



VSE Project Number: U1869.4059.231

To Whom It May Concern:

Per your request, we have reviewed the proposed ground mount solar array installation at the above referenced site. The purpose of our review was to determine the adequacy of the proposed concrete drilled pier with embedded anchor foundations for the ground mount solar array installation. Design of all other structural components of the ground mount system is beyond the scope of this letter and is the responsibility of others.

Based upon our review the concrete drilled pier with embedded anchor foundations are adequate when installed as described in this letter and the plans stamped by our office.

Design Parameters

Code: Ontario Building Code (2015 NBC)

Importance Category: Low

Terrain: Open

1/50 Hourly Wind Pressure: 0.35 kPa

1/50 Ground Snow Load: 2.7 kPa

1/50 Associated Rain Load: 0.4 kPa

Ground Mount Geometry

Solar array tilt: 30°, 45°, 60°

Array height at column: 13'-5"

Ground Mount Foundation

See attached detail.



Concrete & Foundation Notes

All concrete mixing, placement, forming, and reinforcing installation shall be performed in accordance with the requirements of "Building Code Requirements for Reinforced Concrete", ACI 318, latest applicable edition. Foundation installation shall be in accordance with the requirements of "Standard Specifications for the Construction of concrete piers", ACI 336, latest applicable edition.

Foundation concrete shall have a minimum compressive strength of 4000 psi at 28 days.

Cement for all concrete shall be Type II with a minimum of 6% entrained air. Maximum aggregate size shall be 3/4".

Max. slump: 5 ± 1 "; Max. water cement ratio: 0.5

Foundation design is based on the following presumptive values. Vector Structural Engineering, LLC strongly recommends independent soils testing be performed by a licensed geotechnical engineer to verify soil capacities, slope stability, and any other related soil parameters.

Allowable bearing: 1500 psf

Allowable skin friction: 250 psf

Allowable lateral bearing: 150 pcf

Limitations

All components of the ground mounted solar array are to be installed per manufacturer's recommendations. The use of solar panel support span tables provided by the manufacturer is allowed only where the site conditions and solar panel configuration match the description of the span tables. Electrical engineering is beyond our scope. All work performed must be in accordance with accepted industry-wide methods and applicable safety standards. Vector Structural Engineering assumes no responsibility for improper installation of the solar panels, racking or foundations. Please note that a representative of Vector Structural Engineering has not physically observed site conditions.

VECTOR STRUCTURAL ENGINEERING, LLC

ON Firm License: 100534525

Russell Emery, P.Eng

ON License: 100532018 - Expires: 10/31/2023

Project Engineer

Enclosures

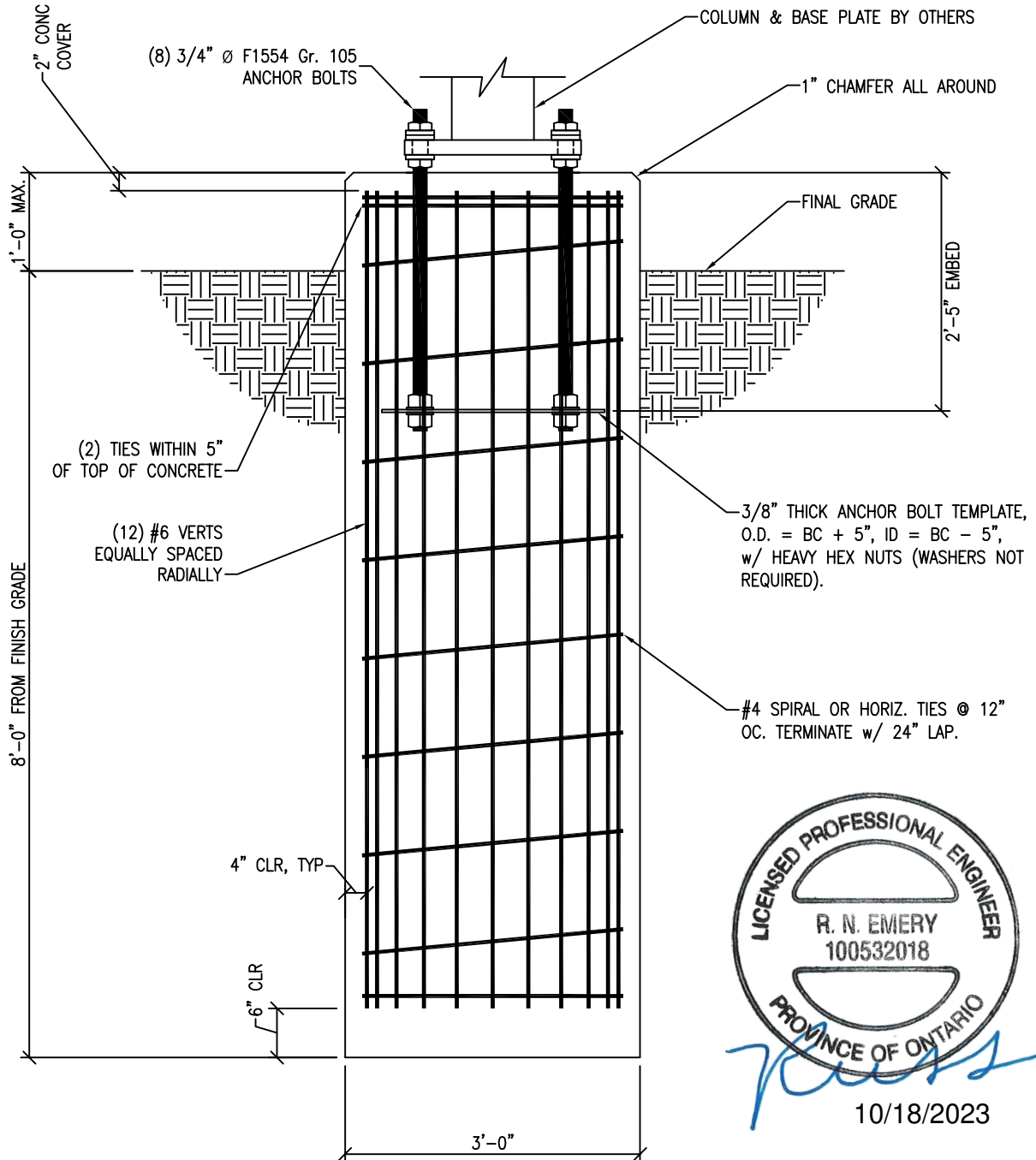




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SUBJECT REINFORCED DRILLED PIER FOR GROUND MOUNTED ARRAY



R. N. Emery
10/18/2023

REINFORCED DRILLED PIER SECTION
N.T.S.

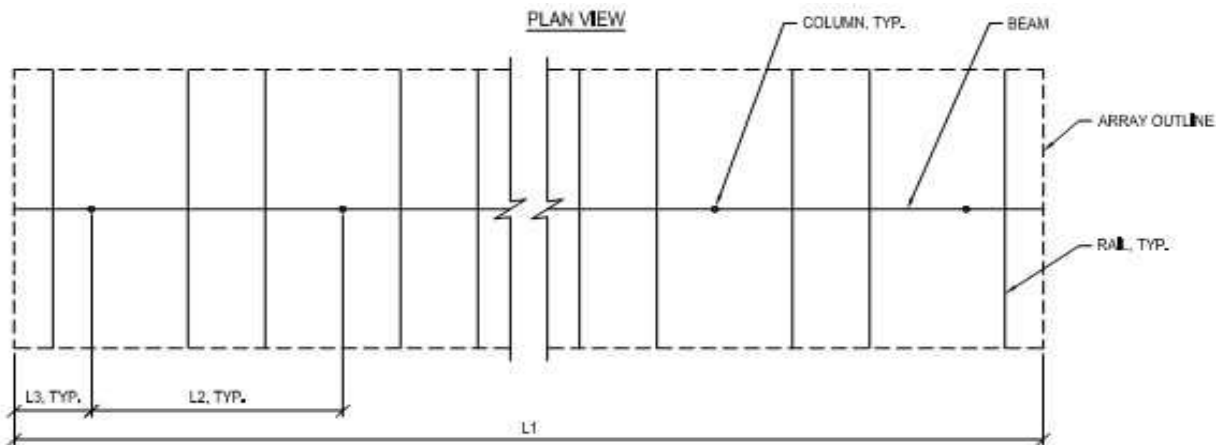
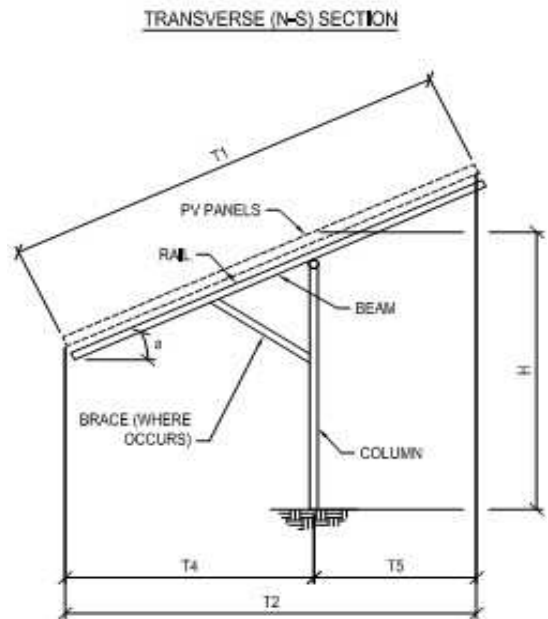
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PROJECT:

30 DEGREE SLOPE

Mount Geometry

Panel Orientation:	Portrait
Panel Width (short dimension) [in]:	45
Panel Length (long dimension) [in]:	90
No. of Panels in Transverse Direction:	2
No. of Panels in Longitudinal Direction:	4
Transverse Length Along Slope (T1) [ft]:	15.0
Projected Transverse Length (T2) [ft]:	13.0
Longitudinal Length (L1) [ft]:	15.1
No. of Columns in Tranverse Direction:	1
Transverse Overhang (T4) [ft]:	6.5
Transverse Overhang (T5) [ft]:	6.5
Array width [ft]:	15.1
Panel Slope from Horizontal (a) [°]:	30
Transverse Ground Slope [°]:	0
Longitudinal Ground Slope [°]:	0
Leading Edge Height [ft]:	9.7
Min. Array Height at Column(H) [ft]:	13.4
Max. Array Height at Column (H) [ft]:	13.4
Trailing Edge Height [ft]:	17.2



Note: All images are for illustration purposes only, and does not necessarily match the proposed installation



JOB NO.: U1869.4059.231
SUBJECT: DEAD LOADS

PROJECT:

30 DEGREE SLOPE

DEAD LOADS

Panel & Rail Weight [psf]:	3.0	
Tributary Area per Column [ft ²]:	226.8	
Weight per Column [lbs]:	680.4	
Beam Weight [plf]:	2.7	
Tributary Length per Column [ft]:	15.1	
Weight per Column [lbs]:	41.1	
Brace Weight [plf]:	NA	
Tributary Length per Column [ft]:		
Weight per Column [lbs]:		
Column Weight [plf]:	2.7	
Max. Column Height [ft]:	13.4	
Min. Column Height [ft]:	13.4	
Max. Column Weight [lbs]:	36.5	
Min. Column Weight [lbs]:	36.5	
Max. Total Weight Per Column [lbs]:	758.0	(1.0 Dead)
Min. Total Weight per Column [lbs]:	758.0	(1.0 Dead)



PROJECT:

30 DEGREE SLOPE

WIND PRESSURES

Calculations per:	ASCE 7-10	
Design Wind Speed, V [mph]:	105	
Risk Category:	I	(Table 1.5-1)
Exposure Category:	B	(Section 26.7)
Elevation [ft]:	1117.2	
Ground Elevation Factor, K_e :		(Not applicable)
α :	7.0	(Table 26.9.1)
z_g [ft]:	1200	(Table 26.9.1)
Velocity Pressure Exposure Coefficient, K_h :	0.60	(Table 27.3-1)
Topographic Factor, K_{ht} :	1.0	(Section 26.8)
Wind Directionality Factor, K_d :	0.85	(Table 26.6-1)
Internal Pressure Coefficient, GC_{pi} :	0.00	(Figure 26.11-1)
Velocity Pressure, q_h [psf]:	14.34	(Equation 27.3-1)
Gust Effect Factor, G:	0.85	(Section 26.9.1)
Panel Slope [degrees]:	30.0	
Wind Flow:	Clear	
Roof Configuration:	Monoslope	

Wind Pressures in Transverse (N-S) Direction

Net Pressure Coefficients per Figure 27.4-4

Clear Wind Flow	C_{NW}	C_{NL}
Case 1 ($\gamma = 0^\circ$, Load Case A)	-1.8	-1.8
Case 2 ($\gamma = 0^\circ$, Load Case B)	-2.5	-0.5
Case 3 ($\gamma = 180^\circ$, Load Case A)	2.1	2.1
Case 4 ($\gamma = 180^\circ$, Load Case B)	2.6	1.0

Design Wind Pressures per Equation 27.4-3 [psf]

Clear Wind Flow	$q_h GC_{NW}$	$q_h GC_{NL}$
Case 1 ($\gamma = 0^\circ$, Load Case A)	-21.9	-21.9
Case 2 ($\gamma = 0^\circ$, Load Case B)	-30.5	-6.1
Case 3 ($\gamma = 180^\circ$, Load Case A)	25.6	25.6
Case 4 ($\gamma = 180^\circ$, Load Case B)	31.7	12.2
Case 5 ($\gamma = 0^\circ$, 16 psf Min. Horiz.)	-16.0	-16.0
Case 6 ($\gamma = 180^\circ$, 16 psf Min. Horiz.)	16.0	16.0



JOB NO.: U1869.4059.231
SUBJECT: GEOMETRY

PROJECT:

30 DEGREE SLOPE

COLUMN WIND LOADS

Column Tributary Area

Panel Slope [degrees]:	30.0
Trib. Along Slope [ft ²):	226.8
Projected Vert. Trib. [ft ²):	113.4
Projected Horiz. Trib. [ft ²):	196.4
Min. Column Height [ft):	13.4

Wind Loads from Transverse Pressures (1.0 Wind)

	Vertical [lbs]	Horizontal [lbs]	Moment [ft-lbs]
Case 1:	-4308	-2487	33427
Case 2:	-3590	-2073	38226
Case 3:	5026	2902	-38999
Case 4:	4308	2487	-25132
Case 5:		-1814	24384
Case 6:		1814	-24384
Max:	5026	2902	38226
Min:	-4308	-2487	-38999



JOB NO.: U1869.4059.231
 SUBJECT: REACTIONS

PROJECT:

30 DEGREE SLOPE

COLUMN REACTIONS (ASD)

Summary of Loads per Column

Dead Loads

1.0 Max. Dead:
 Down [lbs]
 0.6 Min. Dead:
 Down [lbs]

Snow Loads

1.0 Snow:
 Down [lbs]

Wind Loads

0.6 Wind:
 Down [lbs]
 Uplift [lbs]
 Shear [lbs]
 Moment [lb-ft]

Reactions by Load Combination per Column

Load Combination	Column Reactions			
	Down [lbs]	Uplift [lbs]	Shear [lbs]	Moment [lb-ft]
1.0 Dead	758	0	0	0
1.0 Dead + 1.0 Snow	758	0	0	0
1.0 Dead + 0.6 Wind	3773	1827	1741	23399
1.0 Dead + 0.75 Snow + 0.45 Wind	3020	851	1306	17549
0.6 Dead + 0.6 Wind	3470	2130	1741	23399
Maximum Design Reactions	3773	2130	1741	23399



PROJECT:

30 DEGREE SLOPE

DRILLED CONCRETE PIER DESIGN

Column Reactions:

Max. Shear, V [k]:	1.7	Max. Down, P _d [k]:	3.8
Max. Moment, M [k-ft]:	23.4	Max. Uplift, P _u [k]:	2.1

Pier Properties:

Pier Shape:	Round	Volume of Concrete [ft ³]:	64
Pier Diameter, b [ft]:	3.0	Volume of Concrete [yd ³]:	2.4
Top of Pier Elevation [ft]:	1.00	Weight of Concrete [k]:	9.5
Pier Depth, d [ft]:	8.0		

Soil Properties:

Allow. Bearing Pressure [psf]:	1,500
1/3 increase for short term loads?	No
Lateral Bearing, S [pcf]:	150
Max. Lateral Bearing (opt'l) [psf]:	
Top Depth to Ignore [ft]:	0
1/3 increase for short term loads?	No
1/2" deflection at t/o pier allowed:	Yes

Optional Parameters for Uplift:

Skin Friction* [psf]:	250
Top Length to Ignore [ft]:	0
1/3 increase for short term loads?	No
Combine w/ Bearing:	No

*per IBC Section 1810.3.3.1.4

Check Bearing:

Bearing Capacity [k]:	18.8
-----------------------	------

Bearing capacity OK.

Check Uplift:

Uplift Capacity [k]:	27.4
----------------------	------

Uplift capacity OK.

