



**WESTERN**<sup>TM</sup>  
UTILITY / TELECOM, INC.

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## Structural Calculations with Foundation Design

For A:

**35' Tall, Concealment Antenna / Light Pole**

Located At:

**Various Puyallup, WA Nodes  
Pierce County**

Prepared for:

**Mastec Network Solutions**



8-Sep-21

Dated:

September 8, 2021

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PROFESSIONAL ENGINEER SEAL

I hereby certify that this structural design report was prepared by me, or under my direct supervision, and that I am a duly licensed Professional Engineer under the laws of the State of Washington.



8-Sep-21

## Loading, Codes, and Materials

### Design Loading:

- Antenna(s): (1) - 12" Ø x 60" Tall Antenna/Radio Shroud, Wt. = 165 lbs., C.L. @ 32.5' ± AGL
- Other: (1) - Nokia 5G Antennas/RRHs in Top Shroud, Wt. = 35 lbs., C.L. @ 31.7' ± AGL
- (1) - 9" Tall x 30" Long Cobra Head Luminaire, Wt. = 45 lbs., C.L. @ 30' ± AGL
- (1) - 2 7/8" OD x 14' (Max.) Long Luminaire Arm, Wt. = 85 lbs. C.L. @ 27.5' ± AGL
- (1) - Nokia B12/B14 Micro RRH, Wt. = 77 lbs. C.L. @ 17.7' ± AGL
- (1) - Nokia B25/B66 Micro RRH, Wt. = 66 lbs. C.L. @ 12' ± AGL
- (1) - CCI Twin RRU PSU, Wt. = 34 lbs. C.L. @ 6' ± AGL
- (1) - Base Cover, Wt. = 66 lbs. C.L. @ 0.33' ± AGL

### Design Criteria:

Basic Wind Speed (V): 97 mph (3-Second Gust) Per ANSI/TIA-222-H & 2018 IBC, Section 1609.1.1, Exc. 5

Risk Category: II Per Table 2-1

Exposure Category: C Per Section 2.6.5.1

Topographic Category: 1 Per Section 2.6.6.2

(V<sub>AASHTO</sub>): 97 mph (3-Second Gust) Per 2015 AASHTO LRFD LTS-1 w/2017 Interims

Ice: Not required for this structure per Annex B

Seismic: Per 2018 IBC Section 1613 ASCE 7-16 Sections 15.1.3 & 12.8

### Standards and Design Codes:

Industry Standards: ANSI/TIA 222-H & 2018 IBC

Concrete: ACI 318-14

Steel: AISC "Steel Construction Manual", 15th Edition

Welding: ANSI/AWS D1.1-15

Soil: Per 2018 IBC, Table 1806.2, Class 5 Material

### Materials:

Pole Shaft: ASTM A53/A500 Gr. B/API 5L Gr. B (Min. Fy = 35 ksi)

Baseplate: ASTM A36

Ports: ASTM A500 Gr. B (Rect.)

Plates: ASTM A36

Welds: E70XX Electrodes

Structural Bolts: ASTM F3125 A325

Anchor Bolts: ASTM F1554 Gr. 55

Rebar: ASTM A615 Gr. 60

### Coatings:

Galvanizing: ASTM A123

**Wind Loading Calculations: Monopole Shaft**

Reference: ANSI/TIA-222-H, Section 2.6.11.6

V =	97	mph (3-Second Gust Basic Wind Speed)
G <sub>H</sub> =	1.10	Gust Response Factor - 1.10 for Poles
K <sub>d</sub> =	0.95	Wind Direction Probability Factor
K <sub>e</sub> =	1.00	Ground Elevation Factor
	II	:Risk Category
	C	:Exposure Category
	1	:Topographic Category

 Velocity Pressure,  $q_z = 0.00256 * K_z * K_{zt} * K_e * K_d * V^2$  Where:

 $K_z$  = Velocity Pressure Exposure Coefficient, Section 2.6.5.2 and Table 2-4

 $K_{zt}$  = Topographic Factor, Section 2.6.6.2, Table 2-4 and 2-5

 $K_e$  = Ground Elevation Factor, Section 2.6.8

 $K_d$  = Wind Direction Probability Factor, Table 2-2

V = Basic Wind Speed, 3-Second Gust, mph

 Section Wind Force,  $F_{ST} = q_z * G_H * (EPA)_s$  Where:

 $(EPA)_s = C_r A_P$ 

Shaft Section Properties					Section Area				Wind Pressure						Wind Loading						
Average Section Elevation (Feet AGL)	Section Width (Point-to-Point) (inches)	Monopole Shaft Wall Thickness (inches)	Section Height (feet)	Section Elevation At Base (Feet)	Gross Section Area (Square Feet)	(mph - feet)	Force Coefficient	Effective Section Area (Square Feet)	Velocity Pressure Coefficient	Topographic Factor	Wind Direction Probability Factor	Ground Elevation Factor	Velocity Pressure (psf)	Gust Effect Factor	Applied Wind Pressure (psf)	Factored Section Base Wind Shear (kips)	Section Base Wind Moment (Foot-kips)	Factored Section Base Wind Moment (Foot-kips)	Factored Section Base Seismic Shear (kips)	Section Base Seismic Moment (Foot-kips)	Section Weight (kips)
Z	D <sub>P</sub>	T <sub>W</sub>	H	Z <sub>Base</sub>	A <sub>P</sub>	C	C <sub>F</sub>	EPA <sub>s</sub>	K <sub>Z</sub>	K <sub>Zt</sub>	K <sub>d</sub>	K <sub>e</sub>	q <sub>Z</sub>	G <sub>H</sub>	q <sub>Z</sub> G <sub>H</sub>	F <sub>ST</sub>	F <sub>ST</sub> *Z	F <sub>ST</sub> *Z	W <sub>T</sub> *C <sub>s</sub>	W <sub>T</sub> *C <sub>s</sub> *Z	W <sub>T</sub>
1.74	20.00	0.250	2.89	0.29	4.8	149.0	0.60	2.89	0.85	1.00	0.95	1.00	19.5	1.10	21.4	0.062	0.09	0.09	0.10	0.15	0.153
4.63	20.00	0.250	2.89	3.18	4.82	149.0	0.60	2.89	0.85	1.00	0.95	1.00	19.5	1.10	21.4	0.062	0.27	0.27	0.10	0.45	0.153
7.52	20.00	0.250	2.89	6.08	4.82	149.0	0.60	2.89	0.85	1.00	0.95	1.00	19.5	1.10	21.4	0.062	0.45	0.45	0.10	0.75	0.153
10.41	20.00	0.250	2.89	8.97	4.82	149.0	0.60	2.89	0.85	1.00	0.95	1.00	19.5	1.10	21.4	0.062	0.63	0.63	0.10	1.05	0.153
13.31	20.00	0.250	2.89	11.9	4.82	149.0	0.60	2.89	0.85	1.00	0.95	1.00	19.5	1.10	21.4	0.062	0.81	0.81	0.10	1.35	0.153
16.20	20.00	0.250	2.89	14.8	4.82	150.2	0.60	2.89	0.86	1.00	0.95	1.00	19.7	1.10	21.7	0.063	1.00	1.00	0.10	1.64	0.153
19.09	20.00	0.250	2.89	17.6	4.82	152.8	0.60	2.89	0.89	1.00	0.95	1.00	20.4	1.10	22.5	0.065	1.22	1.22	0.10	1.94	0.153
21.98	20.00	0.250	2.89	20.5	4.82	155.1	0.60	2.89	0.92	1.00	0.95	1.00	21.1	1.10	23.2	0.067	1.45	1.45	0.10	2.24	0.153
24.88	20.00	0.250	2.89	23.4	4.82	157.1	0.60	2.89	0.94	1.00	0.95	1.00	21.6	1.10	23.8	0.069	1.69	1.69	0.10	2.54	0.153
27.77	20.00	0.250	2.89	26.3	4.82	158.9	0.60	2.89	0.97	1.00	0.95	1.00	22.1	1.10	24.3	0.070	1.93	1.93	0.10	2.84	0.153
30.66	20.00	0.250	2.89	29.2	4.82	160.6	0.60	2.89	0.99	1.00	0.95	1.00	22.6	1.10	24.8	0.072	2.18	2.18	0.10	3.14	0.153
33.55	20.00	0.250	2.89	32.1	4.82	162.1	0.60	2.89	1.01	1.00	0.95	1.00	23.0	1.10	25.3	0.073	2.44	2.44	0.10	3.44	0.153
<b>Loading Summations:</b>																<b>0.788</b>	<b>14.15</b>	<b>14.15</b>	<b>1.24</b>	<b>21.53</b>	<b>1.83</b>

