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STRUCTURAL ENGINEERING CALCULATIONS

FOR

POLE AND PAD MOUNTING SHELF (PMS)

POLE ANCHORAGE

PROJECT: XXXXX

ENGINEER:

CRAIG N. POWELL, P.E.

Reviewed By:

DESIGN CRITERIA:

- 2021 IBC BUILDING CODE
- ASCE 7-16

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PROJECT CONTACTS

Engineering Team:

[redacted]

Client:
DDB Unlimited
Bryan Campbell
2301 US-77
Pauls Valley, OK 73075

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PROJECT SCOPE

Provide ***Client*** with structural engineering anchorage calculations for the PMS to a supporting pole in accordance with the latest edition of IBC and any local jurisdiction amendments. Structurally related drawings will be provided by ***Client*** to ***SolidBox*** for review purposes. Calculations and stamped drawings will be provided to the ***Client*** for submittal to the local jurisdiction. Calculations to include considerations for seismic analysis, and anchorage. The project did not focus on the main support poll or it's anchorage to the earth.

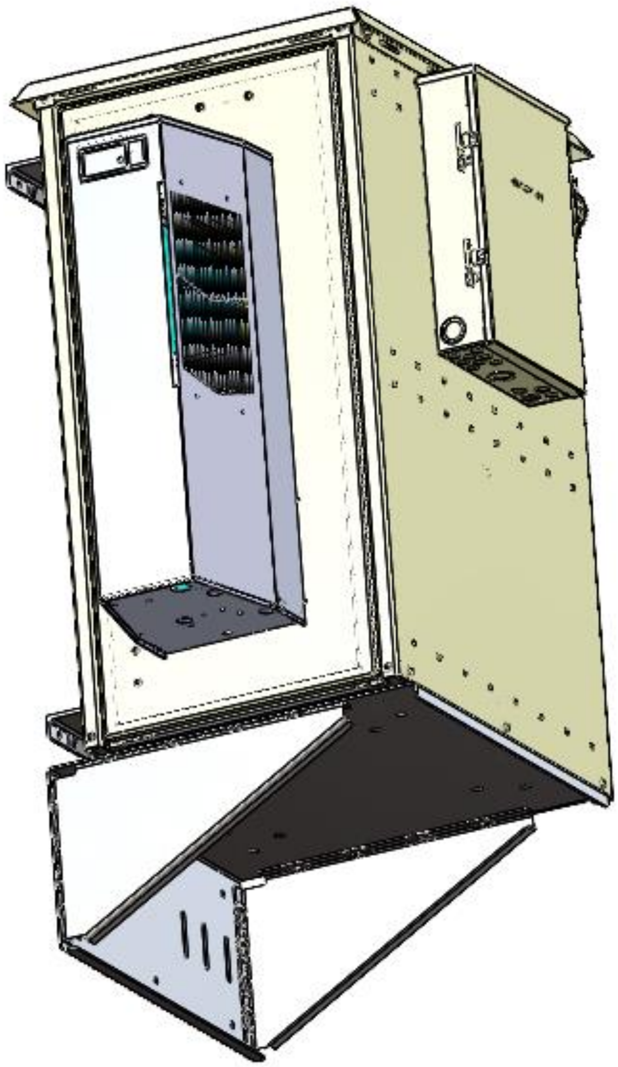

Figure 1: Pole and Pad Mounting Shelf (PMS) with Enclosure Load, as submitted.

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Figure 2: Typical pole installation shows an area roughly four (4) inches wide in the middle of the PMS in contact with the pole.

The initial evaluation of this configuration with the current weight scheme caused high stress in the lower member of the PMS (Figure 3). SolidBox previously evaluated the PMS as a full wall support across the back so three-point bending was not a concern. For the remainder of the report, the addition of 3"x3"x0.25" square tube or 4" C-Channel was used to absorb energy of the three point bending of the PMS and pole (Figure 4).

