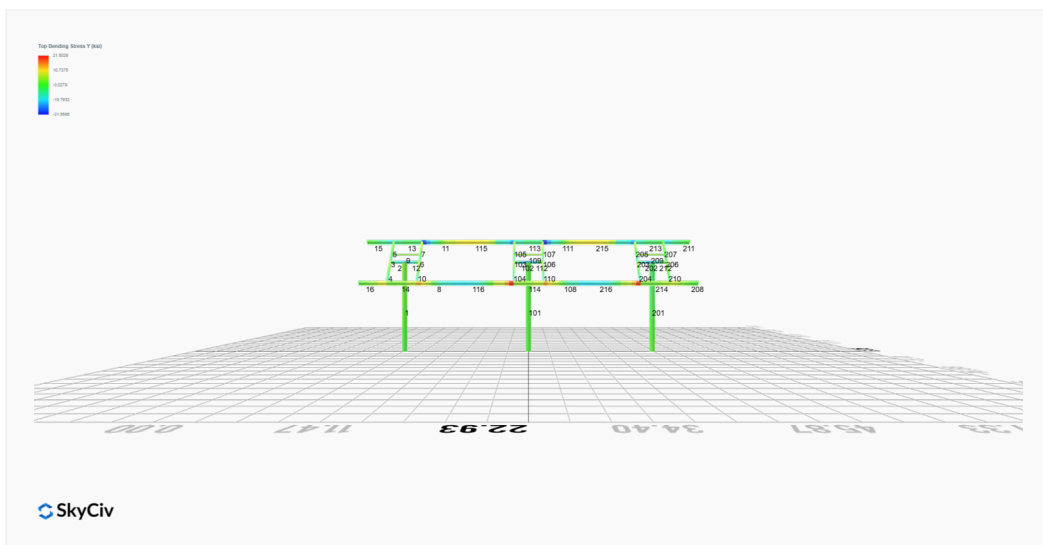
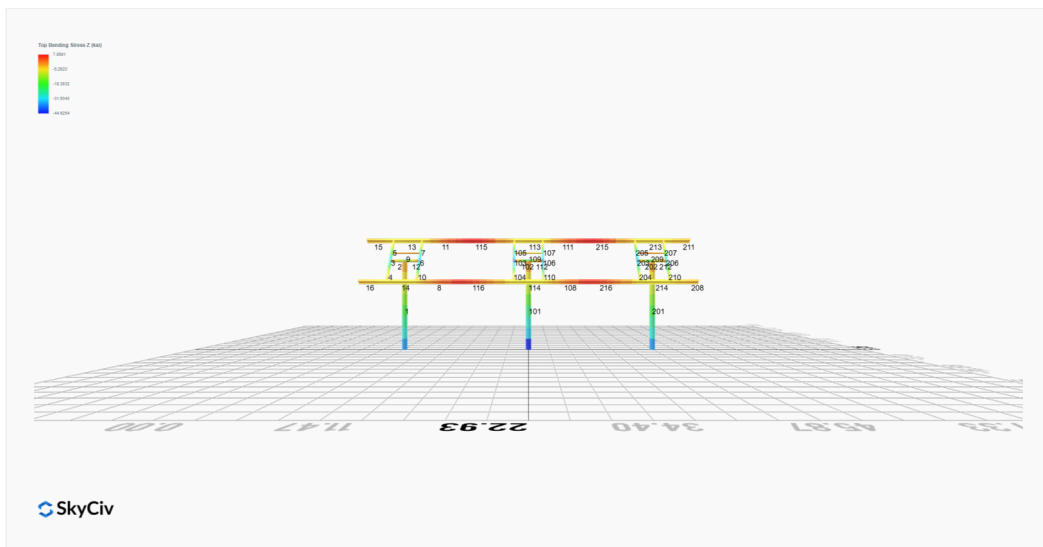
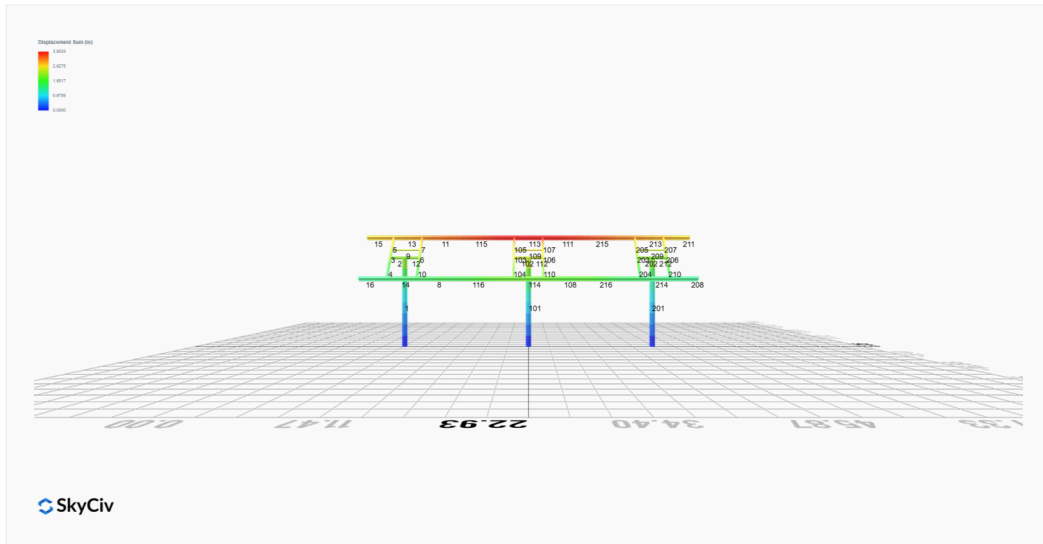