Overall Length of Pole = 34.71 feet

Base Elevation of Pole = 0.29 feet (AGL)

Top of Steel Elevation = 35.00 feet (AGL)

Wind Loading Calculations - Sectorized Antennas and Mounts:															Factored Loads							
Description	CL Elevation (feet)	Offset from Shaft C.L. (in.)	Quantity Per Sector	Weight (lbs)	Height (inches)	Width (inches)	Depth (inches)	Shielding Factor $K_a$	$C_a$ Calc (Normal)	$C_a$ Calc (Transverse)	(EPA) <sub>N</sub> (ft <sup>2</sup> )	(EPA) <sub>T</sub> (ft <sup>2</sup> )	(EPA) <sub>A</sub> (ft <sup>2</sup> )	Unfactored Wind Pressure (psf)	Factored $V_{wind}$ (kips)	Factored Wind Torque (ft-kips)	Factored $M_{wind}$ (ft-kips)	$V_{seismic}$ (kips)	Factored Seismic Torque (ft-kips)	Factored $M_{seismic}$ (ft-kips)	Factored Total Wt (kips)	
<b>Shear, Moment, and Weight Summations:</b>															0.00	0.00	0.00	0.00	0.00	0.00	0.00	

Wind Loading Calculations - Miscellaneous Appurtenances:															Factored Loads							
Description	CL Elevation (feet)	Offset from Shaft C.L. (in.)	Quantity	Weight (lbs)	Shape Round (R) or Flat (F)	Height (inches)	Width (inches)	Area Factor	$A_A$ (ft <sup>2</sup> )	Aspect Ratio (Height / Width)	C	$C_a$	$C_e A_A$ (ft <sup>2</sup> )	$\Sigma C_e A_A$ (ft <sup>2</sup> )	Unfactored Wind Pressure (psf)	Factored $V_{wind}$ (kips)	Factored Wind Torque (ft-kips)	Factored $M_{wind}$ (ft-kips)	$V_{seismic}$ (kips)	Factored Seismic Torque (ft-kips)	Factored $M_{seismic}$ (ft-kips)	Factored Total Wt (kips)
12" Ø x 60" Tall Antenna/Radio Shrd	32.5	0.0	1	165.0	R	60.0	20.0	1.00	8.33	3.00	162	0.51	4.26	4.26	22.9	0.097	0.00	3.16	0.11	0.00	3.63	0.20
Nokia 5G Antennas/RRHs in Top Sh	31.7	0.0	1	35.0	R	24.0	20.0	0.00	3.33	1.20	161	0.50	1.67	0.00	22.7	0.000	0.00	0.00	0.02	0.00	0.75	0.04
9" Tall x 30" Long Cobra Head Lumi	30.0	186.0	1	45.0	F	9.0	30.0	1.00	1.88	3.33	N/A	1.24	2.32	2.32	22.5	0.052	0.81	1.56	0.03	0.47	0.91	0.05
2 7/8" OD x 14' (Max.) Long Luminai	27.5	96.9	1	85.0	R	2.9	168.0	1.00	3.35	58.43	1334	0.60	2.01	2.01	22.1	0.044	0.36	1.22	0.06	0.46	1.58	0.10
Nokia B12/B14 Micro RRH	17.7	0.0	1	77.0	F	22.1	12.1	0.00	1.86	1.82	N/A	1.20	2.23	0.00	20.1	0.000	0.00	0.00	0.05	0.00	0.92	0.09
Nokia B25/B66 Micro RRH	12.0	0.0	1	66.0	F	22.0	12.1	0.00	1.85	1.82	N/A	1.20	2.22	0.00	19.5	0.000	0.00	0.00	0.04	0.00	0.54	0.08
CCI Twin RRU PSU	6.0	0.0	1	34.0	F	14.0	8.4	0.00	0.82	1.67	N/A	1.20	0.98	0.00	19.5	0.000	0.00	0.00	0.02	0.00	0.14	0.04
Base Cover	0.3	0.0	1	66.0	F	9.0	22.0	1.00	1.38	2.44	N/A	1.20	1.65	1.65	19.5	0.032	0.00	0.01	0.04	0.00	0.01	0.08
<b>Shear, Moment, and Weight Summations:</b>															0.23	1.17	5.96	0.39	0.94	8.49	0.69	

<p><b>Wind Loading Summary - Factored Base Reactions:</b>          For Load Combination: 1.2D + 1.0W<sub>o</sub> :</p> <p><b>Design Base Moment, <math>M_{base}</math> = 20.2 ft-kips</b> : <math>M_{Shaft} + M_{appurtenance} + M_{Pd}</math></p> <p><b>Design Base Shear, <math>V_{base}</math> = 1.01 kips</b> : <math>V_{Shaft} + V_{Appurtenance}</math></p> <p><b>Design Base Torsion, <math>T_{base}</math> = 1.17 kips</b> : <math>T_{Shaft} + T_{Appurtenance}</math></p> <p><b>Design Base Weight, <math>WT_{base}</math> = 2.89 kips</b> : <math>Wt_{Shaft} + Wt_{Appurtenance}</math></p>	<p><b>Seismic Loading Summary - Factored Base Reactions:</b>          For Load Combination: 1.2D + 1.0E<sub>v</sub> + 1.0E<sub>h</sub> :</p> <p><b>Design Base Moment, <math>M_{base}</math> = 30.03 ft-kips</b> : <math>M_{Shaft} + M_{appurtenance} + M_{Pd}</math></p> <p><b>Design Base Shear, <math>V_{base}</math> = 1.63 kips</b> : <math>V_{Shaft} + V_{Appurtenance}</math></p> <p><b>Design Base Torsion, <math>T_{base}</math> = 0.94 ft-kips</b> : <math>T_{Shaft} + T_{Appurtenance}</math></p> <p><b>Design Base Weight, <math>WT_{base}</math> = 3.37 kips</b> : <math>Wt_{Shaft} + Wt_{Appurtenance}</math></p>
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### Wind and Ice Loading Calculations: Monopole Shaft

Reference: ANSI/TIA-222-H, Section 2.6.9.6

$V_i =$	30.0	mph (3-Second Gust Basic Wind Speed)
$G_H =$	1.10	Gust Response Factor - 1.10 for Poles
$K_d =$	0.95	Wind Direction Probability Factor
$K_e =$	1.00	Ground Elevation Factor
$I_{ice} =$	1.00	Importance Factor, $t_i$
$t_i =$	0.5	Base Ice Thickness, in.
	II	:Classification of Structure
	C	:Exposure Category
	1	:Topographic Category