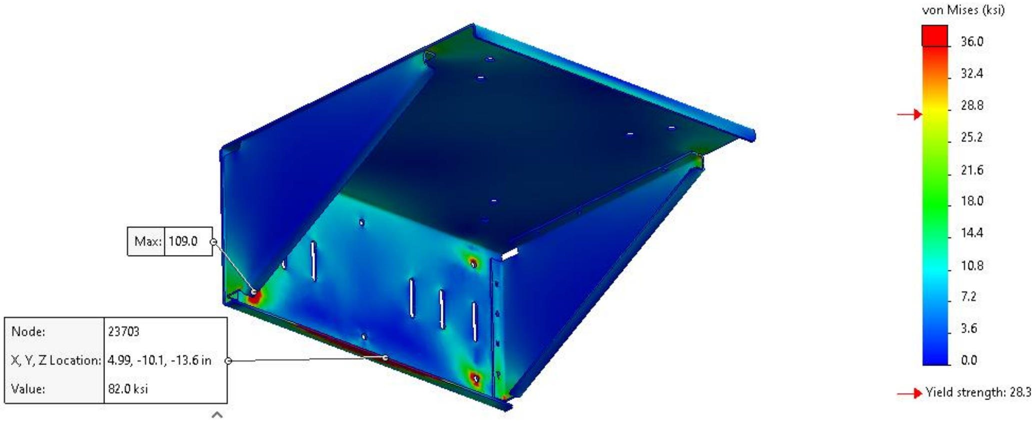

Figure 3: Original configuration required additional support to mitigate stress.

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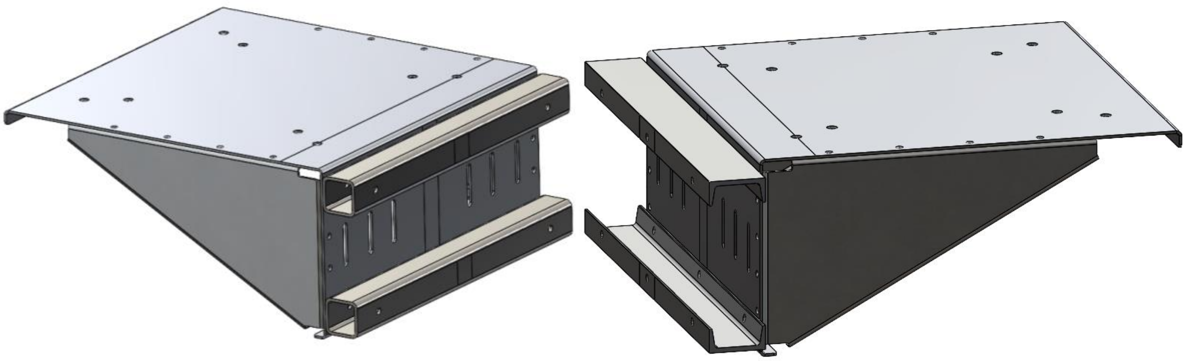


Figure 4: Addition of 3 x 3 x 0.25 in square tube or 4" C-Channel used in the analysis.

As a result of the structural member the main box can be repositioned on the PMS. This has added stregnth benefits and will be required to satisfy the limits of the code. See Figure 5 for positon details