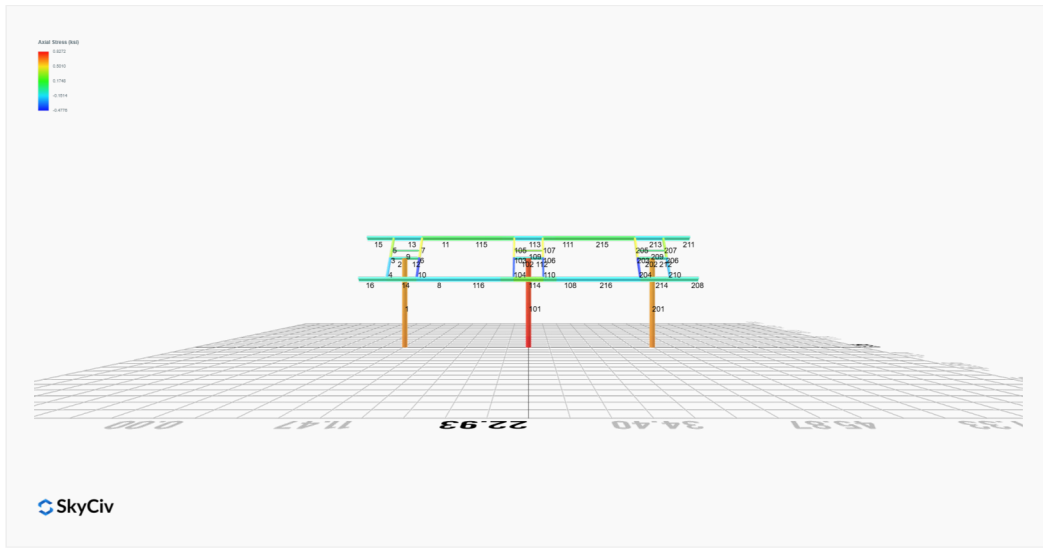
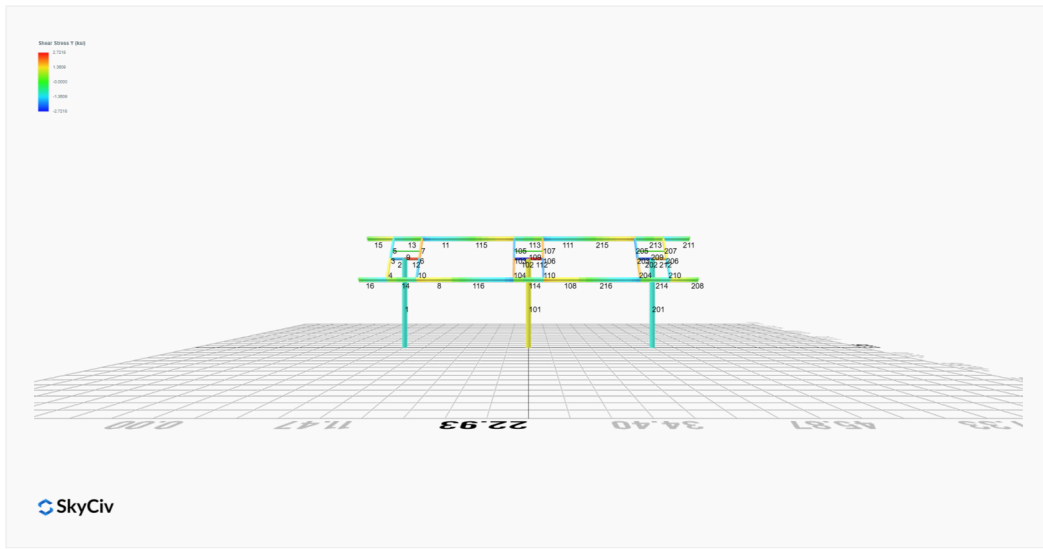
SkyCiv



SkyCiv

FEM Results (Envelope Worst Case)





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

LRFD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. 1.4D	0.0187	3.1461	0.0616	0.2217	-0.0629	-0.1748
ULS: 2. 1.2D + 1.6L + 0.5(S or Lr or R)	0.0245	3.6436	0.0807	0.2903	-0.0826	-0.2381
ULS: 2. 1.2D + 1.6L + 0.5(S or Lr or R)	0.0160	2.6967	0.0528	0.1899	-0.0539	-0.1506
ULS: 3. 1.2D + 1.6(S or Lr or R) + L	0.0429	5.7270	0.1421	0.5121	-0.1463	-0.4217
ULS: 5. 1.2D + E + L + 0.2S	0.0194	3.0755	0.0639	0.2301	-0.0654	-0.1859
ULS: 7. 0.9D + 1.0E	0.0120	2.0225	0.0396	0.1424	-0.0404	-0.1139
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case A only	-6.2001	8.7813	0.3574	1.2085	-1.7907	77.9024
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case B only	0.0245	3.6436	0.0807	0.2903	-0.0826	-0.2381
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case A only	6.2400	-1.4890	-0.1901	-0.6069	1.5916	-76.3643
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case B only	0.0245	3.6436	0.0807	0.2903	-0.0826	-0.2381
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case A only	-6.2076	7.8339	0.3291	1.1065	-1.7593	77.7821
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case B only	0.0160	2.6967	0.0528	0.1899	-0.0539	-0.1506
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case A only	6.2307	-2.4356	-0.2175	-0.7057	1.6179	-76.0814
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case B only	0.0160	2.6967	0.0528	0.1899	-0.0539	-0.1506
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case A only	-3.0693	8.2957	0.2802	0.9703	-0.9989	38.6182
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case B only	0.0429	5.7270	0.1421	0.5121	-0.1463	-0.4217
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case A only	3.1528	3.1596	0.0054	0.0591	0.6977	-38.9511
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case B only	0.0429	5.7270	0.1421	0.5121	-0.1463	-0.4217
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case A only	-3.0946	5.2647	0.1902	0.6455	-0.9023	38.5595
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case B only	0.0160	2.6967	0.0528	0.1899	-0.0539	-0.1506
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case A only	3.1245	0.1299	-0.0831	-0.2604	0.7861	-38.3604
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case B only	0.0160	2.6967	0.0528	0.1899	-0.0539	-0.1506
ULS: 6. 0.9D + 1.0W_Wind downforce Case A only	-6.2111	7.1595	0.3156	1.0579	-1.7443	77.6771
ULS: 6. 0.9D + 1.0W_Wind downforce Case B only	0.0120	2.0225	0.0396	0.1424	-0.0404	-0.1139
ULS: 6. 0.9D + 1.0W_Wind uplift Case A only	6.2262	-3.1095	-0.2305	-0.7524	1.6300	-75.9113
ULS: 6. 0.9D + 1.0W_Wind uplift Case B only	0.0120	2.0225	0.0396	0.1424	-0.0404	-0.1139

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 2. D + L	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 3. D + (S or Lr or R)	0.0302	4.1412	0.0997	0.3590	-0.1024	-0.3003
ULS: 3. D + (S or Lr or R)	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0260	3.6677	0.0858	0.3087	-0.0880	-0.2577
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 5b. D + 0.7E	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0260	3.6677	0.0858	0.3087	-0.0880	-0.2577
ULS: 8. 0.6D + 0.7E	0.0080	1.3483	0.0264	0.0948	-0.0269	-0.0765
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.7195	5.3289	0.2089	0.7052	-1.0634	46.3310
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.7430	-0.8326	-0.1188	-0.3813	0.9616	-45.8648
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7740	5.9790	0.2096	0.7193	-0.8525	34.6544
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0260	3.6677	0.0858	0.3087	-0.0880	-0.2577
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8242	1.3573	-0.0369	-0.0977	0.6696	-34.7619
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0260	3.6677	0.0858	0.3087	-0.0880	-0.2577

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	-2.7860	4.5583	0.1675	0.5677	-0.8076	34.6482
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8109	-0.0628	-0.0783	-0.2471	0.7111	-34.4964
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0134	2.2472	0.0440	0.1582	-0.0449	-0.1262
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.7244	4.4298	0.1911	0.6411	-1.0442	46.2691
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0080	1.3483	0.0264	0.0948	-0.0269	-0.0765
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.7373	-1.7313	-0.1362	-0.4439	0.9784	-45.7075
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0080	1.3483	0.0264	0.0948	-0.0269	-0.0765

Worst Case Reactions (LRFD)

Note: Downforce / downwind wind load cases are assumed to govern.