Velocity Pressure,  $q_z = 0.00256 * K_z * K_{zt} * K_e * K_d * V^2$  Where:  
 See Page 2 for Variable Descriptions

Section Wind Force,  $F_{ST} = q_z * G_H * (EPA)_s$  Where:  
 $(EPA)_s = C_f A_P$

Excalated Ice Thickness,  $t_{iz} = t_i * I_{ice} * K_{iz} * (K_{zt})^{0.35}$  Where:  
 $K_{iz} = (z / 33)^{0.10}$

Shaft Section Properties					Section Area			Escalated Ice Thickness				Wind Pressure			Wind Loading				
Average Section Elevation (Feet)	Section Pipe Diameter (inches)	Monopole Shaft Wall Thickness (inches)	Section Height (feet)	Section Elevation At Base (Feet)	Gross Section Area (Square Feet)	Force Coefficient	Effective Section Area (Square Feet)	Height Escalation Factor	Topographic Factor	Importance Factor Ice Thickness (Inches)	Escalated Ice Thickness (Inches)	Velocity Pressure (psf)	Gust Effect Factor	Applied Wind Pressure (psf)	Section Base Wind Shear (kips)	Factored Section Base Wind Shear (kips)	Section Base Wind Moment (Foot-kips)	Factored Section Base Wind Moment (Foot-kips)	Section Weight (kips)
Z	D <sub>p</sub>	T <sub>w</sub>	H	Z <sub>Base</sub>	A <sub>p</sub>	C <sub>f</sub>	EPA <sub>s</sub>	K <sub>iz</sub>	K <sub>zt</sub>	I <sub>ice</sub>	t <sub>iz</sub>	q <sub>z</sub>	G <sub>H</sub>	q <sub>z</sub> G <sub>H</sub>	F <sub>ST</sub>	1.6*F <sub>ST</sub>	F <sub>ST</sub> *Z	1.6*F <sub>ST</sub> *Z	W <sub>T</sub>
1.74	20.0	0.250	2.9	0.3	4.8	1.20	6.2	0.74	1.00	1.00	0.74	1.18	1.10	1.30	0.008	0.013	0.01	0.02	0.21
4.63	20.0	0.250	2.9	3.2	4.8	1.20	6.3	0.82	1.00	1.00	0.82	1.45	1.10	1.60	0.010	0.016	0.04	0.07	0.21
7.52	20.0	0.250	2.9	6.1	4.8	1.20	6.3	0.86	1.00	1.00	0.86	1.61	1.10	1.77	0.011	0.018	0.08	0.13	0.22
10.41	20.0	0.250	2.9	9.0	4.8	1.20	6.3	0.89	1.00	1.00	0.89	1.72	1.10	1.89	0.012	0.019	0.12	0.19	0.22
13.31	20.0	0.250	2.9	11.9	4.8	1.20	6.3	0.91	1.00	1.00	0.91	1.81	1.10	1.99	0.013	0.020	0.16	0.26	0.22
16.20	20.0	0.250	2.9	14.8	4.8	1.20	6.3	0.93	1.00	1.00	0.93	1.89	1.10	2.08	0.013	0.021	0.21	0.33	0.22
19.09	20.0	0.250	2.9	17.6	4.8	1.20	6.3	0.95	1.00	1.00	0.95	1.95	1.10	2.15	0.014	0.022	0.3	0.4	0.22
21.98	20.0	0.250	2.9	20.5	4.8	1.20	6.3	0.96	1.00	1.00	0.96	2.01	1.10	2.22	0.014	0.022	0.3	0.5	0.22
24.88	20.0	0.250	2.9	23.4	4.82	1.20	6.3	0.97	1.00	1.00	0.97	2.07	1.10	2.3	0.014	0.023	0.4	0.6	0.22
27.77	20.0	0.250	2.9	26.3	4.82	1.20	6.4	0.98	1.00	1.00	0.98	2.12	1.10	2.3	0.015	0.024	0.4	0.6	0.23
30.66	20.0	0.250	2.9	29.2	4.82	1.20	6.4	0.99	1.00	1.00	0.99	2.16	1.10	2.4	0.015	0.024	0.5	0.7	0.23
33.55	20.0	0.250	2.9	32.1	4.82	1.20	6.4	1.00	1.00	1.00	1.00	2.20	1.10	2.4	0.015	0.025	0.5	0.8	0.23
<b>Loading Summations:</b>															<b>0.15</b>	<b>0.25</b>	<b>2.9</b>	<b>4.7</b>	<b>2.65</b>

Overall Height of Steel = 34.71 feet      Deflection at Top of Pole = 0.19 inches  
 Base Elevation of Pole = 0.29 feet (AGL)      Sway at Top of Pole = 0.03 degrees  
 Top of Steel Elevation = 35.00 feet (AGL)      Moment Due to P-Δ Effects = 0.03 ft-kips

**Wind and Ice Loading Calculations - Sectorized Antennas and Mounts:**

Description	CL Elevation (feet)	Offset from Shaft C.L. (in.)	Quantity Per Sector	Weight (lbs)	Height (inches)	Width (inches)	Depth (inches)	Shielding Factor $K_s$	Escalated Ice Thickness (Inches)	$C_a$ Calc (Normal)	$C_a$ Calc (Transverse)	$(EPA)_N$ (ft <sup>2</sup> )	$(EPA)_T$ (ft <sup>2</sup> )	$(EPA)_A$ (ft <sup>2</sup> )	Wind Pressure (psf)	Factored Loads			
																Factored $V_{Wind-No\ Ice}$ (kips)	Factored Wind Torque (ft-kips)	Factored $M_{Wind-No\ Ice}$ (ft-kips)	Factored Total $Wt_{No\ Ice}$ (kips)
<b>Shear, Moment, and Weight Summations:</b>																0.00	0.00	0.0	0.00

**Wind and Ice Loading Calculations - Miscellaneous Appurtenances:**

Description	CL Elevation (feet)	Offset from Shaft C.L. (in.)	Quantity	Weight (lbs)	Shape Round (R) or Flat (F)	Height (inches)	Width (inches)	Area Factor	$A_A$ (ft <sup>2</sup> )	Aspect Ratio (Height / Width)	C	$C_a$	$C_d A_A$ (ft <sup>2</sup> )	$\Sigma C_d A_A$ (ft <sup>2</sup> )	Wind Pressure (psf)	Factored Loads			
																Factored $V_{Wind-No\ Ice}$ (kips)	Factored Wind Torque (ft-kips)	Factored $M_{Wind-No\ Ice}$ (ft-kips)	Factored Total $Wt_{No\ Ice}$ (kips)
12" Ø x 60" Tall Antenna/Radio Shroud	32.5	0.0	1	259	R	61	21.00	1.00	8.9	2.9	162	0.51	4.55	4.5	2.41	0.02	0.00	0.57	0.31
Nokia 5G Antennas/RRHs in Top Shroud	31.7	0.0	1	81	R	25	21.0	0.00	3.64	1.19	161	0.50	1.82	0.00	2.39	0.00	0.00	0.00	0.10
9" Tall x 30" Long Cobra Head Luminaire	30.0	186.0	1	86	F	10	30.99	1.00	2.15	0.32	N/A	1.24	2.7	3	2.4	0.01	1.87	0.3	0.10
2 7/8" OD x 14' (Max.) Long Luminaire	27.5	96.9	1	121	R	4	168.98	1.00	4.53	0.02	1334	0.60	2.7	3	2.3	0.01	0.98	0.3	0.15
Nokia B12/B14 Micro RRH	17.7	0.0	1	94	F	23	13.07	0.00	2.09	1.76	N/A	1.20	2.5	0	2.1	0.00	0.00	0.0	0.11
Nokia B25/B66 Micro RRH	12.0	0.0	1	81	F	23	13.00	0.00	2.07	1.76	N/A	1.20	2.5	0	2.0	0.00	0.00	0.0	0.10
CCI Twin RRU PSU	6.0	0.0	1	42	F	15	9.24	0.00	0.95	1.61	N/A	1.20	1.1	0	2.0	0.00	0.00	0.0	0.05
Base Cover	0.3	0.0	1	84.7	F	10	22.63	1.00	1.51	0.43	N/A	1.20	1.8	2	2.0	0.01	0.00	0.0	0.10
<b>Shear, Moment, and Weight Summations:</b>																0.04	2.85	1.15	1.02