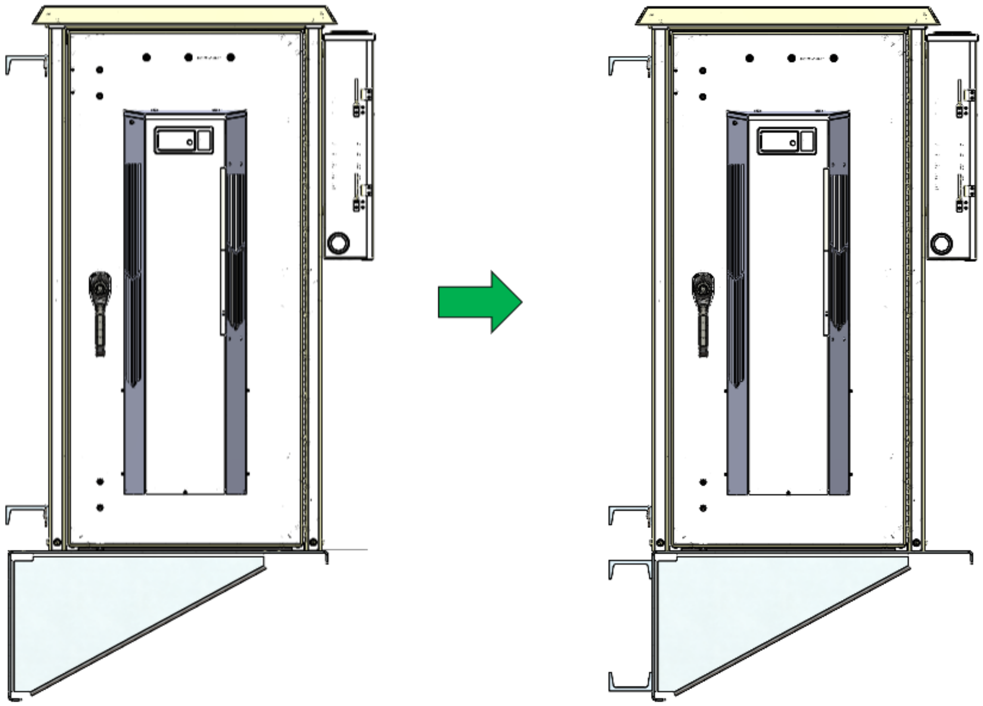


Figure 5: Reposition of the upper assembly because of the new spacers required on the lower PMS.

ICC EVALUATION, PRODUCT SPECIFICATION LITERATURE, AND DESIGN AIDS

- ASCE 7-16 – MINIMUM DESIGN LOADS FOR BUILDINGS AND OTHER STRUCTURES
- 2021 IBC
- ALUMINUM ASSOCIATION 2015 EDITION OF THE ALUMINUM DESIGN MANUAL

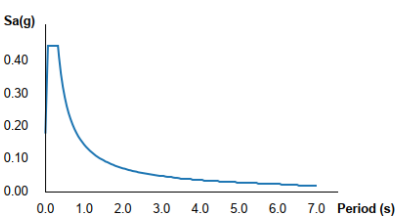
LOCATION DETAILS

ATC Hazards by Location

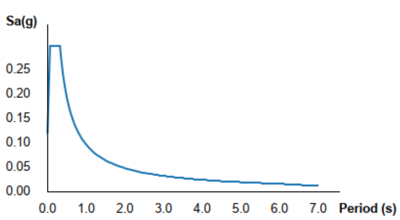
Search Information

Address:	41.0887754,-74.1827119
Coordinates:	41.089499, -74.182295
Elevation:	251 ft
Timestamp:	2024-01-30T19:29:07.393Z
Hazard Type:	Seismic
Reference Document:	ASCE7-16
Risk Category:	III
Site Class:	D

MCER Horizontal Response Spectrum



Design Horizontal Response Spectrum



Basic Parameters

Name	Value	Description
S_S	0.285	MCE_R ground motion (period=0.2s)
S_1	0.06	MCE_R ground motion (period=1.0s)
S_{MS}	0.448	Site-modified spectral acceleration value
S_{M1}	0.145	Site-modified spectral acceleration value
S_{DS}	0.299	Numeric seismic design value at 0.2s SA
S_{D1}	0.097	Numeric seismic design value at 1.0s SA

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STRUCTURAL CALCULATIONS

Structural Requirements

The ASCE 7-16 code (Minimum Design Loads and Associated Criteria for Buildings and Other Structures) provides guidelines for protection against failure in building structures. The following structural requirements are used as they are directly applicable to the structure designed by DDB Unlimited, for these general conditions:

Risk Categorization:

This structure falls under Risk Category III (Building or structurs, the failure of whitch could pose a substantial risk to human life).

Wind:

ASCE 7-16	Select a dataset to view contours.
MRI 10-Year	75 mph
MRI 25-Year	82 mph
MRI 50-Year	88 mph
MRI 100-Year	94 mph
Risk Category I	104 mph
Risk Category II	112 mph
Risk Category III	122 mph
Risk Category IV	126 mph

Wind loads are calculated based on the flat plane profile of the enclosure either perpendicular to or parallel to the enclosure. For loads going from the box with the negative pressure on the pole, no negative pressure is applied. The overall cross section is larger than necessary so results will be conservitive in nature.