Check Lateral Bearing:

Top of Pier Constrained?:	No
Applied Lateral Force, P [lb]:	1,741
Point of Application, h [ft]:	14.4
S _{max} [psf]:	
S [psf]:	800
A = 2.34*P/(Sb):	1.70
Required Pier Depth, d _{reqd} [ft]:	6.10

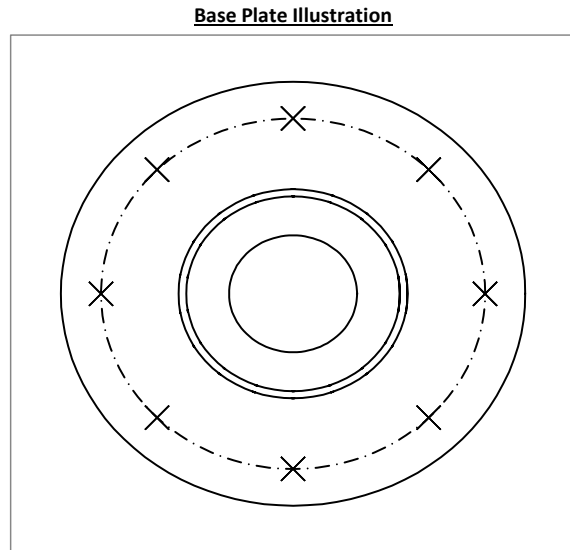
IBC Section 1807.3.2.1

IBC Eq. 18-1

Result: **Lateral bearing capacity OK.**

Monopole Baseplate & Anchorage Design per TIA-222-H Annex Q & TIA-222-H Section 4.9.9

Quantity	Symbol	Value	Units	
Number of sides		Round		
Pole O.D.	D_T	10.75	in	
Pole wall thickness	t_T	0.365	in	
Pole yield strength	F_{yp}	35	ksi	
Basic Input & Geometry	Base plate fillet weld size	0.25	in	
	Anchor diameter	d	0.75 in	
	Number of anchors	n	8	
	Anchor grade		F1554-105	
	Base plate thickness	t_{TP}	0.5	in
	Base plate yield strength	F_{yf}	36	ksi
	Anchor hole diameter		1	in
	Slotted to outside edge?		No	
	Flat washer diameter		1.46875	
	Zinc drain hole diameter		1	
	Zinc drain circle		7.5	in
	Bolt circle diameter	D_{BC}	18	in
	Plate O.D.	D_{OD}	21.77	in
	Plate I.D.		6	in

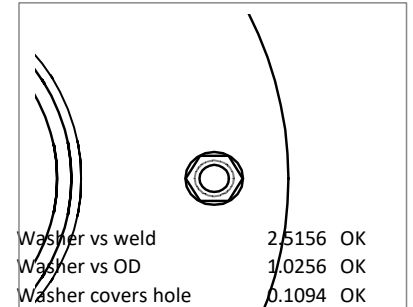


LRFD Loads	Max. Column Reactions		
	Axial down	$R_{u,c}$	4.53 k
	Axial up	$R_{u,t}$	2.56 k
	Shear	V_u	2.90 k
Moment	M_u	39.00 k-ft	

Checks	Anchor unity check	34.1%	OK	
	Min. number of sides	Round	OK	6 minimum
	Min. number of anchors	8	OK	8 minimum
	Min. anchor diameter	0.75"	OK	0.75" minimum
Min. anchor rod spacing	6.89"	OK	3" minimum	

Note: when number of anchors is less than minimum and when maximum anchor rod spacing is exceeded, adjustments are made to the effective plate width calculations as if requirements of TIA-222-H Annex Q were met.

Fit Check



Washer vs weld	2.5156	OK
Washer vs OD	1.0256	OK
Washer covers hole	0.1094	OK



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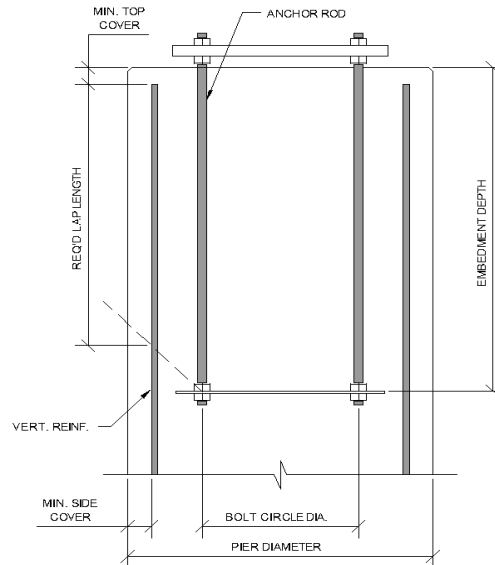
PROJECT:

30 DEGREE TILT

Anchorage Embedment Design

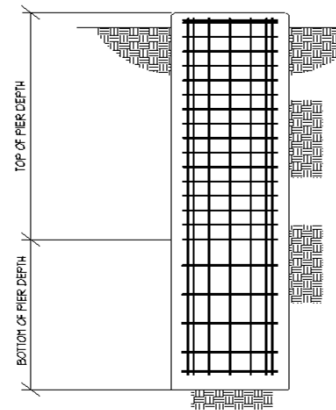
(per ACI 318-14)

Vertical Bar Size:	#6	
# of Vertical Bars:	12	
Concrete Compressive Strength [psi]:	4000	
Pier Diameter [ft]:	3	
Pier Depth [ft]:	8	
Top of Pier Elevation [in]:	12	
Concrete Volume [yd ³]:	2.4	
Side Concrete Cover [in]:	4	
Top Concrete Cover [in]:	2	
Horizontal Tie Size:	#4	
Bolt Circle Diameter [in]:	18	
# of Anchor Rods:	8	
Anchor Rod Diameter [in]:	0.75	
ψ_t (bar location factor):	1.0	Table 25.4.2.4
ψ_e (epoxy coating factor):	1.0	Table 25.4.2.4
ψ_s (bar size factor):	0.8	Table 25.4.2.4
λ (concrete type factor):	1.0	Table 25.4.2.4
Vertical Bar Diameter [in]:	0.8	
Horizontal Tie Diameter [in]:	0.500	
Buffer [in]:	1.87	
Req'd Lap Length [in]:	22.2	in (Section 25.4.2.2)
Min. Req'd Embedment Depth [in]:	28.3	



Transverse Reinforcement Design

Seismic Design Category:	D
Apply Seismic Detailing?	No
Site Class:	D
Type of Transverse Reinforcement:	Spiral
Transverse f_y [ksi]:	60
Seismic Hooks Required?	No
Tie Size OK?	Yes
Spacing at Top of Pier [in]:	12
Spacing at Bottom of Pier [in]:	12
Total Pier Length [ft]:	9
Top Pier Length [ft]:	9
Bottom Pier Length [ft]:	0





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PROJECT:

30 DEGREE SLOPE

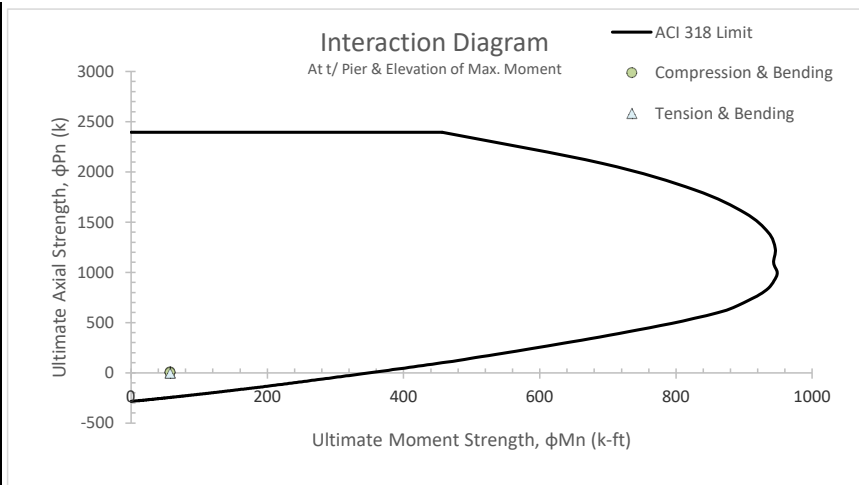
Drilled Pier Reinforcement:

Design Requirements:

Max. Moment, M (k-ft):	39.0	Max. Down, P _{down} (k):	4.5	Required Foundation UC Limit:	100%
Max. Shear, V (k):	2.9	Max. Uplift, P _{up} (k):	-2.6	Mu, M+V*H+Pmax*E (k-ft):	57.4
Height of V (ft):	6.333	Eccentricity for P (in):	0	(Uplift is negative for comparison w/ Interaction Diagram)	
		Concrete Self-weight (k):	6.5	(0.145 pcf)	

Pier Properties:

Code Reference:	ACI 318-14
Pier Diameter (ft):	3
Top of Pier Elevation (in):	12
Pier Depth (ft):	8
Vertical Bar Size:	#6
Bar Diameter (in):	0.75
Bar Area (in ²):	0.44
Seismic Design Category:	D
# of Vertical Bars:	12
Vert. Yield Strength (psi):	60000
Horizontal Reinf. Type:	Spiral
Horizontal Reinf. Size:	#4
Horizontal Reinf. Diameter (in):	0.5
Side Concrete Cover (in):	4
Vert. Edge Distance (in):	4.5
Conc. Comp. Strength, f _c (psi):	4000
Angle Between Bars, δ (radians):	0.524
Area of Steel (in ²):	5.3
Gross Column Area (in ²):	1017.9
Min. Reinforcement Ratio:	0.50%
β ₁ :	0.85
Concrete Yield Strain, ε _{cu} (in/in):	0.003
P _o (k):	3760
φ:	0.75
Pn Factor:	0.85
φP _u (pure compression, k):	2397
E _s (ksi):	29000
Steel Yield Strain, ε _{ty} (in/in):	0.002069
Number of verticals in top row:	1