Result	Value (kip, kip-ft)
Axial	8.7813
Shear X	-6.2400
Shear Z	0.3574
Moment X	1.2085
Moment Y (Twist)	1.7907
Moment Z	77.9024

Worst Case Reactions (ASD)

Note: Downforce / downwind wind load cases are assumed to govern.

Result	Value (kip, kip-ft)
Axial	5.9790
Shear X	-3.7430
Shear Z	0.2096
Moment X	0.7193
Moment Y (Twist)	1.0634
Moment Z	46.3310

Reaction Forces for Foundation 2 (Node ID#101), (kip, kip-ft)

LRFD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. 1.4D	-0.0374	3.6176	-0.0000	0.0000	0.0000	0.4492
ULS: 2. 1.2D + 1.6L + 0.5(S or Lr or R)	-0.0489	4.2598	-0.0000	0.0000	0.0001	0.5796
ULS: 2. 1.2D + 1.6L + 0.5(S or Lr or R)	-0.0321	3.1008	-0.0000	0.0000	0.0000	0.3838
ULS: 3. 1.2D + 1.6(S or Lr or R) + L	-0.0857	6.8094	0.0000	0.0000	0.0001	1.0225
ULS: 5. 1.2D + E + L + 0.2S	-0.0388	3.5644	-0.0000	0.0000	0.0000	0.4617
ULS: 7. 0.9D + 1.0E	-0.0241	2.3256	-0.0000	0.0000	0.0000	0.2865
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case A only	-7.3513	10.5579	-0.0000	-0.0000	0.0000	91.1619
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case B only	-0.0489	4.2598	-0.0000	0.0000	0.0001	0.5796
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case A only	7.2716	-2.0484	0.0000	0.0001	0.0000	-87.6168
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case B only	-0.0489	4.2598	-0.0000	0.0000	0.0001	0.5796
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case A only	-7.3364	9.3999	-0.0000	-0.0000	0.0000	90.7181
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case B only	-0.0321	3.1008	-0.0000	0.0000	0.0000	0.3838
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case A only	7.2902	-3.2082	0.0000	0.0000	0.0000	-87.5791
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case B only	-0.0321	3.1008	-0.0000	0.0000	0.0000	0.3838
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case A only	-3.7371	9.9587	-0.0000	-0.0000	0.0001	46.2801
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case B only	-0.0857	6.8094	0.0000	0.0000	0.0001	1.0225
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case A only	3.5702	3.6575	0.0000	0.0001	0.0001	-43.6304
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case B only	-0.0857	6.8094	0.0000	0.0000	0.0001	1.0225
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case A only	-3.6865	6.2516	-0.0000	0.0000	0.0000	45.2476
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case B only	-0.0321	3.1008	-0.0000	0.0000	0.0000	0.3838
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case A only	3.6269	-0.0525	0.0000	0.0000	0.0000	-43.8872
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case B only	-0.0321	3.1008	-0.0000	0.0000	0.0000	0.3838
ULS: 6. 0.9D + 1.0W_Wind downforce Case A only	-7.3294	8.6252	-0.0000	-0.0000	0.0000	90.4568
ULS: 6. 0.9D + 1.0W_Wind downforce Case B only	-0.0241	2.3256	-0.0000	0.0000	0.0000	0.2865
ULS: 6. 0.9D + 1.0W_Wind uplift Case A only	7.2992	-3.9839	0.0000	0.0000	0.0000	-87.5222
ULS: 6. 0.9D + 1.0W_Wind uplift Case B only	-0.0241	2.3256	-0.0000	0.0000	0.0000	0.2865

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 2. D + L	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 3. D + (S or Lr or R)	-0.0604	4.9019	0.0000	0.0000	0.0001	0.7115
ULS: 3. D + (S or Lr or R)	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0520	4.3225	0.0000	0.0000	0.0000	0.6120
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 5b. D + 0.7E	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	-0.0520	4.3225	0.0000	0.0000	0.0000	0.6120
ULS: 8. 0.6D + 0.7E	-0.0161	1.5504	-0.0000	0.0000	0.0000	0.1901
ULS: 5a. D + 0.6W_Wind downforce Case A only	-4.4120	6.3649	-0.0000	-0.0000	0.0000	54.1629
ULS: 5a. D + 0.6W_Wind downforce Case B only	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 5a. D + 0.6W_Wind uplift Case A only	4.3649	-1.2004	0.0000	0.0000	0.0000	-52.6739
ULS: 5a. D + 0.6W_Wind uplift Case B only	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.3403	7.1578	-0.0000	-0.0000	0.0000	41.0783
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0520	4.3225	0.0000	0.0000	0.0000	0.6120
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2399	1.4850	0.0000	0.0000	0.0000	-39.3711
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0520	4.3225	0.0000	0.0000	0.0000	0.6120
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-3.3163	5.4200	-0.0000	-0.0000	0.0000	40.6208
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	3.2664	-0.2540	0.0000	0.0000	0.0000	-39.5043
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	-0.0268	2.5840	-0.0000	0.0000	0.0000	0.3189
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-4.4021	5.3317	-0.0000	-0.0000	0.0000	53.9050
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	-0.0161	1.5504	-0.0000	0.0000	0.0000	0.1901
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	4.3764	-2.2344	0.0000	0.0000	0.0000	-52.6783
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	-0.0161	1.5504	-0.0000	0.0000	0.0000	0.1901

Worst Case Reactions (LRFD)

Note: Downforce / downwind wind load cases are assumed to govern.

Result	Value (kip, kip-ft)
Axial	10.5579
Shear X	-7.3513
Shear Z	0.0000
Moment X	0.0001
Moment Y (Twist)	0.0001
Moment Z	91.1619

Worst Case Reactions (ASD)

Note: Downforce / downwind wind load cases are assumed to govern.

Result	Value (kip, kip-ft)
Axial	7.1578
Shear X	-4.4120
Shear Z	-0.0000
Moment X	0.0000
Moment Y (Twist)	0.0001
Moment Z	54.1629

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

LRFD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. 1.4D	0.0187	3.1461	-0.0616	-0.2217	0.0630	-0.1747
ULS: 2. 1.2D + 1.6L + 0.5(S or Lr or R)	0.0245	3.6436	-0.0807	-0.2903	0.0827	-0.2380
ULS: 2. 1.2D + 1.6L + 0.5(S or Lr or R)	0.0160	2.6967	-0.0528	-0.1899	0.0539	-0.1505
ULS: 3. 1.2D + 1.6(S or Lr or R) + L	0.0429	5.7270	-0.1421	-0.5121	0.1465	-0.4215
ULS: 5. 1.2D + E + L + 0.2S	0.0194	3.0755	-0.0639	-0.2300	0.0654	-0.1858
ULS: 7. 0.9D + 1.0E	0.0120	2.0225	-0.0396	-0.1423	0.0404	-0.1138
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case A only	-6.2001	8.7813	-0.3574	-1.2085	1.7908	77.9035