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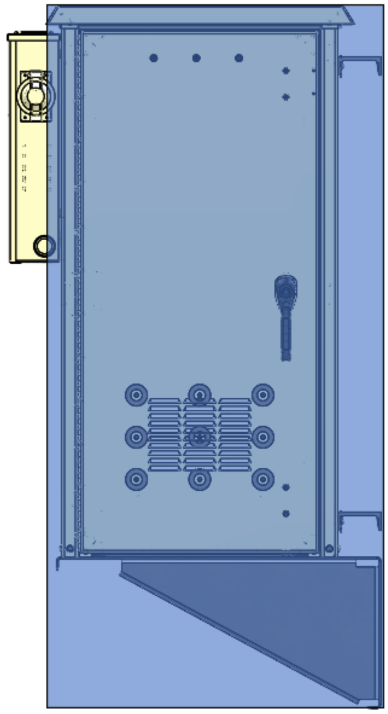

Figure 6: Example cross section used for wind loads shows a larger total area resulting in a more conservative analysis.

Seismic:

The seismic design catergory is B based on Risk Catergory III and S_{DS} of 0.299 per ASCE 7-6 11.6-1. As a failure (fall) could pose a risk to human life. This is a non-structural element that is not providing life-safety equipment (Sprinklers, stairwells, etc.) after an earthquake; per ASCE 7-6 13.1.3 the Inportance factor is 1.0 as it is also not realtated to any toxic, explosive, or hazardous materials. Section 13.1.4 states that this item is <u>exempt from seismic loading requirements</u> because it is a mechanical and electrical component in seismic Design Catergory B.

Snow:

ASCE 7-16 — *Select a dataset to view contours.*

Ground Snow Load .... 30 lb/sqft

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Load Definitions

SolidBox utilizes the "Load Combinations for Allowable Stress Design" method detailed in the ASCE 7-16 code to validate the structural integrity of the structure. The loads listed herein consider the most conservative loads that would produce the most unfavorable effects on each structural member within the structure. Any load combinations that are not applicable, due to environmental conditions, are removed.

Loads Combinations

Table 1: ASCE Load Combinations for Allow Stress Design (ASCE 7-16 2.4)

Load Case	Load Combination
1	D
2	$D + L$
3	$D + S$
4	$D + 0.75L + 0.75(L_r or\ S\ or\ R)$
5	$D + (0.6W)$
6	$D + 0.75L + 0.75(0.6W) + 0.75(L_r or\ S\ or\ R)$
7	$0.6D + 0.7W$
8	$D + 0.7E_v + 0.7E_h$
9	$D + 0.525E_v + 0.525E_h + 0.75L + 0.75S$
10	$0.6D - 0.7E_v + 0.7E_h$

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D = Dead Load. The dead load considers the weight of all materials and the static payload of the enclosure

L = Live Load (ASCE minimum is 5 psf, per ASCE 7-16 Table 4.3-1)

S = Snow Load 30 psf

E_v = Horizontal Seismic Load

E_h = Vertical Seismic Load

W = Wind Load (Both perpendicular and paralell aplied

Furthermore since S > L and there is no requirement for seismic design Load cases 2, 8, 9, and 10 will be ignored.

Analysis Method

Finite Element Analysis Software (Numerical Method)

The FEA and CFD software used in this analysis is SOLIDWORKS Simulation version 2022 SP5.0. This is a commercially available FEA code.

Study Types

The "elastic stress analysis method" is used to satisfy all the design by analysis requirements set forth in ASCE code. Static and Buckling analyses are done for all primary and secondary structure. Static analysis is done for all mechanical joints and validated with hand calculations. Fatigue analysis is not performed, as the allowable stress are below the infinite life of the materials. Thermal, resonance, dynamic, and non-linear studies were also not required.