(IBC Sections 1810.3.9.4.1 and 1810.3.9.4.2)

Table 22.2.2.4.3

Section 22.2.2.1

Eqn. 22.4.2.2

Table 21.2.2

Table 22.4.2.1

Table 22.4.2.1

Table 22.4.2.1

Section 21.2.2.1

Axial & Bending Checks:

Steel/Concrete Ratio: 0.52% > Min. Reinf. Ratio

Compression & Bending

	@ t/ Pier	@ Max. M		
φPn (k):	3.4	9.2		
φMn (k-ft):	353.4	359.8		
UC:	16.3%	16.1%	OK, Adequate	$(Pu^2 + Mu^2)^{0.5} / (\phi Pn^2 + \phi Mn^2)^{0.5}$

Tension & Bending

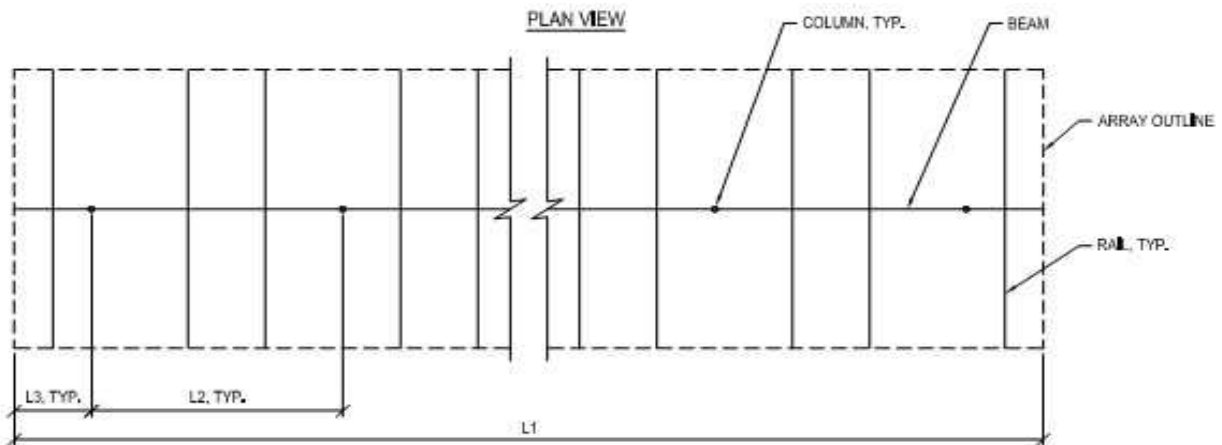
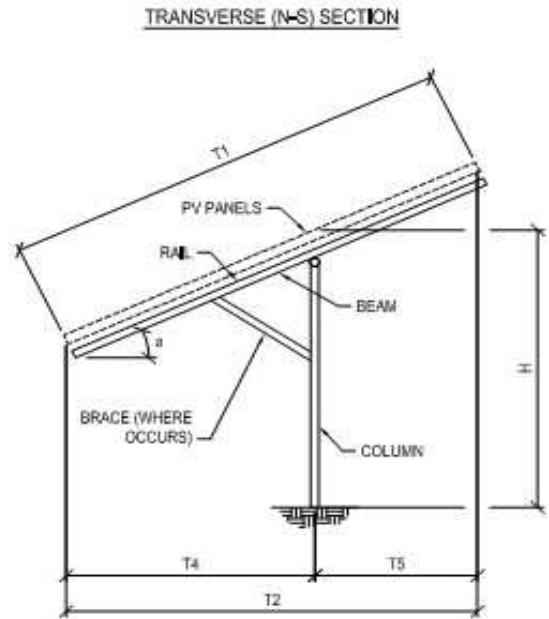
	@ t/ Pier	@ Max. M		
φPn (k):	-2.6	3.3		
φMn (k-ft):	346.9	353.3		
UC:	16.6%	16.3%	OK, Adequate	$(Pu^2 + Mu^2)^{0.5} / (\phi Pn^2 + \phi Mn^2)^{0.5}$

PROJECT:

45 DEGREE SLOPE

Mount Geometry

Panel Orientation:	Portrait
Panel Width (short dimension) [in]:	45
Panel Length (long dimension) [in]:	90
No. of Panels in Transverse Direction:	2
No. of Panels in Longitudinal Direction:	4
Transverse Length Along Slope (T1) [ft]:	15.0
Projected Transverse Length (T2) [ft]:	10.6
Longitudinal Length (L1) [ft]:	15.1
No. of Columns in Tranverse Direction:	1
Transverse Overhang (T4) [ft]:	5.3
Transverse Overhang (T5) [ft]:	5.3
Array width [ft]:	15.1
Panel Slope from Horizontal (a) [°]:	45
Transverse Ground Slope [°]:	0
Longitudinal Ground Slope [°]:	0
Leading Edge Height [ft]:	8.1
Min. Array Height at Column(H) [ft]:	13.4
Max. Array Height at Column (H) [ft]:	13.4
Trailing Edge Height [ft]:	18.7



Note: All images are for illustration purposes only, and does not necessarily match the proposed installation



JOB NO.: U1869.4059.231
SUBJECT: DEAD LOADS

PROJECT:

45 DEGREE SLOPE

DEAD LOADS

Panel & Rail Weight [psf]:	2.7	
Tributary Area per Column [ft ²]:	226.8	
Weight per Column [lbs]:	612.3	
Beam Weight [plf]:	2.7	
Tributary Length per Column [ft]:	15.1	
Weight per Column [lbs]:	41.1	
Brace Weight [plf]:	NA	
Tributary Length per Column [ft]:		
Weight per Column [lbs]:		
Column Weight [plf]:	2.7	
Max. Column Height [ft]:	13.4	
Min. Column Height [ft]:	13.4	
Max. Column Weight [lbs]:	36.5	
Min. Column Weight [lbs]:	36.5	
Max. Total Weight Per Column [lbs]:	689.9	(1.0 Dead)
Min. Total Weight per Column [lbs]:	689.9	(1.0 Dead)



JOB NO.: U1869.4059.231

SUBJECT: SNOW LOADS

PROJECT:

45 DEGREE SLOPE

SNOW LOADS

Design Snow Load, S [psf]: (1.0 Snow)

Tributary Area per Column [ft²]:

Snow Load per Column [lbs]: (1.0 Snow)



PROJECT:

45 DEGREE SLOPE

WIND PRESSURES

Calculations per:	ASCE 7-10	
Design Wind Speed, V [mph]:	105	
Risk Category:	I	(Table 1.5-1)
Exposure Category:	B	(Section 26.7)
Elevation [ft]:	1117.2	
Ground Elevation Factor, K_e :		(Not applicable)
α :	7.0	(Table 26.9.1)
z_g [ft]:	1200	(Table 26.9.1)
Velocity Pressure Exposure Coefficient, K_h :	0.61	(Table 27.3-1)
Topographic Factor, K_{ht} :	1.0	(Section 26.8)
Wind Directionality Factor, K_d :	0.85	(Table 26.6-1)
Internal Pressure Coefficient, GC_{pi} :	0.00	(Figure 26.11-1)
Velocity Pressure, q_h [psf]:	14.69	(Equation 27.3-1)
Gust Effect Factor, G:	0.85	(Section 26.9.1)
Panel Slope [degrees]:	45.0	
Wind Flow:	Clear	
Roof Configuration:	Monoslope	

Wind Pressures in Transverse (N-S) Direction

Net Pressure Coefficients per Figure 27.4-4

Clear Wind Flow	C_{NW}	C_{NL}
Case 1 ($\gamma = 0^\circ$, Load Case A)	-1.6	-1.8
Case 2 ($\gamma = 0^\circ$, Load Case B)	-2.3	-0.7
Case 3 ($\gamma = 180^\circ$, Load Case A)	2.2	2.2
Case 4 ($\gamma = 180^\circ$, Load Case B)	2.6	1.4

Design Wind Pressures per Equation 27.4-3 [psf]

Clear Wind Flow	$q_h GC_{NW}$	$q_h GC_{NL}$
Case 1 ($\gamma = 0^\circ$, Load Case A)	-20.0	-22.5
Case 2 ($\gamma = 0^\circ$, Load Case B)	-28.7	-8.7
Case 3 ($\gamma = 180^\circ$, Load Case A)	27.5	27.5
Case 4 ($\gamma = 180^\circ$, Load Case B)	32.5	17.5
Case 5 ($\gamma = 0^\circ$, 16 psf Min. Horiz.)	-16.0	-16.0
Case 6 ($\gamma = 180^\circ$, 16 psf Min. Horiz.)	16.0	16.0



JOB NO.: U1869.4059.231
SUBJECT: GEOMETRY

PROJECT:

45 DEGREE SLOPE

COLUMN WIND LOADS

Column Tributary Area

Panel Slope [degrees]:	45.0
Trib. Along Slope [ft ²]:	226.8
Projected Vert. Trib. [ft ²]:	160.4
Projected Horiz. Trib. [ft ²]:	160.4
Min. Column Height [ft]:	13.4

Wind Loads from Transverse Pressures (1.0 Wind)

	Vertical [lbs]	Horizontal [lbs]	Moment [ft-lbs]
Case 1:	-3405	-3405	44702
Case 2:	-3005	-3005	48884
Case 3:	4407	4407	-59225
Case 4:	4006	4006	-47464
Case 5:		-2566	34485
Case 6:		2566	-34485
Max:	4407	4407	48884
Min:	-3405	-3405	-59225



JOB NO.: U1869.4059.231
SUBJECT: REACTIONS

PROJECT:

45 DEGREE SLOPE

COLUMN REACTIONS (ASD)

Summary of Loads per Column

Dead Loads

1.0 Max. Dead:
 Down [lbs]
 0.6 Min. Dead:
 Down [lbs]

Snow Loads

1.0 Snow:
 Down [lbs]

Wind Loads

0.6 Wind:
 Down [lbs]
 Uplift [lbs]
 Shear [lbs]
 Moment [lb-ft]

Reactions by Load Combination per Column

Load Combination	Column Reactions			
	Down [lbs]	Uplift [lbs]	Shear [lbs]	Moment [lb-ft]
1.0 Dead	690	0	0	0
1.0 Dead + 1.0 Snow	7557	0	0	0
1.0 Dead + 0.6 Wind	3334	1353	2644	35535
1.0 Dead + 0.75 Snow + 0.45 Wind	7823	0	1983	26651
0.6 Dead + 0.6 Wind	3058	1629	2644	35535
Maximum Design Reactions	7823	1629	2644	35535



PROJECT:

45 DEGREE SLOPE

DRILLED CONCRETE PIER DESIGN

Column Reactions:

Max. Shear, V [k]:	2.6	Max. Down, P_d [k]:	7.8
Max. Moment, M [k-ft]:	35.5	Max. Uplift, P_u [k]:	1.6

Pier Properties:

Pier Shape:	Round	Volume of Concrete [ft ³]:	64
Pier Diameter, b [ft]:	3.0	Volume of Concrete [yd ³]:	2.4
Top of Pier Elevation [ft]:	1.00	Weight of Concrete [k]:	9.5
Pier Depth, d [ft]:	8.0		

Soil Properties:

Allow. Bearing Pressure [psf]:	1,500
1/3 increase for short term loads?	No
Lateral Bearing, S [pcf]:	150
Max. Lateral Bearing (opt'l) [psf]:	
Top Depth to Ignore [ft]:	0
1/3 increase for short term loads?	No
1/2" deflection at t/o pier allowed:	Yes

Optional Parameters for Uplift:

Skin Friction* [psf]:	250
Top Length to Ignore [ft]:	0
1/3 increase for short term loads?	No
Combine w/ Bearing:	No

*per IBC Section 1810.3.3.1.4

Check Bearing:

Bearing Capacity [k]:	18.8
-----------------------	------

Bearing capacity OK.

Check Uplift:

Uplift Capacity [k]:	27.4
----------------------	------

Uplift capacity OK.

Check Lateral Bearing:

Top of Pier Constrained?:	No
Applied Lateral Force, P [lb]:	2,644
Point of Application, h [ft]:	14.4
S_{max} [psf]:	
S [psf]:	800
$A = 2.34 * P / (S_b)$:	2.58
Required Pier Depth, d_{reqd} [ft]:	7.80

IBC Section 1807.3.2.1

IBC Eq. 18-1

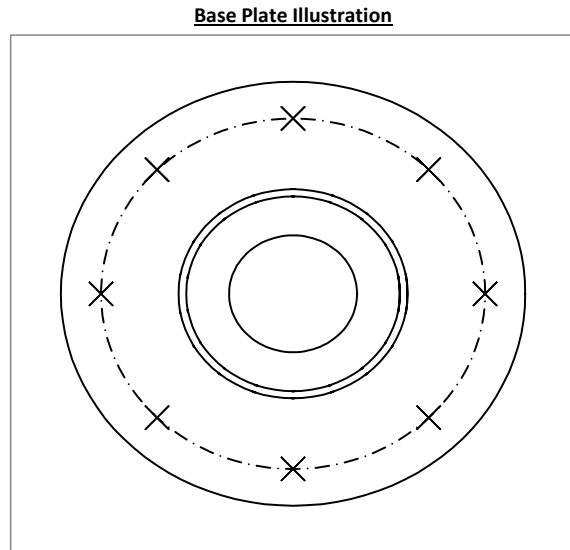
Result: **Lateral bearing capacity OK.**

PROJECT:

45 DEGREE SLOPE

Monopole Baseplate & Anchorage Design per TIA-222-H Annex Q & TIA-222-H Section 4.9.9

Quantity	Symbol	Value	Units	
Number of sides		Round		
Pole O.D.	D_T	10.75	in	
Pole wall thickness	t_T	0.365	in	
Pole yield strength	F_{yp}	35	ksi	
Basic Input & Geometry	Base plate fillet weld size	0.25	in	
	Anchor diameter	d	0.75	in
	Number of anchors	n	8	
	Anchor grade		F1554-105	
	Base plate thickness	t_{TP}	0.5	in
	Base plate yield strength	F_{yf}	36	ksi
	Anchor hole diameter		1	in
	Slotted to outside edge?		No	
	Flat washer diameter		1.46875	
	Zinc drain hole diameter		1	
	Zinc drain circle		7.5	in
	Bolt circle diameter	D_{BC}	18	in
	Plate O.D.	D_{OD}	21.77	in
	Plate I.D.		6	in

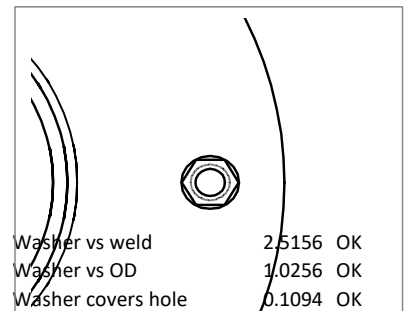


LRFD Loads	Max. Column Reaction			
	Axial down	$R_{u,c}$	9.39	k
	Axial up	$R_{u,t}$	1.95	k
	Shear	V_u	4.41	k
Moment	M_u	59.23	k-ft	

Checks	Anchor unity check	52.5%	OK	
	Min. number of sides	Round	OK	6 minimum
	Min. number of anchors	8	OK	8 minimum
	Min. anchor diameter	0.75"	OK	0.75" minimum
Min. anchor rod spacing	6.89"	OK	3" minimum	

Note: when number of anchors is less than minimum and when maximum anchor rod spacing is exceeded, adjustments are made to the effective plate width calculations as if requirements of TIA-222-H Annex Q were met.

Fit Check





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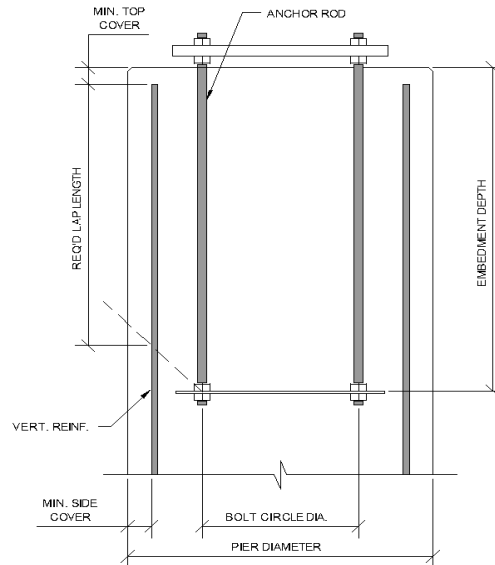
PROJECT:

45 DEGREE SLOPE

Anchorage Embedment Design

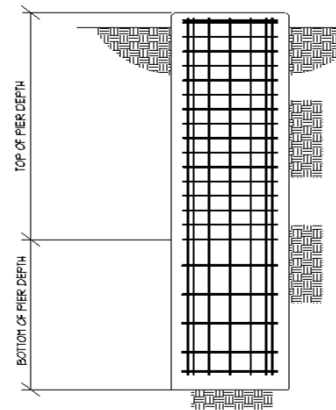
(per ACI 318-14)

