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Structural Design Calculations

Site No.: **4BS0539A - Cedar Street WT**
Project: **Anchor**
Client: **Centerline Communications**
Date: **December 5, 2023**

Synopsis:

The final T-Mobile Anchor equipment installation will consists of:

- Three (3) RFS APXVAARR24 antennas (1 per sector)
- Three (3) Ericsson AIR6449 antennas (1 per sector)
- Two (2) Commscope HBXX-6516DS antennas (sector B & C)
- Three (3) Ericsson RRUS-4460 remote radio heads (RRHs)(1 per sector)
- Three (3) Ericsson RRUS-4449 RRHs (1 per sector)

Material Properties:

Structural steel yield stress, $F_{ys} := 36 \cdot ksi$

Steel yield stress (pipe), $F_{yp} := 35 \cdot ksi$

Modulus of elasticity of steel, $E_s := 29 \cdot 10^6 \cdot psi$

Steel unit weight, $\gamma_s := 490 \cdot pcf$

Loads:

Environmental Loads:

Wind Load:

Exposure category, B (ASCE 7-10 Sec 26.7.3)

Risk Category, Category IV (Water tank) (ASCE 7-10 Table 1.5-1)

Basic Wind Velocity, $V_w := 137$ mph (MSBC Table 1604.11)

Antenna Height, $Height := 73ft$

Exposure coefficient, $K_z = 0.9$ (ASCE 7-10 Table 29.3-1)

Wind Directionality Factor, $K_d := 0.9$ (ASCE 7-10 Table 26.6-1)

Velocity wind pressure, $q_z := .00256 \cdot V_w^2 \cdot K_z \cdot K_d \cdot psf = 39.03 \cdot psf$ (ASCE 7-10 Sec. 27.3.2)

Force coeff: Flat, $C_f := 1.4$ (ASCE 7-10 Fig. 29.5-1)

Wind Load factor, $LF := .6$ (ASCE 7-10 Sect 2.4)

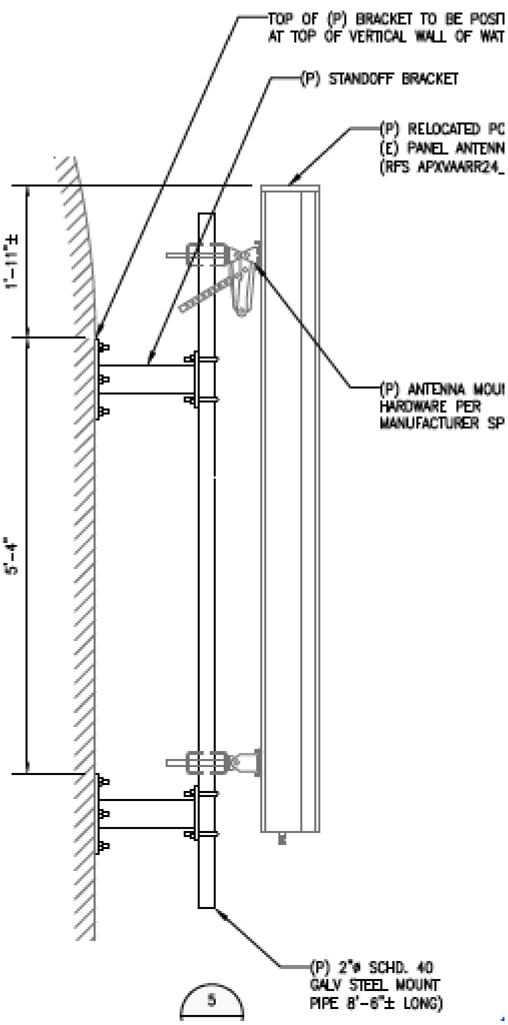
Wind load pressure, $WL_f := q_z \cdot C_f = 54.64 \cdot psf$ (ASCE 7-10 C26.5-1)

Radial ice thickness, $t_{ice} := .75 \cdot in$

Density of ice, $\gamma_{ice} := 56 \cdot pcf$

Analysis:

Figure 1: Proposed Antenna Installation (from drawings)



Antenna (APXVAARR24) - Governs

Width, $w_{a1} := 24 \cdot in$

Depth, $t_{a1} := 7.1 \cdot in$

Length, $l_{a1} := 96 \cdot in$

Weight, $W_{a1} := 155 \cdot lb$

RRH (NA)

Width, $w_{r1} := 0 \cdot in$

Depth, $t_{r1} := 0 \cdot in$

Length, $l_{r1} := 0 \cdot in$

Weight, $W_{r1} := 0 \cdot lb$

RRH separation, $d_{rrh} := 0 \cdot in$

Pipe

Diameter, $\phi_p := 2.375 \cdot in$

Length, $l_p := 8.5 \cdot ft$

Weight, $w_p := 3.65 \cdot plf$

Weight of ice:

$$W_{ant\_ice} := \left[\left[\left[w_{a1} + (2 \cdot t_{ice})\right] \cdot \left[t_{a1} + (2 \cdot t_{ice})\right] \cdot \left[l_{a1} + (2 \cdot t_{ice})\right]\right] - w_{a1} \cdot t_{a1} \cdot l_{a1}\right] \cdot \gamma_{ice} = 162.79\,lb$$

$$W_{rrh\_ice} := \left[\left[\left[w_{r1} + (2 \cdot t_{ice})\right] \cdot \left[t_{r1} + (2 \cdot t_{ice})\right] \cdot \left[l_{r1} + (2 \cdot t_{ice})\right]\right] - w_{r1} \cdot t_{r1} \cdot l_{r1}\right] \cdot \gamma_{ice} = 0.11\,lb$$

Side Wind Loading:

Effective depth of equipment, $D_{eff} := \max(t_{r1}, t_{a1}) + 4 \cdot in + \phi_p = 1.12\,ft$

Effective length of equipment, $L_{eff} := l_{a1} + d_{rrh} + l_{r1} = 8\,ft$

Wind force on equipment, $P_{wind\_eq} := D_{eff} \cdot L_{eff} \cdot WL_f \cdot LF = 294.51\,lb$

Distance of assembly from wall, $d_1 := 12 \cdot in$

Number of mounts, $n_s := 2$

Mount separation, $d_2 := 5.33 \cdot ft$

Moment at each mount, $M := \frac{P_{wind\_eq} \cdot d_1}{n_s} = 147.26\,lb \cdot ft$

Number of studs per mount, $n_b := 8$

Spacing of studs, $s_{stud} := 9 \cdot in$

Maximum tensile force on stud, $T_{bolt\_side} := \frac{\frac{M}{s_{stud}}}{\frac{(n_b - 2)}{2}} = 65.45\,lb$

Front Wind Loading:

Effective width of equipment, $W_{eff} := \max(w_{a1}, w_{r1}) = 2\,ft$

Effective length of equipment, $L_{eff} = 8\,ft$

Wind force on equipment, $w_{wind\_eq} := W_{eff} \cdot WL_f \cdot LF = 65.57 \cdot plf$

Misc dead load (brackets, clamps, bolts, etc..), $W_{misc} := 50 \cdot lb$

Weight of pipe, $W_p := l_p \cdot w_p = 31.02\,lb$

Number of mounts, $n_s = 2$

Distance from top of antenna to top mount, $d_3 := 2 \cdot ft$

Mount separation, $d_2 = 5.33\,ft$

Gravity load from equipment, $P_{g\_eq} := W_{ant\_ice} + W_{rrh\_ice} + W_{a1} + W_{r1} + W_{misc} + W_p = 398.93\,lb$

Mount Reactions:

Top, $$R_t := \frac{P_{wind\_eq} \cdot \left[d_2 - \left(\frac{L_{eff}}{2} - d_3 \right) \right] + P_{g\_eq} \cdot d_1}{d_2} = 258.85\,lb$$