**Wind Loading Summary - Base Reactions:**

 For Load Combination: 1.2D + 1.0D<sub>i</sub> + 1.0W<sub>i</sub>:

<b>Design Base Moment, <math>M_{pole} = 5.9</math> ft-kips</b>	: $M_{Shaft} + M_{appurtenance} + M_{PD}$
<b>Design Base Shear, <math>V_{pole} = 0.29</math> kips</b>	: $V_{Shaft} + V_{Appurtenance}$
<b>Design Base Torsion, <math>T_{base} = 1.15</math> ft-kips</b>	: $T_{Shaft} + T_{Appurtenance}$
<b>Design Base Weight, <math>WT_{pole} = 4.2</math> kips</b>	: $Wt_{Shaft} + Wt_{Appurtenance}$

### Wind Loading Calculations: Monopole Shaft

Reference: AASHTO LRFD-LTS-1, 2015 (w/ 2017 Interim Revs), Sec. 3

 Design Wind Pressure,  $P_z = 0.00256 * K_z * K_d * G * V^2$  Where:

$V_{(ult)}$ =	97	mph (3-Second Gust)
G =	1.14	Gust Effect Factor, Section 3.8.6, Min. Value = 1.14
$K_d$ =	0.95	Wind Direction Probability Factor
I =	1	Importance Factor
	II	:Risk Category
	C	:Exposure Category
	1	:Topographic Category
$C_v$ =	1.0	:Wind Drag Coefficient (= 0.8 for the Extreme Limit State and 1.0 otherwise), Section 3.8.7

$K_z$  = Velocity Pressure Exposure Coefficient, Section 3.8.4 and Eqn. 3.8.4-1  
 $K_d$  = Wind Direction Probability Factor, Table 3.8.5-1  
 $V$  = Basic Wind Speed, 3-Second Gust, mph

 Section Wind Force,  $F_{ST} = P_z * (EPA)_s$  Where:

$(EPA)_s = C_d A_p$   
 $C_d$  = Drag Coefficient, Section 3.8.7

Shaft Section Properties					Section Area				Wind Pressure						Wind Loading				
Average Section Elevation (Feet)	Section Pipe Diameter (inches)	Monopole Shaft Wall Thickness (inches)	Section Height (feet)	Section Elevation At Base (Feet)	Gross Section Area (Square Feet)	(mph - feet)	Drag Coefficient	Effective Section Area (Square Feet)	Velocity Pressure Coefficient	Wind Direction Probability Factor	Importance Factor	Velocity Pressure (psf)	Gust Effect Factor	Applied Wind Pressure (psf)	Section Base Wind Shear (kips)	Factored Section Base Wind Shear (kips)	Section Base Wind Moment (Foot-kips)	Factored Section Base Wind Moment (Foot-kips)	Section Weight (kips)
Z	D <sub>P</sub>	T <sub>W</sub>	H	Z <sub>Base</sub>	A <sub>P</sub>	C <sub>v</sub> *V <sup>d</sup>	C <sub>d</sub>	EPA <sub>s</sub>	K <sub>z</sub>	K <sub>d</sub>	I	P <sub>z</sub>	G	P <sub>z</sub> G	F <sub>ST</sub>	1.0*F <sub>ST</sub>	F <sub>ST</sub> *Z	1.0*F <sub>ST</sub> *Z	W <sub>T</sub>
1.74	20.00	0.250	2.89	0.29	4.82	161.7	0.45	2.17	0.85	0.95	1.00	19.5	1.14	22.2	0.048	0.048	0.07	0.07	0.15
4.63	20.00	0.250	2.89	3.18	4.82	161.7	0.45	2.17	0.85	0.95	1.00	19.5	1.14	22.2	0.048	0.048	0.21	0.21	0.15
7.52	20.00	0.250	2.89	6.1	4.82	161.7	0.45	2.17	0.85	0.95	1.00	19.5	1.14	22.2	0.048	0.048	0.35	0.35	0.15
10.41	20.00	0.250	2.89	9.0	4.82	161.7	0.45	2.17	0.85	0.95	1.00	19.5	1.14	22.2	0.048	0.048	0.49	0.49	0.15
13.31	20.00	0.250	2.89	11.9	4.82	161.7	0.45	2.17	0.85	0.95	1.00	19.5	1.14	22.2	0.048	0.048	0.63	0.63	0.15
16.20	20.00	0.250	2.89	14.8	4.82	161.7	0.45	2.17	0.86	0.95	1.00	19.7	1.14	22.5	0.049	0.049	0.78	0.78	0.15
19.09	20.00	0.250	2.89	17.6	4.82	161.7	0.45	2.17	0.89	0.95	1.00	20.4	1.14	23.3	0.051	0.051	0.95	0.95	0.15
21.98	20.00	0.250	2.89	20.5	4.82	161.7	0.45	2.17	0.92	0.95	1.00	21.1	1.14	24.0	0.052	0.052	1.13	1.13	0.15
24.88	20.00	0.250	2.89	23.4	4.82	161.7	0.45	2.17	0.94	0.95	1.00	21.6	1.14	24.6	0.053	0.053	1.31	1.31	0.15
27.77	20.00	0.250	2.89	26.3	4.82	161.7	0.45	2.17	0.97	0.95	1.00	22.1	1.14	25.2	0.055	0.055	1.50	1.50	0.15
30.66	20.00	0.250	2.89	29.2	4.82	161.7	0.45	2.17	0.99	0.95	1.00	22.6	1.14	25.7	0.056	0.056	1.70	1.70	0.15
33.55	20.00	0.250	2.89	32.1	4.82	161.7	0.45	2.17	1.01	0.95	1.00	23.0	1.14	26.2	0.057	0.057	1.89	1.89	0.15
<b>Loading Summations:</b>															<b>0.61</b>	<b>0.61</b>	<b>11.00</b>	<b>11.00</b>	<b>1.83</b>

Overall Length of Pole = 34.71 feet      Deflection at Top of Pole = 0.54 inches  
 Base Elevation of Pole = 0.29 feet (AGL)      Sway at Top of Pole = 0.07 degrees  
 Top of Steel Elevation = 35.00 feet (AGL)      Moment Due to P-Δ Effects = 0.05 ft-kips



**Wind Loading Calculations - Sectorized Antennas and Mounts:**

Description	CL Elevation (feet)	Offset from Shaft C.L. (in.)	Quantity Per Sector	Weight (lbs)	Height (inches)	Width (inches)	Depth (inches)	Shielding Factor $K_s$	$C_a$ Calc (Normal)	$C_a$ Calc (Transverse)	$(EPA)_N$ (ft <sup>2</sup> )	$(EPA)_T$ (ft <sup>2</sup> )	$(EPA)_A$ (ft <sup>2</sup> )	Wind Pressure (psf)	Factored Loads			
															Factored $V_{wind}$ (kips)	Factored Torque (ft-kips)	Factored $M_{wind}$ (ft-kips)	Factored Total Wt (kips)
<b>Shear, Moment, and Weight Summations:</b>															0.00	0.00	0.00	0.00