FEA Elements

In each FEA study performed in this analysis, a mixed mesh (solids, beams, and shells) is used to most accurately represent the components of the design. Solid tetrahedral elements represent the "solids" that cannot be represented by beam or shell elements. The tetrahedral element has 10 nodes; 6 at its vertices, and 4 at its mid-sides. Each node on the tetrahedral element has 3 translational degrees of freedom. Shell elements are represented by triangles with 6 nodes; 3 at its vertices, and 3 at its mid-sides. Each node on the triangular shell element has 3 translational and 3 rotational degrees of freedom. Beam elements represent the slender structural components that have a uniform cross section throughout their length. Within SOLIDWORKS, beam elements capture the detailed cross-section properties of the CAD model, and utilize those properties to calculate moments of inertia, neutral axes, and the distances of the extreme fibers, from the neutral axes.

Mesh Quality

In each FEA study performed in this analysis, a uniform density mesh is applied globally to keep error below 5%. However, in areas of fillets, "mesh control" is applied. The locally refined mesh is typically 10-25% of the global mesh size. In the analyses of specific high-stress regions of the casting, the mesh is refined locally until a 5% von Mises convergence criterion is satisfied.

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Bolted Connections

Bolt connectors are used to simulate the stresses found at bolted joints. The bolt connectors allow the bolt preload to be applied on the appropriate bearing area and include the effects of the bolt's elasticity.

Model Simplification

The CAD model is simplified to represent only primary structure. This simplified model is used in the FEA. All mechanical joints, e.g., splices, hardware, and anchoring points are analyzed individually within their own FEAs and through hand-calculations to ensure compliance with standard engineering practices.

FEA Boundary Conditions & Connections

Anchor Points: Virtual bolts are applied to the sides of the structure and given an axial load based on the pre-load recommendations for that bolt size. A virtual wall was applied to a 4in wide section in the midde of the contact area to simulate the step-bend nature of power poles.

Section & Material Properties

Table 2: Section & Material Properties

Component	Material	Density	Modulus	Tension Ultimate/Yield	Shear Ultimate	Endurance limit
C-Channel	Alum. 6061 – T6	lb/in^3	10,000 ksi	45/40 ksi	30 ksi	14 ksi
Sheet Metal	Alum 5052 - H32	$0.097lb.in^3$	10,200 ksi	31 / 23 ksi	20	17 ksi
Hardware	Stainless Steel	$0.290\ lb/in^3$	27,500 ksi	/ 70 ksi		
Square Tube	Galv. A36 Steel	$0.283\ lb/in^3$	11,501 ksi	58 / 36 ksi		

The allowable stress value for each material is listed in Table 3. For Aluminum SolidBox utilizes the lower allowable stress between the Ultimate Tensile Stress /1.95 or Yield /1.65 per the Aluminum Design Manual. For steel, the design factor is 1.67 from the American Institute of Steel Construction. Those safety factors and ASCE combined loading, to create a conservative allowable stress for the analysis. The yield stress values are obtained from the manufacturers' material specification sheets and crosschecked against values established by the *Aluminum Association 2015 edition* of the *Aluminum Design Manual*. The most conservative values are used throughout the analysis.

Table 3: Allowable Stresses for Materials

Stress Type	Rupture Allowable Stress	Yield Allowable Stress	Maximum Allowable Stress (lesser)
C-Channel (AL 6061-T6)	23.07 ksi	24.24 ksi	23.07 ksi
Sheet Metal (Aluminum 5052-H32)	15.9 ksi	13.9 ksi	13.9 ksi
Hardware (Stainless Steel)			41.9 ksi
Galvanized Carbon steel (Square Tube)			21.5 ksi

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Loads & Anchorage

The PMS is loaded with a standard OD (DDB) enclosure. The enclosure is anchored to the top surface of the PMS via 4 anchor bolts. The validation of fastening system between the enclosure and the PMS is outside the scope of this analysis. The payload of the enclosure is 780lb as configured. (Table 4)

Table 4: Designed loads for this configuration

Item	Weight	Unit	Weight Location
Main Body Cabinet	212.3	lb.	Calculated
N36 - HVAC	100	lb.	Center of HVAC unit
Internal electric Wire	20	lb.	In electrical box
External Wire/Cable	30	lb.	Bottom of Electric Box
Battery 4x	287.6	lb.	*Slightly away from center of box (away from pole)
Server Hardware	130.6	lb.	*Slightly away from center of box (away from pole)

The PMS is mounted to a standard Galvanized steel pole that meets the ASCE minimum requirements. Analysis of the pole, mount location, and anchorage is outside the scope of this analysis. i.e., the ability to withstand a 1,000 lbs concentrated load, total hardware installed, soil preparations, etc.