Vertical Bar Size:	#6	
# of Vertical Bars:	12	
Concrete Compressive Strength [psi]:	4000	
Pier Diameter [ft]:	3	
Pier Depth [ft]:	8	
Top of Pier Elevation [in]:	12	
Concrete Volume [yd ³]:	2.4	
Side Concrete Cover [in]:	4	
Top Concrete Cover [in]:	2	
Horizontal Tie Size:	#4	
Bolt Circle Diameter [in]:	18	
# of Anchor Rods:	8	
Anchor Rod Diameter [in]:	0.75	
ψ_t (bar location factor):	1.0	Table 25.4.2.4
ψ_e (epoxy coating factor):	1.0	Table 25.4.2.4
ψ_s (bar size factor):	0.8	Table 25.4.2.4
λ (concrete type factor):	1.0	Table 25.4.2.4
Vertical Bar Diameter [in]:	0.8	
Horizontal Tie Diameter [in]:	0.500	
Buffer [in]:	1.87	
Req'd Lap Length [in]:	22.2	in (Section 25.4.2.2)
Min. Req'd Embedment Depth [in]:	28.3	



Transverse Reinforcement Design

Seismic Design Category:	D
Apply Seismic Detailing?	No
Site Class:	D
Type of Transverse Reinforcement:	Spiral
Transverse f_{yt} [ksi]:	60
Seismic Hooks Required?	No
Tie Size OK?	Yes
Spacing at Top of Pier [in]:	12
Spacing at Bottom of Pier [in]:	12
Total Pier Length [ft]:	9
Top Pier Length [ft]:	9
Bottom Pier Length [ft]:	0





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PROJECT:

45 DEGREE SLOPE

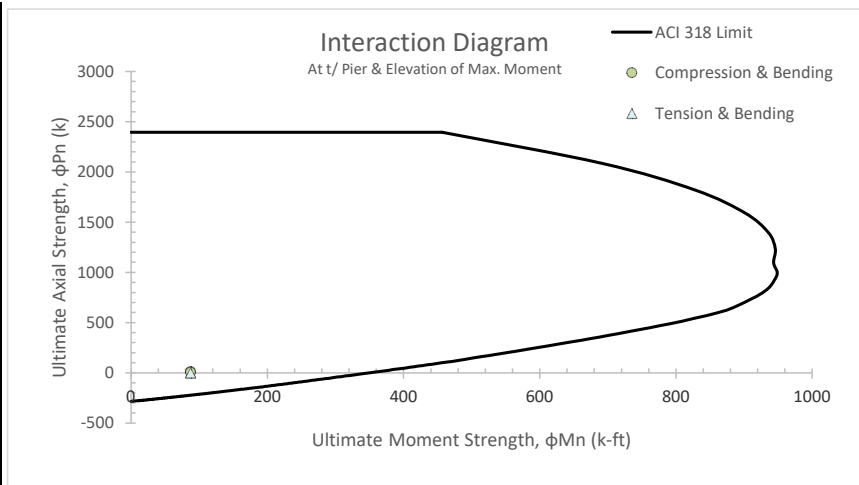
Drilled Pier Reinforcement:

Design Requirements:

Max. Moment, M (k-ft):	59.2	Max. Down, P _{down} (k):	9.4	Required Foundation UC Limit:	100%
Max. Shear, V (k):	4.4	Max. Uplift, P _{up} (k):	-2.0	Mu, M+V*H+Pmax*E (k-ft):	87.1
Height of V (ft):	6.333	Eccentricity for P (in):	0	(Uplift is negative for comparison w/ Interaction Diagram)	
		Concrete Self-weight (k):	6.5	(0.145 pcf)	

Pier Properties:

Code Reference:	ACI 318-14
Pier Diameter (ft):	3
Top of Pier Elevation (in):	12
Pier Depth (ft):	8
Vertical Bar Size:	#6
Bar Diameter (in):	0.75
Bar Area (in ²):	0.44
Seismic Design Category:	D
# of Vertical Bars:	12
Vert. Yield Strength (psi):	60000
Horizontal Reinf. Type:	Spiral
Horizontal Reinf. Size:	#4
Horizontal Reinf. Diameter (in):	0.5
Side Concrete Cover (in):	4
Vert. Edge Distance (in):	4.5
Conc. Comp. Strength, f _c (psi):	4000
Angle Between Bars, δ (radians):	0.524
Area of Steel (in ²):	5.3
Gross Column Area (in ²):	1017.9
Min. Reinforcement Ratio:	0.50%
β ₁ :	0.85
Concrete Yield Strain, ε _{cu} (in/in):	0.003
P _o (k):	3760
φ:	0.75
Pn Factor:	0.85
φP _u (pure compression, k):	2397
E _s (ksi):	29000
Steel Yield Strain, ε _{ty} (in/in):	0.002069
Number of verticals in top row:	1



(IBC Sections 1810.3.9.4.1 and 1810.3.9.4.2)

Table 22.2.2.4.3

Section 22.2.2.1

Eqn. 22.4.2.2

Table 21.2.2

Table 22.4.2.1

Table 22.4.2.1

Table 21.2.2.1

Section 21.2.2.1

Axial & Bending Checks:

Steel/Concrete Ratio: 0.52% > Min. Reinf. Ratio

Compression & Bending

	@ t/ Pier	@ Max. M	
φPn (k):	7.0	12.9	
φMn (k-ft):	357.4	363.8	
UC:	24.5%	24.2%	OK, Adequate (Pu ² +Mu ²) ^{0.5} /(φPn ² +φMn ²) ^{0.5}

Tension & Bending

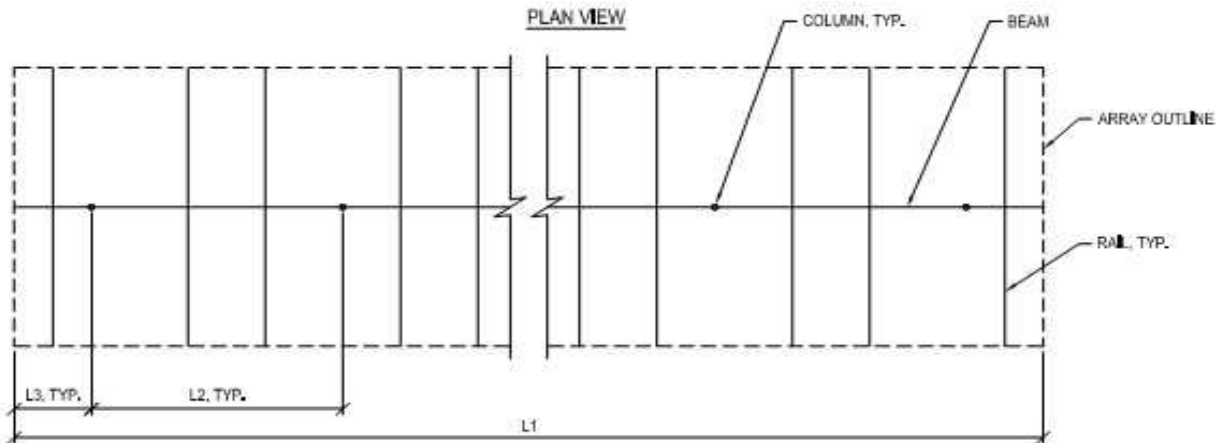
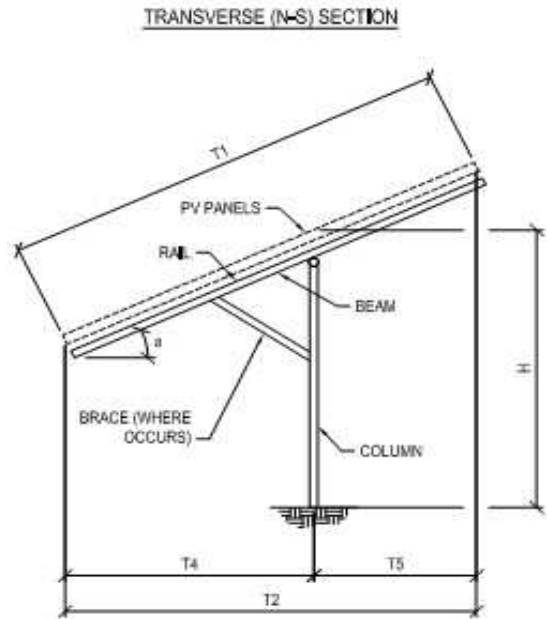
	@ t/ Pier	@ Max. M	
φPn (k):	-2.0	3.9	
φMn (k-ft):	347.6	354.0	
UC:	25.1%	24.6%	OK, Adequate (Pu ² +Mu ²) ^{0.5} /(φPn ² +φMn ²) ^{0.5}

PROJECT:

60 DEGREE SLOPE

Mount Geometry

Panel Orientation:	Portrait
Panel Width (short dimension) [in]:	45
Panel Length (long dimension) [in]:	90
No. of Panels in Transverse Direction:	2
No. of Panels in Longitudinal Direction:	4
Transverse Length Along Slope (T1) [ft]:	15.0
Projected Transverse Length (T2) [ft]:	10.6
Longitudinal Length (L1) [ft]:	15.1
No. of Columns in Tranverse Direction:	1
Transverse Overhang (T4) [ft]:	5.3
Transverse Overhang (T5) [ft]:	5.3
Array width [ft]:	15.1
Panel Slope from Horizontal (a) [°]:	60
Transverse Ground Slope [°]:	0
Longitudinal Ground Slope [°]:	0
Leading Edge Height [ft]:	8.1
Min. Array Height at Column(H) [ft]:	13.4
Max. Array Height at Column (H) [ft]:	13.4
Trailing Edge Height [ft]:	18.7