**Wind Loading Calculations - Miscellaneous Appurtenances:**

Description	CL Elevation (feet)	Offset from Shaft C.L. (in.)	Quantity	Weight (lbs)	Shape Round (R) or Flat (F)	Height (inches)	Width (inches)	Area Factor	$A_A$ (ft <sup>2</sup> )	Aspect Ratio (Height / Width)	$C_1V_d$	Wind Drag Coefficient, $C_d$	$C_dA_A$ (ft <sup>2</sup> )	$\Sigma C_dA_A$ (ft <sup>2</sup> )	Wind Pressure (psf)	Factored Loads			
																Factored $V_{wind}$ (kips)	Factored Torque (ft-kips)	Factored $M_{wind}$ (ft-kips)	Factored Total Wt (kips)
12" Ø x 60" Tall Antenna/Radio Shroud	32.5	0.0	1	165	R	60.0	20.0	1.00	8.33	3.00	162	0.45	3.75	3.75	26.1	0.10	0.02	3.18	0.20
Nokia 5G Antennas/RRHs in Top Shroud	31.7	0.0	1	35	R	24.0	20.0	0.00	3.33	1.20	162	0.45	1.50	0.00	25.9	0.00	0.00	0.00	0.04
9" Tall x 30" Long Cobra Head Luminaire	30.0	186.0	1	45	F	9.0	30.0	1.00	1.88	3.33	N/A	1.20	2.25	2.25	25.6	0.06	0.89	1.73	0.05
2 7/8" OD x 14' (Max.) Long Luminaire Arm	27.5	96.9	1	85	R	2.9	168.0	1.00	3.35	58.43	1358	0.45	1.51	1.51	25.2	0.04	0.31	1.04	0.10
Nokia B12/B14 Micro RRH	17.7	0.0	1	77	F	22.1	12.1	0.00	1.86	1.82	N/A	1.19	2.21	0.00	22.9	0.00	0.00	0.00	0.09
Nokia B25/B66 Micro RRH	12.0	0.0	1	66	F	22.0	12.1	0.00	1.85	1.82	N/A	1.19	2.20	0.00	22.2	0.00	0.00	0.00	0.08
CCI Twin RRU PSU	6.0	0.0	1	34	F	14.0	8.4	0.00	0.82	1.67	N/A	1.19	0.97	0.00	22.2	0.00	0.00	0.00	0.04
Base Cover	0.3	0.0	1	66	F	9.0	22.0	1.00	1.38	2.44	N/A	1.20	1.65	1.65	22.2	0.04	0.01	0.01	0.08
<b>Shear, Moment, and Weight Summations:</b>															0.23	1.23	5.96	0.69	

**Wind Loading Summary - Factored Base Reactions:**

**Design Base Moment,  $M_{AASHTO} = 17.01$  ft-kips**  
**Design Base Shear,  $V_{AASHTO} = 0.84$  kips**  
**Design Base Torsion,  $T_{AASHTO} = 1.23$  ft-kips**  
**Design Base Weight,  $WT_{AASHTO} = 2.89$  kips**

### Stress Check - Monopole Shaft / Access Ports

**Access Port Information:**

Port Width =	6.0	in.	Number of Ports =	1
Port Height =	12.0	in.		
C.L. Port =	25.0	in. (Above Base Plate)		

**Monopole Shaft Information:**

Pole Diameter @ Port, D =	20.00	in.	Wall Slenderness Ratio, $\lambda = D/t =$	86.0
Design Wall Thickness, t =	0.2325	in.	Plastic Design Slenderness Ratio, $\lambda_p =$	59.2
Yield Stress, $F_Y =$	35.0	ksi	Limiting Slenderness Ratio, $\lambda_{Max} =$	400
Distance to Extreme Fiber, C =	10.00	in.	Effective Section Modulus, $S_{eff} =$	70.35 in <sup>3</sup>
Effective Yield Stress, $F'_Y =$	35.0	ksi	Effective Radius of Gyration, $R_{eff} =$	4.20 in.

**MP Shaft Section Properties at Access Ports:**

Nominal Pipe Section:	Reinforced Radio Port:	X - X Axis:	Y - Y Axis:
Mast Area, $A_{Nominal} =$	14.44 in <sup>2</sup>	Mast Area, $A_{Reinf} =$	9.03 in <sup>2</sup>
Mom Of Inertia, $I_{Nominal} =$	703.5 in <sup>4</sup>	Mom Of Inertia, $I_{Reinf} =$	159.61 in <sup>4</sup>
Port Yield Stress, $F_Y =$	46 ksi	Dist. to Extreme Fiber, $C_x =$	7.87 in.

**Design Flexural Strength:**

Compact Slenderness Ratio, $\lambda_p =$	59.2	Effective Section Modulus, $S_{eff} =$	20.0 in <sup>3</sup>
Noncompact Slenderness Ratio, $\lambda_r =$	256	<b>Section Is Non-Compact</b>	
Factored Moment, $M_{BP} =$	30.0 ft-kips	Nominal Flexural Strength, $M_n =$	76.48 ft-kips
		Design Flexural Strength, $\phi_b M_n =$	68.8 ft-kips (OK)

**Design Compressive Strength:**

		Nominal Compressive Strength, $P_n = F'_Y * A_{Nominal} =$	316 kips
Factored Weight, $W_{tBP} =$	3.37 kips	Design Compressive Strength, $\phi_c P_n =$	284 kips (OK)

**Design Shear Strength:**

$F_{nv} =$	21.0 ksi	Nominal Shear Strength, $V_n = F_{nv} * A_{Nominal} =$	94.82 kips
Factored Shear, $V_{BP} =$	1.63 kips	Design Shear Strength, $\phi_v V_n =$	85.34 kips (OK)

**Design Torsional Strength:**

$F_{nt} =$	21.00 ksi		
$C_t =$	142.63	Nominal Torsional Strength, $T_n = F_{nt} * C_t =$	250 ft-kips
Factored Torsion, $T_{BP} =$	1.17 ft-kips	Design Torsional Strength, $\phi_t T_n =$	237.13 kips (OK)

**Combined Flexure and Axial Force Check: (Section 4.8.2)**

$$|P_u / \phi_c P_n| + |M_u / \phi_b M_n| + [ |V_u / \phi_v V_n| + |T_u / \phi_r T_n| ]^2 = 0.45 < 1.00 \text{ OK}$$

### Summary - Access Ports

**Monopole Shaft:**

USE: 20" OD x 0.25" wall, A53/A500 Gr B/API 5L Gr. B (Min. Fy = 35ksi) Monopole Shaft

**Access Ports:**

- (1) - 6" x 12" Reinforced Access Port, C.L. @ 25'-0" ± AGL
- (1) - 12" x 56" Unreinforced Access Port, C.L. @ 17'-8" ± AGL
- (1) - 12" x 56" Unreinforced Access Port, C.L.'s @ 12'-0" ± AGL
- (1) - 12" x 42" Unreinforced Access Port, C.L.'s @ 6'-0" ± AGL
- (1) - 12" x 14" Unreinforced Access Port, C.L.'s @ 1'-11" ± AGL

### Stress Check - Monopole Shaft @ Base

**Monopole Shaft Information:**

Pole Diameter @ Base, $D_{Base}$ =	20.00 in.	Mast Area, $A_{Nominal}$ =	14.44 in <sup>2</sup>
Nominal Wall Thickness, $t$ =	0.2500 in.	Mom Of Inertia, $I_{Nominal}$ =	703.5 in <sup>4</sup>
Distance to Extreme Fiber, $C$ =	10.00 in.	Section Modulus, $S_{Modulus}$ =	70.3 in <sup>3</sup>
Yield Stress, $F_Y$ =	35.0 ksi	Plastic Section Modulus, $Z_{Modulus}$ =	90.9 in <sup>3</sup>
Wall Slenderness Ratio, $\lambda = D/t$ or $b/t$ =	80.0	Average Radius of Gyration, $R_{Gyration}$ =	6.98 in.