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case B only	0.0245	3.6436	-0.0807	-0.2903	0.0827	-0.2380
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case A only	6.2400	-1.4890	0.1901	0.6070	-1.5915	-76.3652
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case B only	0.0245	3.6436	-0.0807	-0.2903	0.0827	-0.2380
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case A only	-6.2076	7.8339	-0.3291	-1.1065	1.7593	77.7832
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind downforce Case B only	0.0160	2.6967	-0.0528	-0.1899	0.0539	-0.1505
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case A only	6.2307	-2.4356	0.2175	0.7057	-1.6178	-76.0823
ULS: 4. 1.2D + W + L + 0.5(S or Lr or R)_Wind uplift Case B only	0.0160	2.6967	-0.0528	-0.1899	0.0539	-0.1505
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case A only	-3.0693	8.2957	-0.2802	-0.9704	0.9991	38.6189
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case B only	0.0429	5.7270	-0.1421	-0.5121	0.1465	-0.4215
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case A only	3.1528	3.1596	-0.0054	-0.0591	-0.6976	-38.9515
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case B only	0.0429	5.7270	-0.1421	-0.5121	0.1465	-0.4215
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case A only	-3.0946	5.2647	-0.1902	-0.6455	0.9023	38.5601
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind downforce Case B only	0.0160	2.6967	-0.0528	-0.1899	0.0539	-0.1505
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case A only	3.1245	0.1300	0.0831	0.2605	-0.7861	-38.3608
ULS: 3. 1.2D + 1.6(S or Lr or R) + 0.5W_Wind uplift Case B only	0.0160	2.6967	-0.0528	-0.1899	0.0539	-0.1505
ULS: 6. 0.9D + 1.0W_Wind downforce Case A only	-6.2111	7.1595	-0.3156	-1.0579	1.7443	77.6779
ULS: 6. 0.9D + 1.0W_Wind downforce Case B only	0.0120	2.0225	-0.0396	-0.1423	0.0404	-0.1138
ULS: 6. 0.9D + 1.0W_Wind uplift Case A only	6.2262	-3.1095	0.2305	0.7524	-1.6299	-75.9120
ULS: 6. 0.9D + 1.0W_Wind uplift Case B only	0.0120	2.0225	-0.0396	-0.1423	0.0404	-0.1138

ASD Load Combination Results

Name	Fx	Fy	Fz	Mx	My	Mz
ULS: 1. D	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 2. D + L	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 3. D + (S or Lr or R)	0.0302	4.1412	-0.0997	-0.3590	0.1025	-0.3002
ULS: 3. D + (S or Lr or R)	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0260	3.6677	-0.0858	-0.3087	0.0881	-0.2576
ULS: 4. D + 0.75L + 0.75(S or Lr or R)	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 5b. D + 0.7E	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 6b. D + 0.75L + 0.75(0.7)E + 0.75S	0.0260	3.6677	-0.0858	-0.3087	0.0881	-0.2576
ULS: 8. 0.6D + 0.7E	0.0080	1.3483	-0.0264	-0.0948	0.0269	-0.0765
ULS: 5a. D + 0.6W_Wind downforce Case A only	-3.7195	5.3289	-0.2089	-0.7052	1.0634	46.3316
ULS: 5a. D + 0.6W_Wind downforce Case B only	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 5a. D + 0.6W_Wind uplift Case A only	3.7430	-0.8326	0.1188	0.3813	-0.9615	-45.8653
ULS: 5a. D + 0.6W_Wind uplift Case B only	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7740	5.9790	-0.2096	-0.7193	0.8525	34.6549
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0260	3.6677	-0.0858	-0.3087	0.0881	-0.2576
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8241	1.3573	0.0369	0.0977	-0.6696	-34.7622
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0260	3.6677	-0.0858	-0.3087	0.0881	-0.2576
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case A only	-2.7860	4.5583	-0.1675	-0.5677	0.8076	34.6487
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind downforce Case B only	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case A only	2.8109	-0.0628	0.0783	0.2471	-0.7110	-34.4968
ULS: 6a. D + 0.75L + 0.75(0.6)W + 0.75(S or Lr or R)_Wind uplift Case B only	0.0134	2.2472	-0.0440	-0.1582	0.0449	-0.1261
ULS: 7. 0.6D + 0.6W_Wind downforce Case A only	-3.7244	4.4298	-0.1911	-0.6411	1.0442	46.2694
ULS: 7. 0.6D + 0.6W_Wind downforce Case B only	0.0080	1.3483	-0.0264	-0.0948	0.0269	-0.0765
ULS: 7. 0.6D + 0.6W_Wind uplift Case A only	3.7373	-1.7313	0.1362	0.4439	-0.9784	-45.7078
ULS: 7. 0.6D + 0.6W_Wind uplift Case B only	0.0080	1.3483	-0.0264	-0.0948	0.0269	-0.0765

Worst Case Reactions (LRFD)

Worst Case Reactions (ASD)

Note: Downforce / downwind wind load cases are assumed to govern.

Result	Value (kip, kip-ft)
Axial	8.7813
Shear X	-6.2400
Shear Z	-0.3574
Moment X	-1.2085
Moment Y (Twist)	1.7908
Moment Z	77.9035

Note: Downforce / downwind wind load cases are assumed to govern.

Result	Value (kip, kip-ft)
Axial	5.9790
Shear X	-3.7430
Shear Z	-0.2096
Moment X	-0.7193
Moment Y (Twist)	1.0634
Moment Z	46.3316

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
2	29000	46	62
4	29000	50	62

Section Dimensions							

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

Section Dimensions							

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

Section Dimensions							

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

Section Properties

208	133.20	102.39	32.87	6.12	40.24	43.62
209	61.16	54.71	3.51	3.51	18.35	18.35
210	116.10	111.33	15.79	11.10	42.08	23.28
211	133.20	102.39	32.87	6.12	40.24	43.62
212	182.47	181.10	20.19	20.19	54.74	54.74
213	133.20	85.85	25.95	6.12	40.24	43.62
214	133.20	85.85	26.28	6.12	40.24	43.62
215	133.20	86.20	25.08	6.12	40.24	43.62
216	133.20	86.20	24.93	6.12	40.24	43.62