Bottom, $R_b := P_{wind\_eq} - R_t = 35.67\,lb$

Number of studs per mount, $n_b = 8$

Maximum tensile force on stud, $$T_{bolt\_front} := \frac{\max(R_t, R_b)}{n_b} = 32.36\,lb$$

Maximum tensile force on bolt (from either side or front loading), $T_{stud} := \max(T_{bolt\_front}, T_{bolt\_side}) = 65.45\,lb$

Allowable tensile load on 5/16" C-D stud, $$T_{allow} := \frac{2900 \cdot lb}{4} = 725\,lb$$

StudWeldTensileCheck := | "OK" if $T_{allow} \ge T_{stud}$
| "NG" otherwise

StudWeldTensileCheck = "OK"

Shear force on stud, $$V_s := \frac{\frac{P_{g\_eq}}{n_s}}{n_b} = 24.93\,lb$$

Allowable shear load for 5/16" C-D stud, $$V_{allow} := \frac{2200 \cdot lb}{4} = 550\,lb$$

StudWeldShearCheck := | "OK" if $V_{allow} \ge V_s$
| "NG" otherwise

StudWeldShearCheck = "OK"

Check Tank Shell

Diameter of tank, $d_{tank} := 72 \cdot ft$

Thickness of tank shell at antenna mount, $t_{tank} := .25 \cdot in$

Length/width of mount base plate, $L_{plate} := 12 \cdot in$

Height of water column at lower antenna mount, $h_{water} := 6 \cdot ft$ (Approx.)

Pressure of water at antenna mount, $WL := (62.4 \cdot pcf) \cdot h_{water} = 2.6 \cdot psi$

Tensile/compressive stress on shell from antenna mount, $$\theta_{mount} := \max\left(\frac{R_t}{L_{plate}^2}, \frac{R_b}{L_{plate}^2} \right) = 1.8 \cdot psi$$

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Allowable stress of shell at antenna mount, $\theta_{allow} := \frac{t_{tank}}{d_{tank}} \cdot (2380 \cdot ksi) = 688.66 \cdot psi$ (AWWA D100-05, 3.4.3.1.1)

Maximum stress due to antenna mount and water pressure, $\theta_{max} := \theta_{mount} + WL = 4.4 \cdot psi$

$$TankCheck := \begin{cases} \text{"OK"} & \text{if } \theta_{allow} > \theta_{max} \\ \text{"NG"} & \text{otherwise} \end{cases}$$

TankCheck = "OK"

Conclusion:

Based on the results of the analysis, the proposed T-Mobile Anchor installation and the existing standpipe water tank are structurally sound, as designed and depicted on plans by this office dated 12/5/23, Rev 4. The analysis was conducted in accordance with the Masachusetts State Building Code, 9th Edition, ASCE 7-10, and AWWA D100-05.

References:

1. American Society of Civil Engineers (2010), Minimum Design Loads for Buildings and Other Structures (7-10), American Society of Civil Engineers, New York, NY
2. Massachusetts State Building Code, 9th Edition.
3. AWWA (American Water Works Association) D100-05

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C-D Stud Load Strengths

STUD MATERIAL	STUD SIZE	MAXIMUM FASTENING TORQUE (INCH LBS.)*	ULTIMATE TENSILE LOAD (LBS.)	MAXIMUM SHEAR LOAD (LBS.)
Low-Carbon,	6-32	6	500	375
Copper-Flashed	8-32	12	765	575
Steel	10-24	14	960	720
	1/4-20	43	1750	1300
	5/16-18	72	2900	2200
	3/8-16	106	4300	3250
Stainless	6-32	10	790	590
Steel	8-32	20	1260	940
	10-24	23	1530	1150
	1/4-20	75	2880	2160
	5/16-18	126	3750	5350
	3/8-16	186	4850	7150
Aluminum	6-32	6.5	350	160
Alloy	8-32	13	560	229
6061	10-24	19	670	310
	1/4-20	40	1240	679
	5/16-18	70.5	2025	1210
	3/8-16	100	2985	1750