Note: All images are for illustration purposes only, and does not necessarily match the proposed installation



JOB NO.: U1869.4059.231
SUBJECT: DEAD LOADS

PROJECT:

60 DEGREE SLOPE

DEAD LOADS

Panel & Rail Weight [psf]:	2.7	
Tributary Area per Column [ft ²]:	226.8	
Weight per Column [lbs]:	612.3	
Beam Weight [plf]:	2.7	
Tributary Length per Column [ft]:	15.1	
Weight per Column [lbs]:	41.1	
Brace Weight [plf]:	NA	
Tributary Length per Column [ft]:		
Weight per Column [lbs]:		
Column Weight [plf]:	2.7	
Max. Column Height [ft]:	13.4	
Min. Column Height [ft]:	13.4	
Max. Column Weight [lbs]:	36.5	
Min. Column Weight [lbs]:	36.5	
Max. Total Weight Per Column [lbs]:	689.9	(1.0 Dead)
Min. Total Weight per Column [lbs]:	689.9	(1.0 Dead)



PROJECT:

60 DEGREE SLOPE

WIND PRESSURES

Calculations per:	ASCE 7-10	
Design Wind Speed, V [mph]:	105	
Risk Category:	I	(Table 1.5-1)
Exposure Category:	B	(Section 26.7)
Elevation [ft]:	1117.2	
Ground Elevation Factor, K_e :		(Not applicable)
α :	7.0	(Table 26.9.1)
z_g [ft]:	1200	(Table 26.9.1)
Velocity Pressure Exposure Coefficient, K_h :	0.61	(Table 27.3-1)
Topographic Factor, K_{ht} :	1.0	(Section 26.8)
Wind Directionality Factor, K_d :	0.85	(Table 26.6-1)
Internal Pressure Coefficient, GC_{pi} :	0.00	(Figure 26.11-1)
Velocity Pressure, q_h [psf]:	14.69	(Equation 27.3-1)
Gust Effect Factor, G:	0.85	(Section 26.9.1)
Panel Slope [degrees]:	60.0	
Wind Flow:	Clear	
Roof Configuration:	Monoslope	

Wind Pressures in Transverse (N-S) Direction

Net Pressure Coefficients per Figure 27.4-4

Clear Wind Flow	C_{NW}	C_{NL}
Case 1 ($\gamma = 0^\circ$, Load Case A)	-1.6	-1.8
Case 2 ($\gamma = 0^\circ$, Load Case B)	-2.3	-0.7
Case 3 ($\gamma = 180^\circ$, Load Case A)	2.2	2.2
Case 4 ($\gamma = 180^\circ$, Load Case B)	2.6	1.4

Design Wind Pressures per Equation 27.4-3 [psf]

Clear Wind Flow	$q_h GC_{NW}$	$q_h GC_{NL}$
Case 1 ($\gamma = 0^\circ$, Load Case A)	-20.0	-22.5
Case 2 ($\gamma = 0^\circ$, Load Case B)	-28.7	-8.7
Case 3 ($\gamma = 180^\circ$, Load Case A)	27.5	27.5
Case 4 ($\gamma = 180^\circ$, Load Case B)	32.5	17.5
Case 5 ($\gamma = 0^\circ$, 16 psf Min. Horiz.)	-16.0	-16.0
Case 6 ($\gamma = 180^\circ$, 16 psf Min. Horiz.)	16.0	16.0



JOB NO.: U1869.4059.231
SUBJECT: GEOMETRY

PROJECT:

60 DEGREE SLOPE

COLUMN WIND LOADS

Column Tributary Area

Panel Slope [degrees]:	60.0
Trib. Along Slope [ft ²):	226.8
Projected Vert. Trib. [ft ²):	160.4
Projected Horiz. Trib. [ft ²):	160.4
Min. Column Height [ft):	13.4

Wind Loads from Transverse Pressures (1.0 Wind)

	Vertical [lbs]	Horizontal [lbs]	Moment [ft-lbs]
Case 1:	-3405	-3405	44702
Case 2:	-3005	-3005	48884
Case 3:	4407	4407	-59225
Case 4:	4006	4006	-47464
Case 5:		-2566	34485
Case 6:		2566	-34485
Max:	4407	4407	48884
Min:	-3405	-3405	-59225



JOB NO.: U1869.4059.231
SUBJECT: REACTIONS

PROJECT:

60 DEGREE SLOPE

COLUMN REACTIONS (ASD)

Summary of Loads per Column

Dead Loads

1.0 Max. Dead:
 Down [lbs]
 0.6 Min. Dead:
 Down [lbs]

Snow Loads

1.0 Snow:
 Down [lbs]

Wind Loads

0.6 Wind:
 Down [lbs]
 Uplift [lbs]
 Shear [lbs]
 Moment [lb-ft]

Reactions by Load Combination per Column

Load Combination	Column Reactions			
	Down [lbs]	Uplift [lbs]	Shear [lbs]	Moment [lb-ft]
1.0 Dead	690	0	0	0
1.0 Dead + 1.0 Snow	690	0	0	0
1.0 Dead + 0.6 Wind	3334	1353	2644	35535
1.0 Dead + 0.75 Snow + 0.45 Wind	2673	1569	1983	26651
0.6 Dead + 0.6 Wind	3058	1629	2644	35535
Maximum Design Reactions	3334	1629	2644	35535



PROJECT: **60 DEGREE SLOPE**

DRILLED CONCRETE PIER DESIGN

Column Reactions:

Max. Shear, V [k]:	2.6	Max. Down, P _d [k]:	3.3
Max. Moment, M [k-ft]:	35.5	Max. Uplift, P _u [k]:	1.6

Pier Properties:

Pier Shape:	Round	Volume of Concrete [ft ³]:	64
Pier Diameter, b [ft]:	3.0	Volume of Concrete [yd ³]:	2.4
Top of Pier Elevation [ft]:	1.00	Weight of Concrete [k]:	9.5
Pier Depth, d [ft]:	8.0		

Soil Properties:

Allow. Bearing Pressure [psf]:	1,500
1/3 increase for short term loads?	No
Lateral Bearing, S [pcf]:	150
Max. Lateral Bearing (opt'l) [psf]:	
Top Depth to Ignore [ft]:	0
1/3 increase for short term loads?	No
1/2" deflection at t/o pier allowed:	Yes

Optional Parameters for Uplift:

Skin Friction* [psf]:	250
Top Length to Ignore [ft]:	0
1/3 increase for short term loads?	No
Combine w/ Bearing:	No

*per IBC Section 1810.3.3.1.4

Check Bearing:

Bearing Capacity [k]:	18.8
-----------------------	------

Bearing capacity OK.

Check Uplift:

Uplift Capacity [k]:	27.4
----------------------	------

Uplift capacity OK.

Check Lateral Bearing:

Top of Pier Constrained?:	No
Applied Lateral Force, P [lb]:	2,644
Point of Application, h [ft]:	14.4
S _{max} [psf]:	
S [psf]:	800
A = 2.34*P/(Sb):	2.58
Required Pier Depth, d _{reqd} [ft]:	7.80

IBC Section 1807.3.2.1

IBC Eq. 18-1

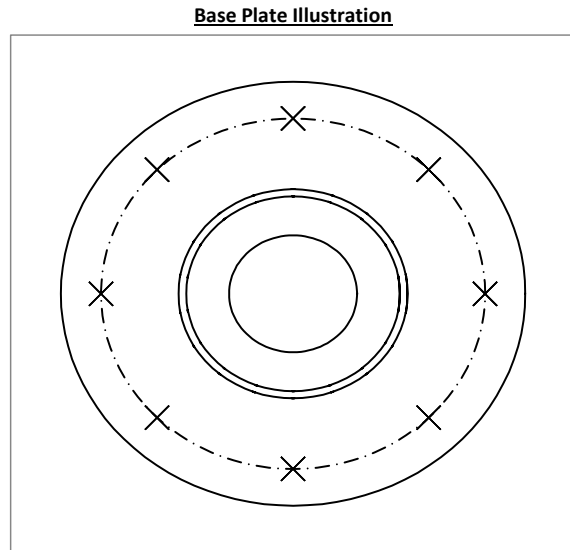
Result: **Lateral bearing capacity OK.**

PROJECT:

60 DEGREE SLOPE

Monopole Baseplate & Anchorage Design per TIA-222-H Annex Q & TIA-222-H Section 4.9.9