Design Ratio

Member ID	P	M _z	M _y	V _y	V _z	(P,M _z ,M _y)	Worst LC	KL/r	δ	Status
1	0.018	0.683	0.028	0.039	0.002	0.703	#13	0.166	Not Required	Pass
2	0.001	0.252	0.242	0.062	0.051	0.494	#13	0.053	Not Required	Pass
3	0.007	0.518	0.042	0.051	0.010	0.544	#13	0.045	Not Required	Pass
4	0.007	0.512	0.070	0.051	0.018	0.571	#13	0.080	Not Required	Pass
5	0.007	0.321	0.057	0.052	0.014	0.323	#13	0.074	Not Required	Pass
6	0.010	0.679	0.089	0.069	0.025	0.736	#13	0.045	Not Required	Pass
7	0.010	0.421	0.126	0.067	0.030	0.437	#13	0.074	Not Required	Pass
8	0.003	0.112	0.097	0.039	0.015	0.179	#13	0.095	Not Required	Pass
9	0.002	0.055	0.076	0.003	0.003	0.130	#13	0.204	Not Required	Pass
10	0.011	0.649	0.127	0.065	0.029	0.668	#13	0.080	Not Required	Pass
11	0.003	0.113	0.094	0.042	0.015	0.177	#21	0.095	Not Required	Pass
12	0.001	0.408	0.330	0.086	0.066	0.739	#13	0.053	Not Required	Pass
13	0.005	0.121	0.302	0.057	0.020	0.337	#21	0.286	Not Required	Pass
14	0.005	0.115	0.301	0.054	0.020	0.320	#21	0.190	Not Required	Pass
15	0.000	0.021	0.043	0.017	0.006	0.058	#21	Not Required	Not Required	Pass
16	0.000	0.021	0.043	0.017	0.006	0.058	#21	Not Required	Not Required	Pass
101	0.022	0.800	0.000	0.046	0.000	0.810	#13	0.166	Not Required	Pass
102	0.002	0.399	0.342	0.091	0.067	0.741	#13	0.053	Not Required	Pass
103	0.010	0.697	0.072	0.070	0.018	0.741	#13	0.045	Not Required	Pass
104	0.010	0.725	0.128	0.073	0.028	0.787	#13	0.080	Not Required	Pass
105	0.010	0.433	0.131	0.069	0.032	0.454	#13	0.074	Not Required	Pass
106	0.010	0.697	0.072	0.070	0.018	0.741	#13	0.045	Not Required	Pass
107	0.010	0.433	0.131	0.069	0.032	0.454	#13	0.074	Not Required	Pass
108	0.003	0.098	0.093	0.043	0.015	0.147	#21	0.095	Not Required	Pass
109	0.007	0.042	0.058	0.001	0.000	0.102	#13	0.204	Not Required	Pass
110	0.010	0.725	0.128	0.073	0.028	0.787	#13	0.080	Not Required	Pass
111	0.003	0.121	0.094	0.040	0.015	0.160	#21	0.095	Not Required	Pass
112	0.002	0.399	0.342	0.091	0.067	0.741	#13	0.053	Not Required	Pass
113	0.005	0.101	0.311	0.055	0.020	0.381	#21	0.286	Not Required	Pass
114	0.007	0.156	0.311	0.058	0.020	0.410	#21	0.286	Not Required	Pass
115	0.004	0.205	0.165	0.040	0.015	0.308	#21	0.346	Not Required	Pass
116	0.003	0.183	0.165	0.043	0.015	0.295	#21	0.346	Not Required	Pass
201	0.018	0.683	0.028	0.039	0.002	0.703	#13	0.166	Not Required	Pass
202	0.001	0.408	0.330	0.086	0.066	0.739	#13	0.053	Not Required	Pass
203	0.010	0.679	0.089	0.069	0.025	0.736	#13	0.045	Not Required	Pass
204	0.011	0.649	0.127	0.065	0.029	0.668	#13	0.080	Not Required	Pass
205	0.010	0.421	0.126	0.067	0.030	0.437	#13	0.074	Not Required	Pass
206	0.007	0.518	0.042	0.051	0.010	0.544	#13	0.045	Not Required	Pass

207	0.007	0.321	0.057	0.052	0.014	0.323	#13	0.074	Not Required	Pass
208	0.000	0.021	0.043	0.017	0.006	0.058	#21	Not Required	Not Required	Pass
209	0.002	0.055	0.076	0.003	0.003	0.130	#13	0.204	Not Required	Pass
210	0.007	0.512	0.070	0.051	0.018	0.571	#13	0.080	Not Required	Pass
211	0.000	0.021	0.043	0.017	0.006	0.058	#21	Not Required	Not Required	Pass
212	0.001	0.252	0.242	0.062	0.051	0.494	#13	0.053	Not Required	Pass
213	0.005	0.121	0.302	0.057	0.020	0.337	#21	0.190	Not Required	Pass
214	0.005	0.115	0.301	0.054	0.020	0.320	#21	0.286	Not Required	Pass
215	0.004	0.201	0.165	0.042	0.015	0.309	#21	0.346	Not Required	Pass
216	0.003	0.189	0.165	0.039	0.015	0.301	#21	0.346	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

IBC 2018 Pile Design



Input	Description
Region	American Standard
Concrete design code	American Concrete Institute (ACI 318:2019)

Cross-section

Input	Description	Value
Shape	Cross-sectional shape	Square
b	Section width	48 in
D	Section depth	48 in

Material Properties

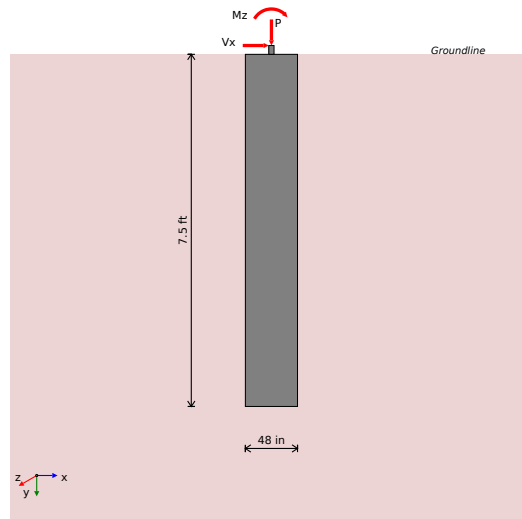
Input	Description	Value
f'_{ck}	Concrete compressive strength	2.5 ksi
f_{yk}	Yield strength of steel	60 ksi
d_b	Rebar diameter	#5 (0.625) in
cover	Concrete cover	3 in

Soil Parameters (IBC 1806)

Input	Description	Value
Soil type	Sand, silty sand, clayey sand, silty gravel & clayey gravel	
q_a	Allowable bearing pressure	2000 psf
R	Allowable lateral pressure	150 psf/ft

Loading

Load	ASD	LRFD
P	5.979 kip	8.781 kip
V _x	-3.743 kip	-6.24 kip
V _z	-0.21 kip	-0.357 kip
M _x	-0.719 kip-ft	-1.209 kip-ft
M _z	46.33 kip-ft	77.9 kip-ft



Required depth to resist lateral loads (ASD)

Allowable lateral pressure

$$R = 150 \text{ psf/ft}$$

Point of application of lateral load:

$$H = h_1 + h_2 + h_e = 0 + 0 + 0 = 0 \text{ ft}$$

Considering x-direction:

Lateral force per section length

$$H_o = \frac{V_x}{1.57 \times D} = \frac{-3.743}{1.57 \times 48} = -0.596 \frac{\text{kip}}{\text{ft}}$$

Moment per section length

$$M_o = \frac{M_z + (V_z \times H)}{1.57 \times D} = \frac{46.33 + (-3.743 \times 0)}{1.57 \times 48} = 7.378 \frac{\text{kip-ft}}{\text{ft}}$$

