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Structural Design Calculations

STATE OF VERMONT
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Site No.: 4BV0490 - Private Silo Sheldon
Project: Anchor
Client: Smartlink
Date: November 12, 2024

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Synopsis:

The proposed T-Mobile equipment installation consists of:

- Three (3) RFS APXVAALL24M antennas (1 per sector)
- Three (3) FRV APXVLL19P antennas (1 per sector)
- Three (3) Ericsson RRUS-4480 remote radio heads (RRHs)(1 per sector)
- Three (3) Ericsson RRUS-4460 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 II	(ASCE 7-10 Table 1.5-1)
Basic Wind Velocity,	$V_w := 115$ mph	(ASCE 7-10)
Antenna Height,	$Height := 52ft$	
Exposure coefficient,	$K_z = 0.82$	(ASCE 7-10 Table 29.3-1)
Wind Directionality Factor,	$K_d := 0.9$	(ASCE 7-10 Table 26.6-1)
Velocity wind pressure,	$q_z := .00256 \cdot V_w^2 \cdot K_z \cdot K_d \cdot psf = 24.93 \cdot psf$	(ASCE 7-10 Sec. 27.3.2)
Gust response factor,	$G_r := 0.85$	(ASCE 7-10 Sec. 26.9.1)
Force coeff: Flat,	$C_f := 1.4$	(ASCE 7-10 Fig. 29.5-1)
Round	$C_r := .85$	
Wind Load factor,	$LF := .6$	(ASCE 7-10 Sect 2.4)
Wind load pressure,	$WL_f := q_z \cdot G_r \cdot C_f = 29.67 \cdot psf$	(ASCE 7-10 C26.5-1)
Radial ice thickness,	$t_{ice} := .75 \cdot in$	
Density of ice,	$\gamma_{ice} := 56 \cdot pcf$	

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Equipment Loads:

Antennas

APXVAALL24M:		APXVLL19P:		Position 3:		Position 4:	
Width,	$w_{a1} := 20 \cdot in$	Width,	$w_{a2} := 12 \cdot in$	Width,	$w_{a3} := 0 \cdot in$	Width,	$w_{a4} := 0 \cdot in$
Depth,	$t_{a1} := 8.5 \cdot in$	Depth,	$t_{a2} := 4.6 \cdot in$	Depth,	$t_{a3} := 0 \cdot in$	Depth,	$t_{a4} := 0 \cdot in$
Length,	$l_{a1} := 96 \cdot in$	Length,	$l_{a2} := 76 \cdot in$	Length,	$l_{a3} := 0 \cdot in$	Length,	$l_{a4} := 0 \cdot in$
Weight,	$W_{a1} := 90 \cdot lb$	Weight,	$W_{a2} := 60 \cdot lb$	Weight,	$W_{a3} := 0 \cdot lb$	Weight,	$W_{a4} := 0 \cdot lb$

RRHs

RRUS-4460:		RRUS-4480:		Position 3:		Position 4:	
Width,	$w_{r1} := 15.7 \cdot in$	Width,	$w_{r2} := 15.7 \cdot in$	Width,	$w_{r3} := 0 \cdot in$	Width,	$w_{r4} := 0 \cdot in$
Depth,	$t_{r1} := 12.1 \cdot in$	Depth,	$t_{r2} := 7.5 \cdot in$	Depth,	$t_{r3} := 0 \cdot in$	Depth,	$t_{r4} := 0 \cdot in$
Length,	$l_{r1} := 19.6 \cdot in$	Length,	$l_{r2} := 22 \cdot in$	Length,	$l_{r3} := 0 \cdot in$	Length,	$l_{r4} := 0 \cdot in$
Weight,	$W_{r1} := 109 \cdot lb$	Weight,	$W_{r2} := 84 \cdot lb$	Weight,	$W_{r3} := 0 \cdot lb$	Weight,	$W_{r4} := 0 \cdot lb$

Weight of antennas/RRHs:

$$W_1 := W_{a1} + W_{r1} = 199\,lb$$

$$W_2 := W_{a2} + W_{r2} = 144\,lb$$

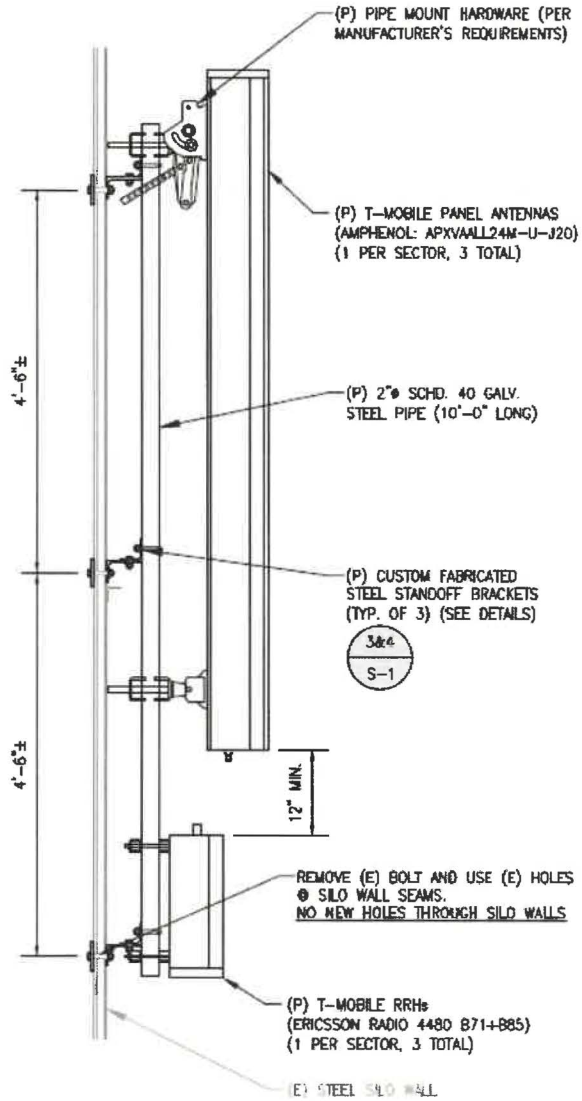
$$W_3 := W_{a3} + W_{r3} = 0$$

$$W_4 := W_{a4} + W_{r4} = 0$$

$$W_{ar} := \sum W = 343\,lb$$

Analysis

Fig 1 - Propopsed Mount (from drawings)