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**Design Flexural Strength: Section 5.8**

Compact Slenderness Ratio, $\lambda_p$ =	58.0	<b>Section Is Non-Compact</b>	$\phi_b$ =	0.9
Noncompact Slenderness Ratio, $\lambda_r$ =	257			
Limiting Slenderness Ratio, $\lambda_{Max}$ =	373	<b>(OK)</b>		
Nominal Flexural Strength, $M_n$ =	248.0 ft-kips	Base Moment, $M_{AASHTO}$ =	17.01 ft-kips	
		Design Flexural Strength, $\phi_b M_n$ =	223.2	<b>ft-kips (OK)</b>

**Design Compressive Strength: Section 5.10**

Compact Slenderness Ratio, $\lambda_p$ =	91	$\phi_c$ =	0.9
$kL/r$ ( $k = 2.1$ ) =	125.3	$Q$ =	1.000
Euler's Buckling Stress = $F_e$ =	18.23 ksi		
Critical Buckling Stress = $F_{cr}$ =	15.67 ksi		
Nominal Compressive Strength = $P_n = F_{cr} * A_g$ =	226.2 kips	Base Weight, $W_{tBase}$ =	2.89 kips
		Design Compressive Strength = $\phi_c P_n = F_{cr} * A_g$ =	203.6 <b>kips (OK)</b>

**Design Shear Strength: Section 5.11.2**

Nominal Shear Stress Capacity = $F_{nv}$ =	21.0 ksi	$\phi_v$ =	0.9
Shear Area = $A_v$ =	7.22 in <sup>2</sup>		
Nominal Shear Strength = $V_n$ =	151.6 kips	Applied Shear Load, $V_{AASHTO}$ =	0.84 kips
		Design Shear Strength = $\phi_v V_n = F_{nv} * A_v$ =	136.4 <b>kips (OK)</b>

**Design Torsion Strength: Section 5.11.3**

Torsional Constant, $C_t$ =	153.1 in	$\phi_t$ =	0.95
Nominal Torsion Stress Capacity, $F_{nt}$ =	21.00 ksi		
Nominal Torsion Strength, $T_n = F_{nt} * C_t$ =	267.9 kip-ft	Applied Torsion Load, $T_{AASHTO}$ =	1.23 ft-kips
		Design Torsion Strength, $\phi_t T_n = F_{nt} * C_t$ =	254.5 <b>ft-kips (OK)</b>

**Combined Force Interaction: Section 5.12.1**

Mom Of Inertia @ T.O. Pole, $I_T$ =	703.49 in <sup>4</sup>	Mom Of Inertia @ B.O. Pole, $I_B$ =	703.49 in <sup>4</sup>
Factored Vertical Load, $P_T$ =	0.69 kips	Factored Weight, $D_p$ =	2.20 kips
$P_{equivalent} = (I_B/I_T)^{1/3} * P_T + 0.38 * D_p$ =	1.52 kips	$P_{Euler\ bottom} = \pi^2 * E * I_B / (k * L)^2$ =	263.20 kips
Coefficient for Amplification, $B = B_2$ =	1		$\geq 1.0$

$$P_u / \phi_c P_n + B * M_u / \phi_b M_n + [ |V_u / \phi_v V_n| + |T_u / \phi_t T_n| ]^2 = 0.09 \quad \text{(OK)}$$

**USE: 20" OD x 0.25" wall, A53/A500 Gr B/API 5L Gr. B (Min. Fy = 35ksi) Monopole Shaft**

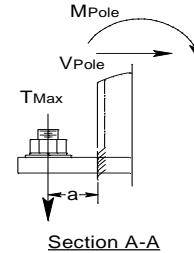
### Anchor Bolt & Base Plate Data:

No. of Anchor Bolts, n = 4	Yield Strength, $F_{y,AB}$ = 55.0 ksi	A.B. Gross Area, $A_g$ = 1.77 in <sup>2</sup>
AB Diameter, $D_{AB}$ = 1.50 in.	Tensile Strength, $F_{u,AB}$ = 75.0 ksi	A.B. Tensile Stress Area, $A_n$ = 1.41 in <sup>2</sup>
AB Circle, $D_{BC}$ = 25.0 in.	Base Plate Width, $W_{BP}$ = 23.0 in.	A.B. Plastic Modulus, $Z_{ar}$ = 0.47 in <sup>3</sup>
AB Length, $L_{AB}$ = 72.0 in.	Pole Diameter, $D_{pole}$ = 20.00 in.	Dist. Btwn Concr. & Lvl'g Nut, $l_{ar}$ = 1.50 in.

### Anchor Bolt Design Per ANSI/TIA 222-H, Section 4.9.9

**Factored Base Reactions:**

$$\begin{aligned} \alpha M_{pole} &= 30.03 \text{ ft-kips} \\ \alpha V_{pole} &= 1.63 \text{ kips} \\ \alpha T_{pole} &= 0.94 \text{ ft-kips} \\ \alpha Wt_{pole} &= 3.37 \text{ kips} \end{aligned}$$



**Factored Compressive Force per bolt:**

$$P_{uc} = [4 * \alpha M_{pole} / (n * D_{B.C.})] + \alpha Wt_{pole} / n = 15.3 \text{ kips}$$

**Factored Tensile Force per bolt:**

$$P_{ut} = [4 * \alpha M_{pole} / (n * D_{B.C.})] - \alpha Wt_{pole} / n = 13.6 \text{ kips}$$

**Factored Shear Force per bolt:**

$$V_u = \alpha V_{pole} / n + \alpha T_{pole} / ((n * D_{BC}) / 2) = 0.63 \text{ kips}$$

**Anchor Bolt Moment**

$$M_{u,ab} = 0.65 * V_u * l_{ar} = 0.62 \text{ in-kips}$$

**Design Anchor Bolt Strengths:**

Design Tensile Strength, $\phi_t R_{nt,AB} = \phi_t * F_{u,AB} * A_n =$	79.3 kips	$\phi_t = \phi_v =$	0.75
Design Compressive Strength, $\phi_c R_{nc,AB} = \phi_c * F_{y,AB} * A_n =$	77.6 kips	$\phi_c =$	1.00
Design Shear Rupture Strength, $\phi_v R_{nv,AB} = \phi_v * 0.5 * F_{u,AB} * A_g =$	49.7 kips		
Design Shear Yield Strength, $\phi_c R_{nv,AB} = \phi_c * 0.6 * F_{y,AB} * A_g / 2 =$	23.3 kips		
Design Flexural Strength, $\phi_t M_{n,AB} = \phi_t * F_{y,AB} * Z =$	23.13 in-kips	$\phi_t =$	0.90

**Combined Shear & Tension Interaction Check:**

**Anchor Rod Moment Interaction Equations N/A**

$$\begin{aligned} [P_{ut} / \phi_t R_{nt,AB}]^2 + [V_u / \phi_v R_{nv,AB}]^2 &= 0.03 < 1.00 \text{ - (OK)} \\ [P_{uc} / \phi_c R_{nc,AB}] + [V_u / \phi_c R_{nv,AB}]^2 &= 0.20 < 1.00 \text{ - (OK)} \end{aligned}$$