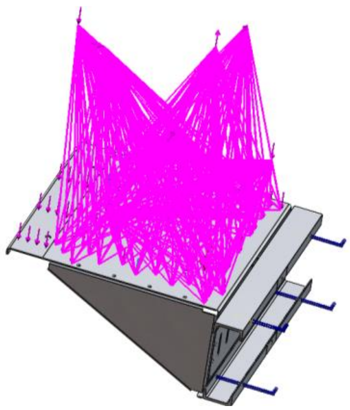

Figure 7: PMS Loading Scenario, anchored to a pole with the prescribed loads in their locations.

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RESULTS

Stress

The FEA results illustrate the distribution of von Mises stress throughout the sheet metal structure. The plot in Figure 9 illustrates the Factor of Safety (FOS) distribution. Any locations that fall short of the factor of safety requirement would appear in a red color.

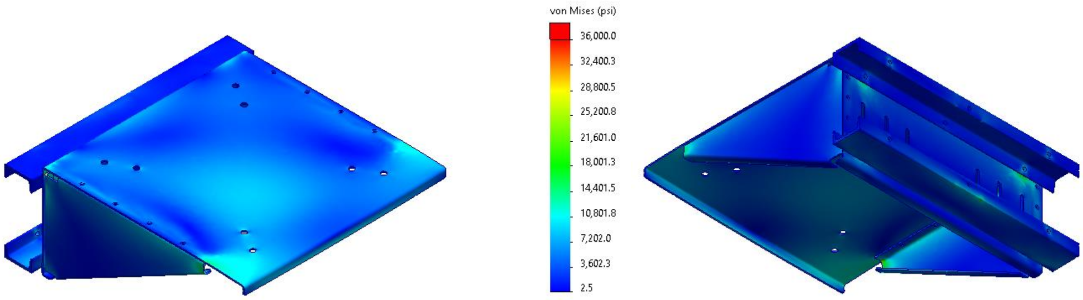

Figure 8: von Mises Stress Contour Plot (ISO 1 & 2 Views) for Load Case 6 Perpendicular wind

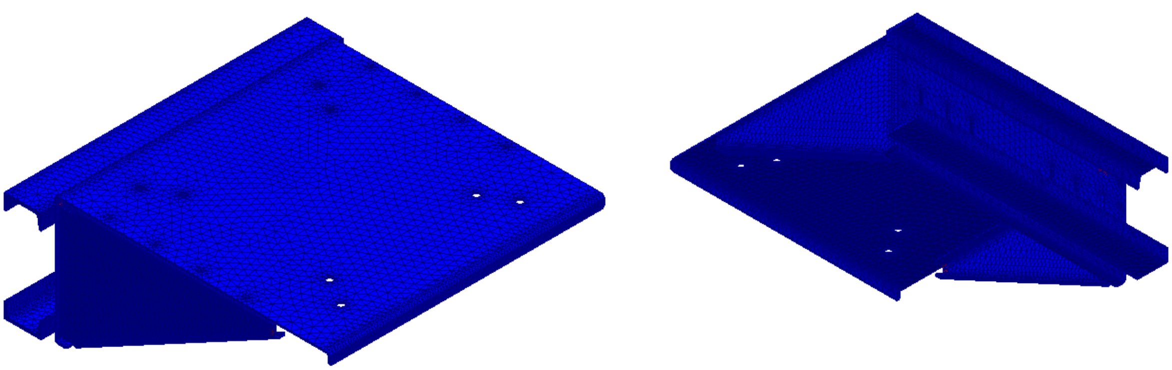

Figure 9: Factor of Safety Plot (Blue indicates a FOS > 1.65)

Two areas have stress above 13,900 psi, the lowest minimum allowable stress, when looking at the FOS plot. These two areas are considered singularities within FEA analysis; this means that the small high-load in the area would plasticly deform locally and the stress would then be distributed to the surrounding material. One is right at the bolt-load and can be mitigated with over-sized washer. The second at the end of the bracket supporting the upper surface. As it was modeled for the FEA, the whole upper surface has the loads distributed where the main electic box sits. If this corner slightly deforms, the rigidity of the box will continue to transfer the load to the upper surface without issue.