Required depth of embedment in earth:

$$L_z^3 - \left(9 \times \frac{H_o \times L_z}{R}\right) - \left(12 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:

$$L_{e,z} = 6.983 \text{ ft}$$

Considering z-direction:

Lateral force per section length

$$H_o = \frac{V_z}{1.57 \times b} = \frac{-0.21}{1.57 \times 48} = -0.033 \frac{\text{kip}}{\text{ft}}$$

Moment per section length

$$M_o = \frac{M_z + (V_z \times H)}{1.57 \times b} = \frac{-0.719 + (-0.21 \times 0)}{1.57 \times 48} = -0.115 \frac{\text{kip-ft}}{\text{ft}}$$

Required depth of embedment in earth:

$$L_z^3 - \left(9 \times \frac{H_o \times L_z}{R}\right) - \left(12 \times \frac{M_o}{R}\right) = 0$$

Solving the cubic equation:

$$L_{e,z} = -1.776 \text{ ft}$$

Minimum embedded depth

Depth of pile required

$$L_{e,req} = \text{MAX}[L_{e,z}, L_{e,z}] = \text{MAX}[6.983, -1.776] = 6.983 \text{ ft}$$

Actual embedded length

$$L_e = L - h_2 - h_e = 7.5 - 0 - 0 = 7.5 \text{ ft}$$

Utilisation

$$\text{Ratio} = \frac{L_{e,req}}{L_e} = \frac{6.983}{7.5} = 0.931$$

UTILITY: 0.93

REFERENCES

CALCULATIONS

RESULTS

End-bearing Capacity (ASD)

Allowable bearing pressure
Unit weight of concrete

$q_a = 2000 \text{ psf}$
 $w_c = 0.15 \text{ kip/ft}^3$

Cross-sectional area:

$$A = b \times D = 48 \times 48 = 16 \text{ ft}^2$$

End-bearing pressure:

$$q = \frac{P}{A} = \frac{5.979}{16} = 373.7 \text{ psf}$$

Utilisation

$$\text{Ratio} = \frac{q}{q_a} = \frac{373.7}{2000} = 0.187$$

UTILITY: 0.19

Lateral Soil Pressure (ASD)

Allowable lateral pressure

$R = 150 \text{ psf/ft}$

Length to least lateral dimension ratio:

$$\frac{L}{\text{MIN}[b, D]} = \frac{7.5}{\text{MIN}[4, 4]} = 1.875$$

L/D ratio ≤ 10 . This pile is classified as a short pile.

Considering x-direction:

Distance from resting surface to pivot point:

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

$$(6 \times M_o) + (4 \times H_o \times L_e)$$

$$a = \frac{(4 \times 7.378 \times 7.5) + (3 \times 0.596 \times 7.5^2)}{(6 \times 7.378) + (4 \times 0.596 \times 7.5)} = 5.18 \text{ ft}$$

Earth pressure against the pile at a distance a/2 from the resting surface:

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

$$p = \frac{0.75 \times [(4 \times 7.378) + (3 \times -0.596 \times 7.5)]^2}{7.5^2 \times [(3 \times 7.378) + (2 \times -0.596 \times 7.5)]} = 0.262 \frac{\text{kip}}{\text{ft}^2}$$

Allowable lateral soil pressure at a depth of a/2:

$$p_a = R \times \frac{a}{2} = 0.15 \times \frac{5.18}{2} = 0.388 \frac{\text{kip}}{\text{ft}^2}$$

Utilisation - pressure at a depth of a/2

$$\text{Ratio} = \frac{p}{p_a} = \frac{0.262}{0.388} = 0.674$$

UTILITY: 0.67

Earth pressure against the pile at distance L_e:

$$s = \frac{6 \times [(2 \times M_o) + (H_o \times L_e)]}{L_e^2} = \frac{6 \times [(2 \times 7.378) + (-0.596 \times 7.5)]}{7.5^2} = 1.097 \frac{\text{kip}}{\text{ft}^2}$$

Allowable lateral soil pressure at a depth of L_e:

$$p_s = R \times L_e = 0.15 \times 7.5 = 1.125 \frac{\text{kip}}{\text{ft}^2}$$

Utilisation - pressure at a depth of L_e

$$\text{Ratio} = \frac{s}{p_s} = \frac{1.097}{1.125} = 0.975$$

UTILITY: 0.98

Considering z-direction:

Distance from resting surface to pivot point:

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

$$a = \frac{(4 \times 0.115 \times 7.5) + (3 \times 0.033 \times 7.5^2)}{(6 \times 0.115) + (4 \times 0.033 \times 7.5)} = 5.371 \text{ ft}$$

Earth pressure against the pile at a distance a/2 from the resting surface:

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

$$p = \frac{0.75 \times [(4 \times -0.115) + (3 \times -0.033 \times 7.5)]^2}{7.5^2 \times [(3 \times -0.115) + (2 \times -0.033 \times 7.5)]} = -0.023 \frac{\text{kip}}{\text{ft}^2}$$

Allowable lateral soil pressure at a depth of a/2:

$$p_a = R \times \frac{a}{2} = 0.15 \times \frac{5.371}{2} = 0.403 \frac{\text{kip}}{\text{ft}^2}$$

Utilisation - pressure at a depth of a/2

$$\text{Ratio} = \frac{p}{p_a} = \frac{-0.023}{0.403} = -0.057$$

UTILITY: 0.06

Earth pressure against the pile at distance L_e:

$$s = \frac{6 \times [(2 \times M_o) + (H_o \times L_e)]}{L_e^2} = \frac{6 \times [(2 \times -0.115) + (-0.033 \times 7.5)]}{7.5^2} = -0.051 \frac{\text{kip}}{\text{ft}^2}$$

Allowable lateral soil pressure at a depth of L_e:

$$p_s = R \times L_e = 0.15 \times 7.5 = 1.125 \frac{\text{kip}}{\text{ft}^2}$$

Utilisation - pressure at a depth of L_e

$$\text{Ratio} = \frac{s}{p_s} = \frac{-0.051}{1.125} = -0.045$$

UTILITY: 0.05

REFERENCES

CALCULATIONS

RESULTS

Shear force and bending moment (LRFD)

Considering x-direction:

Lateral force per section length

$$H_o = \frac{V_z}{1.57 \times D} = \frac{-6.24}{1.57 \times 48} = -0.994 \frac{\text{kip}}{\text{ft}}$$

Moment per section length

$$M_o = \frac{M_x + (V_x \times H)}{1.57 \times D} = \frac{77.9 + (-6.24 \times 0)}{1.57 \times 48} = 12.41 \frac{\text{kip-ft}}{\text{ft}}$$

Distance from resting surface to pivot point:

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

$$a = \frac{(4 \times 12.41 \times 7.5) + (3 \times 0.994 \times 7.5^2)}{(6 \times 12.41) + (4 \times 0.994 \times 7.5)} = 5.179 \text{ ft}$$