### Base Plate Design Per ANSI/TIA 222-H, Section 4.7

**Factored Base Plate Loading:**

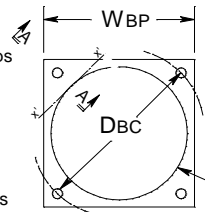
$$BP \text{ Bending, } M_{plate} = P_{ut} * a = 33.9 \text{ in.-kips}$$

**Design Base Plate Bending Strength,**

$$\phi F_{B, BP} = 0.90 * F_{y, BP} = 32.4 \text{ ksi}$$

**Minimum Base Plate thickness:**

$$t_{min} = [4 * M_{plate} / (b * \phi F_{B, BP})]^{1/2} = 0.578 \text{ inches}$$



BP Yield Strength,  $F_{y, BP} = 36.0 \text{ ksi}$

b = length of x'-x' = 12.5 in.

a =  $(D_{BC} - D_{pole}) / 2 = 2.5 \text{ in.}$

Failure across x'-x', modeled as fixed-end cantilevered beam.

Use: (4) - 1.5"  $\phi$  x 72" Long, Grade 55 Anchor Bolts on a 25"  $\phi$  B.C.

Structural Usage = 19.7%

Use: 1.25" Thick by 23" Square, Grade 36 Base Plate

Structural Usage = 68.0%

**Base Plate-to-Pole Shaft weld Design:**

Minimum weld size per ANSI/AWS d1.1, Table 5.8, Low-Hydrogen process = 1/8 inch

Upper Weld Size,  $w_t = 0.313 \text{ in.}$

Weld Tensile Strength,  $F_{weld} = 70.0 \text{ ksi (E70XX)}$

Lower Weld Size,  $w_b = 0.188 \text{ in.}$

Design Weld Strength,  $\phi F_w = 31.5 \text{ ksi}$

Distance to Centroid of Upper Weld,  $L_{tw} = D_{pole} / 2 + w_t / 3 = 10.10 \text{ inches}$

Distance to Centroid of Lower Weld,  $L_{bw} = D_{pole} / 2 - w_b / 3 = 9.94 \text{ inches}$

Section Modulus of Upper Weld,  $S_{tw} = 0.707 * w_t * \pi * L_{tw}^2 = 70.9 \text{ in.}^3$

Section Modulus of Lower Weld,  $S_{bw} = 0.707 * w_b * \pi * L_{bw}^2 = 41.1 \text{ in.}^3$

Total Weld Area,  $A_{weld} = 22.3 \text{ in.}^2$

Required Weld Strength,  $f_w = M_{pole} / \Sigma S_w + Wt_{pole} / A_{weld} = 3.37 \text{ ksi (OK)}$

Use: Socketed Pole into Base Plate with 5/16" Upper Fillet Weld with 3/16" Lower fillet weld



## Seismic Base Shear Calculations

### Factored Base Reactions from Wind Loading:

$$\begin{aligned} M_{base} &= 20.2 \text{ ft-kips} \\ V_{base} &= 1.01 \text{ kips} \\ Wt_{base} &= 2.89 \text{ kips} \end{aligned}$$

### Seismic Parameters :

Per 2018 IBC Section 1613, ASCE 7-16 Sections 15.1.3 & 12.8 & ANSI/TIA-222-H

$$\begin{aligned} \text{Site Classification} &= \mathbf{D} && \text{Chapter 20, Table 20.3-1} \\ \text{Short-Period Spectral Acceleration, } S_s &= 1.270 \text{ g} \\ \text{1-Second Period Spectral Acceleration, } S_1 &= 0.437 \text{ g} \end{aligned}$$

### Seismic Shear Factors:

$$\begin{aligned} I &= 1.00 && \text{Table 1.5-2} && \text{Location:} \\ R &= 1.50 && \text{Table 15.4-2} \\ T_L &= 6 && \text{s, Annex B Fig. B-19} \\ F_a &= 1.20 && \text{Values for } S_1, S_s, F_a, \text{ and } F_v \text{ obtained from ASCE 7 online Hazard Tool based on ASCE 7-16} \\ F_v &= 1.85 && \text{(Based on the location indicated above).} \end{aligned}$$

### Seismic Design Classifications:

$$\begin{aligned} \text{Occupancy Category:} & \mathbf{I} && \text{I - IV, Table 1-1} \\ \text{Seismic Design Category:} & \mathbf{D} && \text{A - F, Section 11.6} \end{aligned}$$

### Seismic Base Shear (Nominal Value) Sec. 2.7.7.1

$$\begin{aligned} V &= C_s * W = \mathbf{1.63 \text{ kips}} \\ C_s &= S_{DS} / (R / I) = 0.677 \\ S_{DS} &= (2 / 3) * S_{MS} = 1.016 \\ S_{MS} &= S_s * F_a = 1.524 \end{aligned}$$

### Seismic Base Shear (Need Not Exceed Value) Sec. 2.7.7.1 & Sec. 2.7.7.1.3.3

$$\begin{aligned} C_s &\leq S_{D1} / [T * (R / I)] \text{ (for } T \leq T_L) \leq S_{D1} * T_L * I / (T^2 * R) \text{ (for } T > T_L) \text{ (for } S_1 \leq 0.2g, \times 1.5) && 1.737 \\ S_{D1} &= (2 / 3) * S_{M1} = 0.539 \\ S_{M1} &= S_1 * F_v = 0.808 \\ T &= 1 / f_1 = 1 / (1 / (2\pi) * (3 * E * I_{avg} * g / (L_p * (W_u + 0.236 * W_L)))^{1/2}) = 0.31 \text{ Seconds} \\ E &= 29000 \text{ ksi} && W_u = 0.275 \text{ kips} \\ I_{avg} &= (I_{top} + I_{bot}) / 2 = 703.49 \text{ in}^4 && W_L = 2.130 \text{ kips} \\ L_p &= 420 \text{ in} && W_t = 2.41 \text{ kips} \\ g &= 386 \text{ in/s}^2 \end{aligned}$$

### Seismic Base Shear (Minimum Value) Sec. 2.7.7.1

$$\begin{aligned} V &= C_s * W = \mathbf{0.11 \text{ kips}} \\ C_s &= 0.044 * S_{DS} * I = 0.045 \geq \mathbf{0.03} \end{aligned}$$

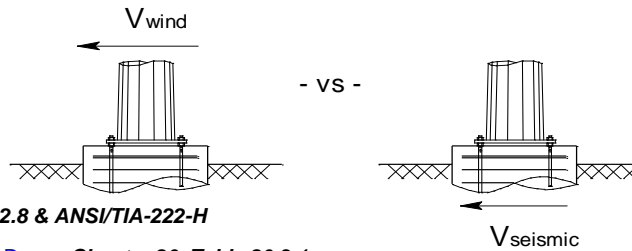
### Seismic Base Shear (Minimum Value, $S_1 \geq 0.6g$ ) Sec. 2.7.7.1

$$\begin{aligned} V &= C_s * W = \mathbf{0.56 \text{ kips}} \\ C_s &= 0.8 * S_1 / (R / I) = 0.233 \end{aligned}$$

### Vertical Seismic Load Effect Sec. 2.7.6

$$\begin{aligned} \text{Total Seismic Vertical Load Effect} &= E_v = 0.2 * S_{DS} * W = \mathbf{0.49 \text{ kips}} \\ \text{Total Seismic Shear} &= \mathbf{1.63 \text{ kips}} \\ \text{Total Wind Shear} &= \mathbf{1.01 \text{ kips}} \end{aligned}$$