Quantity	Symbol	Value	Units	
Number of sides		Round		
Pole O.D.	D_T	10.75	in	
Pole wall thickness	t_T	0.365	in	
Pole yield strength	F_{yp}	35	ksi	
Basic Input & Geometry	Base plate fillet weld size	0.25	in	
	Anchor diameter	d	0.75 in	
	Number of anchors	n	8	
	Anchor grade		F1554-105	
	Base plate thickness	t_{TP}	0.5	in
	Base plate yield strength	F_{yf}	36	ksi
	Anchor hole diameter		1	in
	Slotted to outside edge?		No	
	Flat washer diameter		1.46875	
	Zinc drain hole diameter		1	
	Zinc drain circle		7.5	in
	Bolt circle diameter	D_{BC}	18	in
	Plate O.D.	D_{OD}	21.77	in
	Plate I.D.		6	in

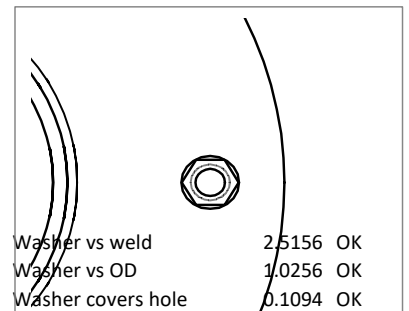


LRFD Loads	Max. Column Reaction		
	Axial down	$R_{u,c}$	4.00 k
	Axial up	$R_{u,t}$	1.66 k
	Shear	V_u	4.41 k
Moment	M_u	59.23 k-ft	

Checks	Anchor unity check	50.9%	OK	
	Min. number of sides	Round	OK	6 minimum
	Min. number of anchors	8	OK	8 minimum
	Min. anchor diameter	0.75"	OK	0.75" minimum
	Min. anchor rod spacing	6.89"	OK	3" minimum

Note: when number of anchors is less than minimum and when maximum anchor rod spacing is exceeded, adjustments are made to the effective plate width calculations as if requirements of TIA-222-H Annex Q were met.

Fit Check





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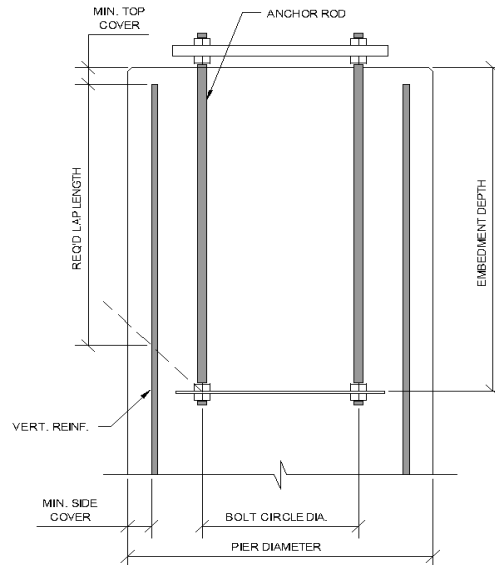
PROJECT:

60 DEGREE SLOPE

Anchorage Embedment Design

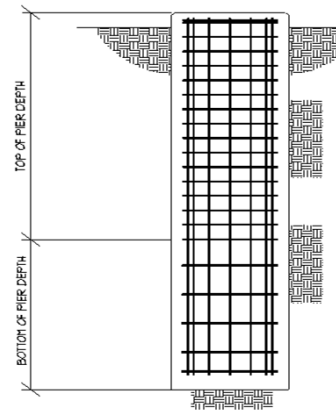
(per ACI 318-14)

Vertical Bar Size:	#6	
# of Vertical Bars:	12	
Concrete Compressive Strength [psi]:	4000	
Pier Diameter [ft]:	3	
Pier Depth [ft]:	8	
Top of Pier Elevation [in]:	12	
Concrete Volume [yd ³]:	2.4	
Side Concrete Cover [in]:	4	
Top Concrete Cover [in]:	2	
Horizontal Tie Size:	#4	
Bolt Circle Diameter [in]:	18	
# of Anchor Rods:	8	
Anchor Rod Diameter [in]:	0.75	
ψ_t (bar location factor):	1.0	Table 25.4.2.4
ψ_e (epoxy coating factor):	1.0	Table 25.4.2.4
ψ_s (bar size factor):	0.8	Table 25.4.2.4
λ (concrete type factor):	1.0	Table 25.4.2.4
Vertical Bar Diameter [in]:	0.8	
Horizontal Tie Diameter [in]:	0.500	
Buffer [in]:	1.87	
Req'd Lap Length [in]:	22.2	in (Section 25.4.2.2)
Min. Req'd Embedment Depth [in]:	28.3	



Transverse Reinforcement Design

Seismic Design Category:	D
Apply Seismic Detailing?	No
Site Class:	D
Type of Transverse Reinforcement:	Spiral
Transverse f_y [ksi]:	60
Seismic Hooks Required?	No
Tie Size OK?	Yes
Spacing at Top of Pier [in]:	12
Spacing at Bottom of Pier [in]:	12
Total Pier Length [ft]:	9
Top Pier Length [ft]:	9
Bottom Pier Length [ft]:	0





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PROJECT:

60 DEGREE SLOPE

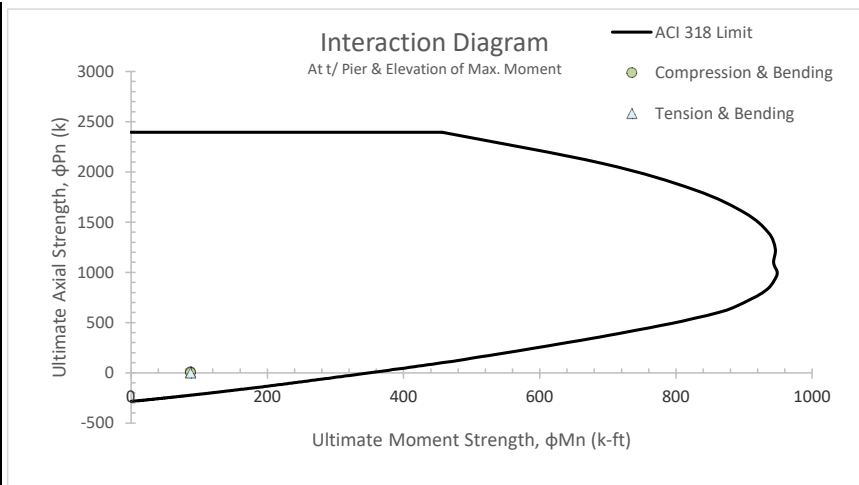
Drilled Pier Reinforcement:

Design Requirements:

Max. Moment, M (k-ft):	59.2	Max. Down, P _{down} (k):	4.0	Required Foundation UC Limit:	100%
Max. Shear, V (k):	4.4	Max. Uplift, P _{up} (k):	-1.7	Mu, M+V*H+Pmax*E (k-ft):	87.1
Height of V (ft):	6.333	Eccentricity for P (in):	0	(Uplift is negative for comparison w/ Interaction Diagram)	
		Concrete Self-weight (k):	6.5	(0.145 pcf)	

Pier Properties:

Code Reference:	ACI 318-14
Pier Diameter (ft):	3
Top of Pier Elevation (in):	12
Pier Depth (ft):	8
Vertical Bar Size:	#6
Bar Diameter (in):	0.75
Bar Area (in ²):	0.44
Seismic Design Category:	D
# of Vertical Bars:	12
Vert. Yield Strength (psi):	60000
Horizontal Reinf. Type:	Spiral
Horizontal Reinf. Size:	#4
Horizontal Reinf. Diameter (in):	0.5
Side Concrete Cover (in):	4
Vert. Edge Distance (in):	4.5
Conc. Comp. Strength, f _c (psi):	4000
Angle Between Bars, δ (radians):	0.524
Area of Steel (in ²):	5.3
Gross Column Area (in ²):	1017.9
Min. Reinforcement Ratio:	0.50%
β ₁ :	0.85
Concrete Yield Strain, ε _{cu} (in/in):	0.003
P _o (k):	3760
φ:	0.75
P _n Factor:	0.85
φP _u (pure compression, k):	2397
E _s (ksi):	29000
Steel Yield Strain, ε _{ty} (in/in):	0.002069
Number of verticals in top row:	1



(IBC Sections 1810.3.9.4.1 and 1810.3.9.4.2)

Table 22.2.2.4.3

Section 22.2.2.1

Eqn. 22.4.2.2

Table 21.2.2

Table 22.4.2.1

Table 22.4.2.1

Table 21.2.2.1

Section 21.2.2.1

Axial & Bending Checks:

Steel/Concrete Ratio: 0.52% > Min. Reinf. Ratio

Compression & Bending

	@ t/ Pier	@ Max. M	
φP _n (k):	3.0	8.8	
φM _n (k-ft):	353.0	359.4	
UC:	24.7%	24.4%	OK, Adequate (Pu ² +Mu ²) ^{0.5} /(φP _n ² +φM _n ²) ^{0.5}

Tension & Bending

	@ t/ Pier	@ Max. M	
φP _n (k):	-1.7	4.2	
φM _n (k-ft):	347.9	354.3	
UC:	25.1%	24.6%	OK, Adequate (Pu ² +Mu ²) ^{0.5} /(φP _n ² +φM _n ²) ^{0.5}