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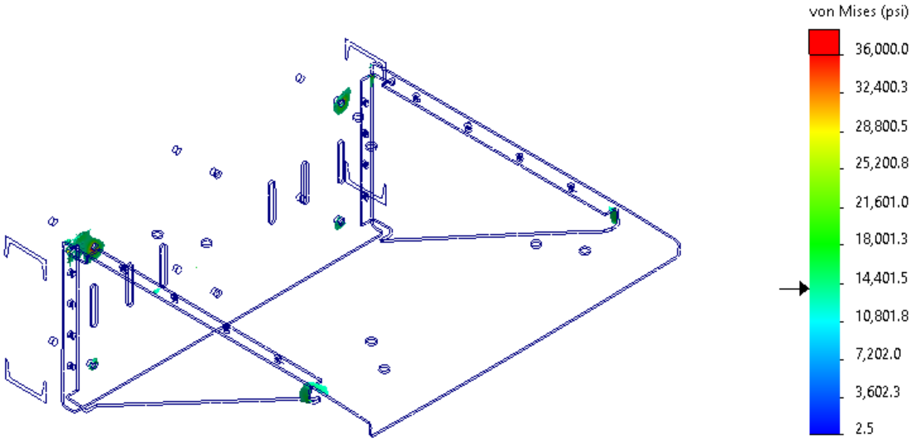

Figure 10: Highlighting the small sections above 13,900psi.

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Fastener Check

All fasteners are cross-checked, through the FEA software and hand-calculations. The following methodology is used to calculate the safety of each bolt:

Bolt Connector - Safety Check

You can determine if a bolt connector in an assembly can safely carry the applied loads, or if it fails.

The software calculates the bolt strength factor of safety (SF) based on the combined load ratio a connector withstands and compares it with the user-defined factor of safety.

Axial load ratio, Ra	Ra is the maximum of: • SF * F / (At * S) • Pre-load / (At * S)	
	SF	Bolt strength factor of safety calculated by the software. SF is the unknown of the combined load ratio equation. The software calculates the factor of safety SF twice: SF1 is calculated based on the first bulleted value of the axial load ratio Ra and SF2 based on the second value of Ra. • If (SF1 * F / (At * S)) > (Pre-load / (At * S)), then the first value of SF1 is considered for the pass/no pass criterion. • If (Pre-load / (At * S)) > (SF1 * F / (At * S)), then the second value of SF2 is considered for the pass/no pass criterion.
	F	Axial load calculated by the software
	At	Tensile area
	Pre-load	Bolt pre-load
	S	Strength value of connector's material or grade (could be yield or ultimate tensile strength based on application). This is the user-defined value for **Bolt Strength**
Bending load ratio, Rb	Rb = SF * D * M / (2 * S * I)	
	SF	Bolt strength factor of safety calculated by the software
	M	Bending moment calculated by the software
	D	Nominal shank diameter
	S	Strength value of connector's material or grade (could be yield or ultimate tensile strength based on application). User-defined value for **Bolt Strength**.
	I =0.25*π*r^4	
Shear load ratio, Rs	Rs = SF * V / (0.5 * At * S)	
	SF	Bolt strength factor of safety calculated by the software
	V	Shear load calculated by the software
	At	Tensile area
	S	Strength value of connector's material or grade (could be yield or ultimate tensile strength based on application). User-defined value for **Bolt Strength**
	The factor of 0.5 is applied to the material yield strength (or ultimate tensile strength) to account for the material shear strength. The calculation of the shear load ratio is more accurate when the yield strength of the material is considered. It is a conservative estimate, when the ultimate tensile strength of the material is considered.	
Combined load ratio	(Ra + Rb)^2 + Rs ^3 <=1 The solution of the third order equation yields the unknown bolt strength factor of safety SF. Only the positive roots or the SF are considered.	