**Design Base Shear is Governed by Seismic Loading**



## Drilled Pier Foundation Design

### Factored Monopole Base Reactions:

$$\begin{aligned} \alpha M_{\text{base}} &= \text{Overturning Moment} = & 30.0 & \text{ ft-kips} \\ \alpha V_{\text{base}} &= \text{Base Shear} = & 1.63 & \text{ kips} \\ \alpha W_{\text{t}_{\text{base}}} &= \text{Base Weight} = & 3.37 & \text{ kips} \end{aligned}$$

### Design Basis:

1. Ref. 2018 IBC Section 1807.3.2.1, Nonconstrained Condition
2. ACI 318-14 - Requirements for Reinforced Concrete.
3. Soil Design Values: Per 2018 IBC, Table 1806.2, Class 5 Material

### Soil Characteristics:

$$\begin{aligned} \text{Based on 2018 IBC Soil Classification for Type:} & & 5 & \quad (1 - 5) \\ \phi R_p = \text{Lateral Bearing Strength at 1' below grade} & = & 150 & \text{ psf/ft} \\ d_{\text{negl}} = \text{Depth of soil below grade neglected} & = & 0.00 & \text{ ft.} \end{aligned}$$

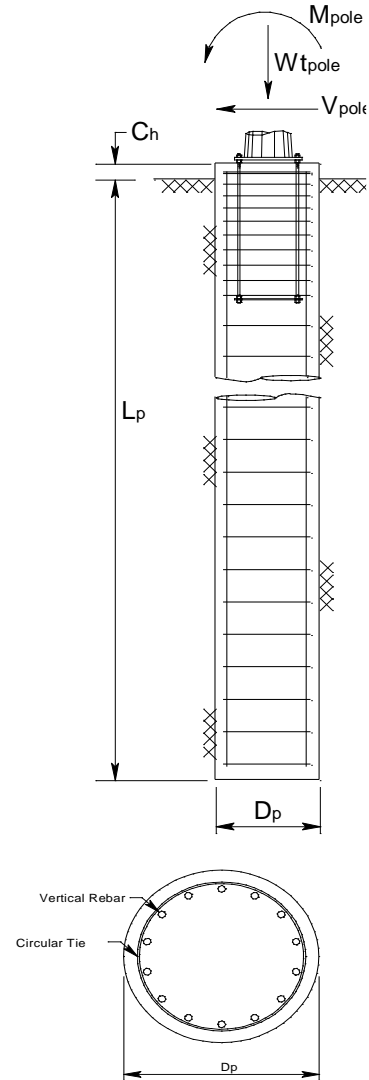
### Drilled Pier Characteristics:

#### Minimum Diameter:

$$\begin{aligned} D_{\text{templ}} &= \text{OD of AB Template} = & 27.4 & \text{ in.} \\ S_b &= \text{Minimum AB and Rebar Separation} = & 0.75 & \text{ in.} \\ \text{Concrete Cover} &= C_{\text{cover}} = & 3.00 & \text{ in.} \\ D_{\text{p}_{\text{min}}} &= D_{\text{templ}} + 2*(S_b + d_b + d_{\text{ties}} + C_{\text{cover}}) = & 37.9 & \text{ in.} \\ \text{Use } D_p &= \text{Pier Diameter} = & 42.0 & \text{ in.} \end{aligned}$$

#### Minimum Length/Depth:

$$\begin{aligned} C_h &= \text{Pier Projection AGL} = & 0.00 & \text{ ft.} \\ S_1 &= 2 * \phi R_p * (L_p - d_{\text{negl}}) / 3 = & 700 & \text{ psf; Where } (L_p - d_{\text{negl}}) \leq 12 \text{ ft.} \\ A &= 2.34 * V_{\text{pole}} / (S_1 * D_p) = & 1.56 & \\ L_{\text{p}_{\text{min}}} &= A/2 * [1 + (1 + 4.36 * h/A)^{1/2}] + d_{\text{negl}} = & 6.42 & \text{ ft.} \\ \text{Use: } L_p &= \text{Below Grade Pier Length} = & 7.00 & \text{ ft.} \\ L_{\text{tot}} &= \text{Total Length of Pier} = & 7.00 & \text{ ft.} \\ \text{Total Volume of Concrete Required} & = & 2.5 & \text{ cu. yds.} \end{aligned}$$



## Drilled Pier Foundation Design

**Reinforcement:**
**Vertical Reinforcement Parameters:**

Vertical Bar Size = <b>8</b>	Tie Bar Size = <b>4</b>
Qty of Vertical Bars = <b>10</b>	$f'_c =$ <b>4.0</b> ksi
$d_b =$ Diameter of Bar = 1.00 in.	$f_y =$ <b>60.0</b> ksi
<b><math>A_s =</math> Total Area of Vert. Bars = 7.85 sq. in.</b>	

**Pier Moment Capacity: Verify  $M_{ult} \leq \phi M_n$** 

$$M_{ult} = 1.3 * [M_{pole} + V_{pole} * (L_p / 3 + d_{negl})] = 44.0 \text{ ft-kips}$$

$$\phi M_n = 613 \text{ ft-kips (OK)}$$

$$A_{smin} = 4 * M_{ult} / \phi * f_y * N * D_p = 0.0931 \text{ sq. in.}$$

$$\rho_{prov} = A_s / (\pi / 4 * D_p^2) = 0.0057$$

$$\rho_{min} = 0.0050 \text{ (OK)}$$

**Vertical Bar Development Length:**

$$L_{db} = [0.04 * d_b * f_y / f'_c] * M_{ult} / \phi M_n = 2.72 \text{ in.}$$

$$L_{db\_prov'd} = 54.5 \text{ in. (OK)}$$

**Shear Reinforcement:**

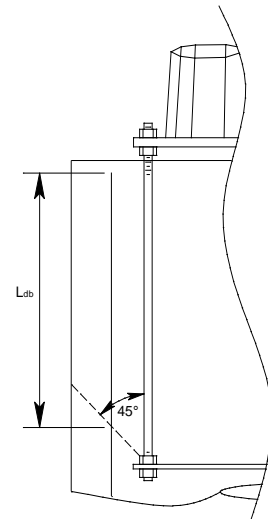
$$\text{Factored Shear, } V_u = 1.4 * V_{pole} = 1.42 \text{ kips}$$

$$\text{Horizontal Tie Shear Capacity, } V_s = 134.4 \text{ kips} \quad \text{ACI 318 Equation 22.5.10.5.3}$$

$$\text{Concrete Shear Capacity, } V_c = 171.4 \text{ kips} \quad \text{ACI 318 Table 22.5.5.1}$$

$$\text{Total Shear Capacity, } \phi V_c + \phi V_s = 229 \text{ kips (OK)}$$

$$D_{tie} = \text{Diameter of Tie} = 36 \text{ " } \phi$$


**Reinforcement Summary:**

- Vertical Bars: 10 - #8 x 6.5 ft. Long A615 Gr. 60 Deformed Vertical Bars  
Spaced evenly (approx. 10.4" o.c.) within Horizontal Ties
- Horizontal Ties: 14 - #4 Horizontal Ties, 36 in. Diameter, with 24 in. lap  
Spaced at 6" o.c. along the anchor bolts and 12" o.c. in remainder of pier
- Rebar Weights:
 

Vertical Bars =	174	pounds
Horizontal Ties =	108	pounds
Horizontal Tie Length =	11' - 6"	