Antenna (APXVAALL24M)

Width, $w_{a1} = 1.67\,ft$

Depth, $t_{a1} = 8.5 \cdot in$

Length, $l_{a1} = 8\,ft$

Weight, $W_{a1} = 90\,lb$

RRH (RRUS-4480)

Width, $w_{r2} = 15.7 \cdot in$

Depth, $t_{r2} = 7.5 \cdot in$

Length, $l_{r2} = 22 \cdot in$

Weight, $W_{r2} = 84\,lb$

Pipe

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

Length, $l_p := l_{a1} + 12 \cdot in + l_{r1} = 10.63\,ft$

Weight, $w_p := 3.65 \cdot plf$

Weight of ice:

$$W_{ant\_ice} := \left[\left[\left[w_{a1} + (2 \cdot t_{ice})\right] \cdot \left[t_{a1} + (2 \cdot t_{ice})\right] \cdot \left[l_{a1} + (2 \cdot t_{ice})\right]\right] - w_{a1} \cdot t_{a1} \cdot l_{a1}\right] \cdot \gamma_{ice} = 150.45\,lb$$

$$W_{rrh\_ice} := \left[\left[\left[w_{r2} + (2 \cdot t_{ice})\right] \cdot \left[t_{r2} + (2 \cdot t_{ice})\right] \cdot \left[l_{r2} + (2 \cdot t_{ice})\right]\right] - w_{r2} \cdot t_{r2} \cdot l_{r2}\right] \cdot \gamma_{ice} = 33.94\,lb$$

According to drawings by this office dated 10/28/24 the existing silo is an abandoned glass-walled structure approximately 22' diameter, and 75' tall (to rim). The method of attachment of the proposed antennas and RRHs will entail removing the existing bolts that fasten the glass-lined panels together and replace them will similar, but longer, bolts that will secure the mounting brackets to the facade of the silo. Steel backing plates will be used to distribute the bolt load to the interior wall of the silo.

Side Wind Loading:

Effective depth of equipment, $D_{eff} := t_{a1} + 4 \cdot in + \phi_p = 1.24\,ft$

Effective length of equipment, $L_{eff} := l_{a1} + 12 \cdot in + l_{r2} = 10.83\,ft$

Wind force on equipment, $P_{wind\_eq} := D_{eff} \cdot L_{eff} \cdot WL_f \cdot LF = 239.02\,lb$

Weight of pipe, brackets, $W_{misc} := 50 \cdot lb$

Distance of assembly from wall, $d_1 := 6 \cdot in$

Number of mounts, $n_s := 3$

Mount separation, $d_2 := 4.5 \cdot ft$

Moment at each mount, $M := \dfrac{P_{wind\_eq} \cdot d_1}{n_s} = 39.84\,lb \cdot ft$

Number of bolts per mount plate, $n_b := 3$

Spacing of bolts, $s_{bolt} := 4 \cdot in$

Maximum tensile force on bolt, $T_{bolt\_side} := \dfrac{\dfrac{M}{s_{bolt} \cdot 2}}{n_b - 2} = 59.76\,lb$

Front Wind Loading:

Effective width of equipment, $W_{eff} := \max(w_{a1}, w_{r2}) = 1.67\,ft$

Effective length of equipment, $L_{eff} = 10.83\,ft$

Wind force on equipment, $P_{wind\_eq} := W_{eff} \cdot L_{eff} \cdot WL_f \cdot LF = 321.37\,lb$

Weight of pipe, brackets, $W_{misc} = 50\,lb$

Distance from top of antenna to top mount, $d_3 := 0 \cdot ft$

Number of mounts, $n_s = 3$

Mount separation, $d_2 = 4.5\,ft$

Gravity load from equipment, $P_{g\_eq} := W_{ant\_ice} + W_{rrh\_ice} + W_{a1} + W_{r2} + W_{misc} = 408.39\,lb$

Mount Reactions:

Top, $$R_t := \frac{P_{wind\_eq}\cdot\left[(d_2\cdot 2) - \left(\frac{L_{eff}}{2} - d_3\right)\right] + P_{g\_eq}\cdot d_1}{d_2\cdot 2} = 150.64\,lb$$

Bottom, $R_b := P_{wind\_eq} - R_t = 170.73\,lb$

Number of bolts per mount plate, $n_b := 4$

Maximum tensile force on bolt, $$T_{bolt\_front} := \frac{\max(R_t, R_b)}{n_b} = 42.68\,lb$$

Maximum tensile force on bolt (from either side or front loading), $T_{bolt} := \max(T_{bolt\_front}, T_{bolt\_side}) = 59.76\,lb$ **OK by inspection**

The proposed additional wind load is minimal when compared to the overall wind load and gravity load acting on the existing silo, therefore the silo is considered structurally adequate by inspection.

Conclusion:

Based on the results of the analysis, the proposed T-Mobile NSB installation is structurally sound, as designed and depicted on plans by this office. The analysis was conducted in accordance with the Vermont 2015 Fire & Building Safety Code, and ASCE 7-10.

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. Vermont 2015 Fire & Building Safety Code (IBC 2015)