Max shear force located at depth a:

$$E = \frac{M_o}{H_o} = \frac{12.41}{-0.994} = 12.48 \text{ ft}$$

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

$$V_{max,x} = (-0.994 \times 48) \times \left[1 - \left[3 \times \left(\frac{4 \times 12.48}{7.5} + 3 \right) \times \left(\frac{5.179}{7.5} \right)^2 \right] + \left[4 \times \left(\frac{3 \times 12.48}{7.5} + 2 \right) \times \left(\frac{5.179}{7.5} \right)^3 \right] \right]$$

$$V_{max,x} = 14.33 \text{ kip}$$

Max bending moment located at a depth of a/2:

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

$$M_{max,x} = (-0.994 \times 48 \times 7.5) \times \left[\left(\frac{12.48}{7.5} + \frac{5.179}{2 \times 7.5} \right) - \left[\left(\frac{4 \times 12.48}{7.5} + 3 \right) \times \left(\frac{5.179}{2 \times 7.5} \right)^3 \right] + \left[\left(\frac{3 \times 12.48}{7.5} + 2 \right) \times \left(\frac{5.179}{2 \times 7.5} \right)^4 \right] \right]$$

$$M_{max,x} = 51.03 \text{ kip-ft}$$

Considering z-direction:

Lateral force per section length

$$H_o = \frac{V_z}{1.57 \times b} = \frac{-0.357}{1.57 \times 48} = -0.057 \frac{\text{kip}}{\text{ft}}$$

Moment per section length

$$M_o = \frac{M_x + (V_x \times H)}{1.57 \times b} = \frac{-1.209 + (-0.357 \times 0)}{1.57 \times 48} = -0.192 \frac{\text{kip-ft}}{\text{ft}}$$

Distance from resting surface to pivot point:

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

$$a = \frac{(4 \times 0.192 \times 7.5) + (3 \times 0.057 \times 7.5^2)}{(6 \times 0.192) + (4 \times 0.057 \times 7.5)} = 5.373 \text{ ft}$$

Max shear force located at depth a:

$$E = \frac{M_o}{H_o} = \frac{-0.192}{-0.057} = 3.381 \text{ ft}$$

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

$$V_{max,z} = (-0.057 \times 48) \times [1 - [3 \times \left(\frac{4 \times 3.381}{7.5} + 3\right) \times \left(\frac{3.373}{7.5}\right)^2] + [4 \times \left(\frac{3 \times 3.381}{7.5} + 2\right) \times \left(\frac{3.373}{7.5}\right)^3]]$$

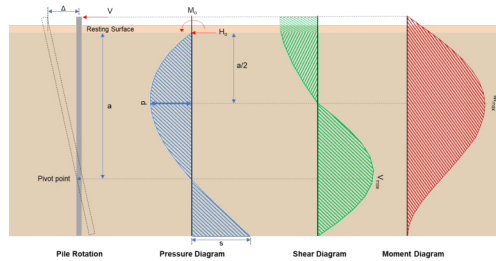
$$V_{max,z} = 0.334 \text{ kip}$$

Max bending moment located at a depth of a/2:

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

$$M_{max,z} = (-0.057 \times 48 \times 7.5) \times \left[\left(\frac{3.381}{7.5} + \frac{5.373}{2 \times 7.5} \right) - \left[\left(\frac{4 \times 3.381}{7.5} + 3 \right) \times \left(\frac{5.373}{2 \times 7.5} \right)^3 \right] + \left[\left(\frac{3 \times 3.381}{7.5} + 2 \right) \times \left(\frac{5.373}{2 \times 7.5} \right)^4 \right] \right]$$

$$M_{max,z} = 1.099 \text{ kip-ft}$$



Minimum Reinforcement Check (LRFD)

Gross area of concrete:

$$A_g = b \times D = 48 \times 48 = 2304 \text{ in}^2$$

Main Reinforcement

22.4.2.2 Required reinforcement:

$$A_{st,req} = \frac{P - (0.85 \times f'_{ck} \times A_g)}{f_{yk} - (0.85 \times f'_{ck})} = \frac{8.781 - (0.85 \times 2.5 \times 2304)}{60 - (0.85 \times 2.5)} = -84.44 \text{ in}^2$$

10.6.1.1 Maximum reinforcement:

$$A_{st,max} = 0.08 \times A_g = 0.08 \times 2304 = 184.3 \text{ in}^2$$

7.6.1.1 Minimum reinforcement:

$$A_{st,min} = 0.0018 \times A_g = 0.0018 \times 2304 = 4.147 \text{ in}^2$$

Governing minimum reinforcement area:

$$(0.0018 \times A_g) \leq A_{st,req} \leq (0.08 \times A_g)$$

$$A_{min} = 4.147 \text{ in}^2$$

Minimum number of reinforcements:

$$A_{bar} = 0.307 \text{ in}^2$$

$$n_{min} = \frac{A_{min}}{A_{bar}} = \frac{4.147}{0.307} = 14$$

25.2.3 Minimum spacing:

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

Use: $n = 16$ pcs at 1.5 in minimum spacing

Total reinforcement area:

$$A_{st} = 16 \times 0.307 = 4.909 \text{ in}^2$$

Shear Reinforcement

25.7.2.2 For main reinforcement ≤ 1.41 in: Use #3(0.375 in)

Maximum spacing of shear Reinforcements:

$$s = \text{MIN}[16 \times d_b, 48 \times d_{b,tie}, \text{MIN}(b, D)] = \text{MIN}[(16 \times 0.625), (48 \times 0.375), \text{MIN}(48, 48)] = 10 \text{ in}$$

Detailing Summary

Main reinforcement

#5 (0.625 in) - 16pcs at 1.5 in min. spacing

Axial Compression Strength (LRFD)

22.4.2.2 Allowable axial compressive strength:

$$\phi P_N = \phi \times 0.8 \times [(0.85 \times f'_{ck} \times [A_g - A_{st}]) + (f_{yk} \times A_{st})]$$

$$\phi P_N = 0.65 \times 0.8 \times [(0.85 \times 2.5 \times [2304 - 4.909]) + (60 \times 4.909)] = 2694 \text{ kip}$$

Utilisation

$$\text{Ratio} = \frac{P}{\phi P_N} = \frac{8.781}{2694} = 0.003$$

UTILITY: 0.00

Shear Strength LRFD)

Effective shear width	$b_w = 48 \text{ in}$
Effective shear depth	$d = 44.31 \text{ in}$
Shear reinforcement area	$A_v = 0.221 \text{ in}^2$
Shear reinforcement spacing	$s = 10 \text{ in}$
Concrete type factor (Normal concrete)	$\lambda = 1$
Strength reduction factor for shear	$\phi = 0.75$
Maximum shear in the x-direction	$V_{max,x} = 14.33 \text{ kip}$
Maximum shear in the z-direction	$V_{max,z} = 0.334 \text{ kip}$

22.5.5.1.1 Max shear strength of concrete:

$$V_{c,max} = 5 \times \lambda \times \sqrt{f'_{ck}} \times b_w \times d = 5 \times 1 \times \sqrt{2.5} \times 48 \times 44.31 = 531.8 \text{ kip}$$