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The bolt check plot, Figure 11, reveals that each anchor bolt meets the 2.0 FOS requirement. **Error! Reference source not found.** lists the final combined load ratio for the weakest anchor bolt in the series (upper right corner in Figure 11). The combined load ratio is below the limitation of 1 (max allowable load ratio when using a 2 FOS value).

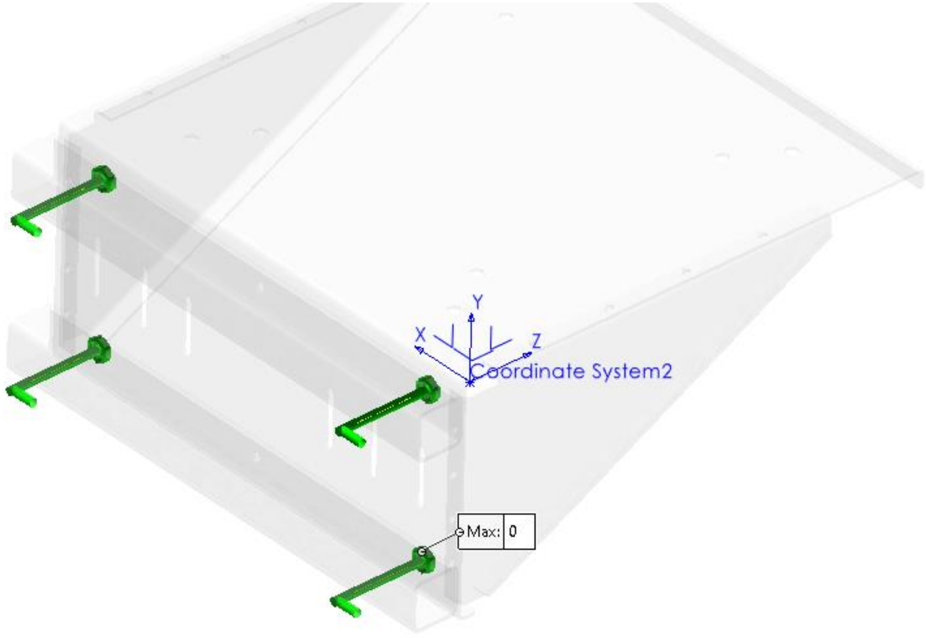

Figure 11: Bolt Check Plot (Green Hardware Passes the 2 FOS Requirement)

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Table 5: Bolt Check Calculation Sheet

	Input	Value
SFd	Desired Factor of Safety	2
D	Nominal Shank Diameter (in)	0.5
S	Allowable Bolt Strength (psi)	92000
Fpre	Bolt Pre-Load (lbs)	125
At	Tensile Area (in2)	0.141

	SW Calculated Forces & Bending Moment	Value
V	Shear Force Resultant (lbs)	2274.5
Fa	Axial Force (lbs)	0
M	Bending Moment Resultant (in-lbs)	441
SF	Factor of Safety	2.9

	Cross-Check Output	Value
	Axial Load Ratio	
Ra	MAX of Axial Load Ratio = SF*Fa/(At*S)	0.00
	or = Fpre/(At*S)	0.01
	Bending Moment Ratio	
Rb	Rb = SF*D*M / (2*S*I) where I = 0.25*PI*r^4	0.78
	0.003	
	Shear Load Ratio	
Rs	Rs = SF*V / (0.5*At*S)	0.70
	Combined Load Ratio	
Rt	Rt = (Ra + Rb)^2 + Rs^3	0.97
	Rt <= 1 (Y/N)	Y

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CONCLUSION

SolidBox has performed a detailed structural analysis on the primary structure of the PMS when anchored to a standard light pole. The standard light pole and it's anchorage was not reviewed in the analysis. The analysis confirms that the the system is able to support the 780.5lbs, per Table 4, payload requirement while meeting the requirements of additional loading set forth by IBC and ASCE 7-16 code. From the initial design three minor changes are required: a 3x3x0.25" square tube or 4" C-Channel spacer to stiffen the connection, over-sized washers to disipate point loading on the sheetmetal, and shifting the cabinet across the PMS (closer to the pole).

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DRAWINGS