Table 22.5.5.1 Shear strength of concrete:

$$V_{c,a} = \left(2 \times \lambda \times \sqrt{f'_{ck}} + \text{MIN} \left[\frac{P}{6 \times A_g}, (0.05 \times f'_{ck}) \right] \right) \times (b_w \times d)$$

$$V_{c,a} = \left(2 \times 1 \times \sqrt{2.5} + \text{MIN} \left[\frac{8.781}{6 \times 2304}, (0.05 \times 2.5) \right] \right) \times (48 \times 44.31) = 214.1 \text{ kip}$$

Governing shear strength of concrete:

$$V_c = \text{MIN}[V_{c,max}, V_{c,a}] = \text{MIN}[531.8, 214.1] = 214.1 \text{ kip}$$

22.5.1.2 Shear strength of steel (a):

$$V_{s,a} = 8 \times \sqrt{f'_{ck}} \times b_w \times d = 8 \times \sqrt{2.5} \times 48 \times 44.31 = 850.8 \text{ kip}$$

22.5.8.5.3 Shear strength of steel (b):

$$V_{s,b} = \frac{A_v \times f_{yk} \times d}{s} = \frac{0.221 \times 60 \times 44.31}{10} = 58.73 \text{ kip}$$

Governing shear strength of steel:

$$V_s = \text{MIN}[V_{s,a}, V_{s,b}] = \text{MIN}[850.8, 58.73] = 58.73 \text{ kip}$$

22.5.1.1 Allowable shear strength:

$$\phi V_n = \phi \times (V_c + V_s) = 0.75 \times (214.1 + 58.73) = 204.6 \text{ kip}$$

$$V_{max} = \text{MAX}[14.33, 0.334] = 14.33 \text{ kip}$$

Utilisation

$$\text{Ratio} = \frac{V_{max}}{\phi V_n} = \frac{14.33}{204.6} = 0.07$$

UTILITY: 0.07

Flexural Strength (LRFD)

Concrete type factor (Normal concrete)	$\lambda = 1$
Strength reduction factor for flexure	$\phi = 0.65$
Modulus of steel reinforcement	$E_s = 200 \text{e}3 \text{ ksi}$
Maximum concrete strain	$\epsilon_c = 0.0030$
Yield strain of steel f_y/E_s	$\epsilon_y = 0.0003$
Section width	$b = 48 \text{ in}$
Distance to the compression rebar	$d_c = 3.688 \text{ in}$
Distance to the tension rebar	$d = 44.31 \text{ in}$
Total bar area	$A_s = 4.909 \text{ in}^2$
Maximum applied axial load	$P = 8.781 \text{ kip}$
Maximum moment in the x-direction	$M_{max,x} = 51.03 \text{ kip-ft}$
Maximum moment in the z-direction	$M_{max,z} = 1.099 \text{ kip-ft}$

Compressive force due to concrete:

$$\beta_1 = 0.85$$

$$C_{rc} = 0.85 \times \beta_1 \times f'_c \times b \times c$$

Compressive force due to bars in compression:

$$C_{rs} = f_1 \times A_{sc}$$

$$\epsilon_1 = (c - d_s) \times \frac{\epsilon_c}{c}$$

$$f_1 = E_s \times \epsilon_1 \quad (\epsilon_1 < \epsilon_{sy}), \quad f_1 = f_y \quad (\epsilon_1 \geq \epsilon_{sy})$$

Tensile force due to bars in tension:

$$T_{rs} = f_2 \times A_{st}$$

$$\epsilon_2 = (d - c) \times \frac{\epsilon_{cu}}{c}$$

$$f_2 = E_s \times \epsilon_2 \quad (\epsilon_2 < \epsilon_{sy}), \quad f_2 = \phi_s \times f_y \quad (\epsilon_2 \geq \epsilon_{sy})$$

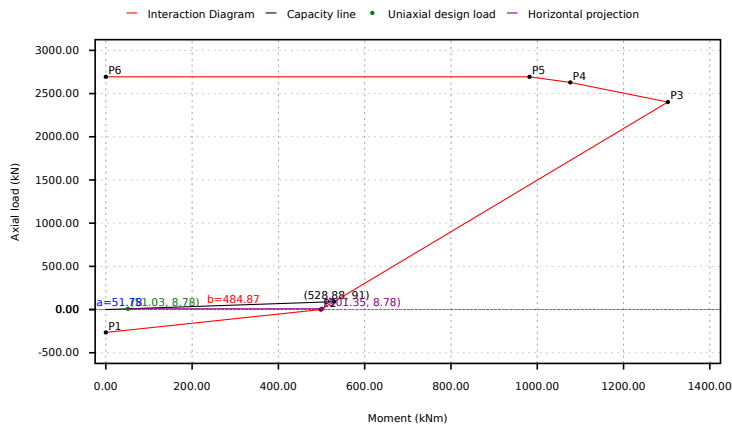
Interaction Diagram Summary

Point	Case	M _r	P _r
P1	Pure Tension	0	-265.1
P2	Pure Bending	498.4	0
P3	Balanced Failure	1303	2402
P4	Decompression	1077	2629
P5	Compression Limit	982	2694
P6	Pure Compression	0	2694

Uniaxial Bending Check

$$M_f = \text{MAX}[51.03, 1.099] = 51.03 \text{ kip-ft}$$

Interaction Diagram



Segment	Signed Distance
P1 - P2	217.8
P2 - P3	427
P3 - P4	2575
P4 - P5	2741
P5 - P6	2685
Status	PASS: Point lies inside the curve

Utilisation

$$\text{Ratio} = \frac{a}{a + b} = \frac{51.78}{51.78 + 484.9} = 0.096$$

Biaxial Bending Check

Maximum moment in the x-direction

$$M_{max,x} = 51.03 \text{ kip-ft}$$

Maximum moment in the z-direction

$$M_{max,z} = 1.099 \text{ kip-ft}$$

Nominal uniaxial moment strength about the x-axis

$$M_{nox} = 501.4 \text{ kip-ft}$$

Nominal uniaxial moment strength about the z-axis

$$M_{noz} = 501.4 \text{ kip-ft}$$

Interaction exponent

$$\alpha = 1$$

UTILITY: 0.10

Bresler (1960)

According to Bresler (method B):

$$\left(\frac{M_{max,x}}{M_{nox}}\right)^\alpha + \left(\frac{M_{max,z}}{M_{noz}}\right)^\alpha = 1.0$$

$$\left(\frac{51.03}{501.4}\right)^1 + \left(\frac{1.099}{501.4}\right)^1 = 0.104$$

UTILITY: 0.10

REFERENCES

CALCULATIONS

RESULTS

Results Summary

Result Name	Results
PILE DETAILS	
Length of the pile	7.50 ft
Dimensions	48 x 48 in
Main bar reinforcement	#5-16pcs at 1.5 in min.
Shear reinforcement	#3 at 10 in max.
UTILISATIONS	
Required depth	0.93
End-bearing capacity	0.19
P _a	0.67
P _s	0.98
Axial compression strength	0.00
Shear strength	0.07
Uniaxial bending strength	0.10
Biaxial bending strength	0.10