Future Trac 30 ft Tent Frame with 127 Tube

Structural evaluation of the Future Trac Frame in accordance with IBC 2012 and ASCE 7-10

Evaluated for use in the following conditions:
1. Risk / Occupancy Category I
2. Temporary Structure - (mean recurrence interval ≤ 2 yr = .67)
3. Enclosed or Open structure
4. 15 ft or 10 ft bay spacing
5. Not designed for
   • snow loading,
   • flood hazard areas or,
   • areas subjected to escarpment effects.

The professional engineer seal on this cover page refers to the calculation sheets contained within this document and to any Appendix or Table sheets that support this document. Any other drawings and documents may require a separate seal for coverage not provided here.

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The professional engineers seal, affixed on this document, signifies a responsibility for the structural adequacy of the design of the structure in the completed project. The content contained within this document does not encompass means, methods and safety of erection.

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1. Summary and Recommendations

This document, based on technical background information as provided by TopTec Products, LLC, covers the structural evaluation of the aluminum frame style structure in accordance with U.S. Building Code requirements. The specifications outlined in the Structural Engineering Institute / American Society of Civil Engineers (SEI/ASCE7) "Minimum Design Loads for Buildings and Other Structures" were followed in determining the integrity of the structure. This document is intended to serve as a basis for the acceptability of this temporary, stand-alone, enclosed structure under standard design wind loads at varying levels of exposure (terrain and wind velocities).

Lightweight Design Inc. compiled this document based on the existing frame tent system with reference to the applicable building codes in the U.S. This report includes the load cases and combinations used in the analysis and gives an indication as to the wind exposure for which the structure is suitable. Certification of this document only shows that the Professional Engineer of that particular state is in agreement with the report's contents. It does not, however, imply that the structure is generally suitable for use within that state, or that every installation is covered by this report.

As this document was compiled based on design information as provided by TopTec Products, LLC, the summary and recommendations for this structure and contained within this document can only be valid if the structure is erected with original TopTec parts and components.

Computer-aided structural frame analysis were involved in the course of the investigation. Different load combinations were considered to identify the critical aspects of the design. Member and detail checks were established to derive the conclusions for the entire report.

For each bay spacing, iteration of calculations were performed to determine the maximum wind speed for each different exposure category. As such, we have arrived at the following conclusions and recommendations;

1.1 Wind Speed Rating

<table>
<thead>
<tr>
<th>30 ft Tube Frame Tent</th>
<th>Wind Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bay Spacing</td>
<td>Exposure B</td>
</tr>
<tr>
<td>10 ft</td>
<td>145 mph</td>
</tr>
<tr>
<td>15 ft</td>
<td>135 mph</td>
</tr>
</tbody>
</table>

For the above mentioned wind speed, exposure category, and return period (or mean recurrence interval, MRI), the structure satisfies the requirements of the "American Society of Civil Engineers Minimum Design Loads for Buildings and Other Structures (ASCE 7), as well as the International Building Code (IBC).
Exposure Categories (IBC)

1609.4.3 Exposure categories. An exposure category shall be determined in accordance with the following:

**Exposure B.** Exposure B shall apply where the ground surface roughness condition, as defined by Surface Roughness B, prevails in the upwind direction for a distance of at least 2,600 feet (792 m) or 20 times the height of the building, whichever is greater.

**Exception:** For buildings whose mean roof height is less than or equal to 30 feet (9144 mm), the upwind distance is permitted to be reduced to 1,500 feet (457 m).

**Exposure C.** Exposure C shall apply for all cases where Exposures B or D do not apply.

**Exposure D.** Exposure D shall apply where the ground surface roughness, as defined by Surface Roughness D, prevails in the upwind direction for a distance of at least 5,000 feet (1524 m) or 20 times the building, whichever is greater. Exposure D shall extend inland from the shoreline for a distance of 600 feet (183 m) or 20 times the height of the building, whichever is greater.

Surface Roughness Categories (IBC)

1609.4.2 Surface roughness categories. A ground surface roughness within each 45-degree (0.79 rad) sector shall be determined for a distance upwind of the site as defined in Section 1609.4.3 from the categories defined below, for the purpose of assigning an exposure category as defined in Section 1609.4.3.

**Surface Roughness B.** Urban and suburban areas, wooded areas or other terrain with numerous closely spaced obstructions having the size of single-family dwellings or larger.

**Surface Roughness C.** Open terrain with scattered obstructions having heights generally less than 30 feet (9144 mm). This category includes flat open country, grasslands, and all water surfaces in hurricane-prone regions.

**Surface Roughness D.** Flat, unobstructed areas and water surfaces outside hurricane-prone regions. This category includes smooth mud flats, salt flats and unbroken ice.

1.2 Dead Loads

Dead loads are defined as the weights of the materials of construction and fixed service equipment. For this analysis the weight of the frame and fabric have been accounted for.

1.3 Hanging Dead Loads

Hanging dead loads are ancillary loads that typically are hanging from the structure, but not necessarily part of the standard structure. These can be due to electrical and mechanical fixtures (lighting, HVAC, suspended items, etc.). A total load per frame of 500 lb is accounted for in this analysis.

1.4 Live Loads

Live loads are loads produced by the use and occupancy of the building are found on Table 1607.1 (IBC). In the case of this structure, there are no additional live loads.

1.5 Snow Loads

This tent structure is assumed to be erected on a temporary basis, in locations, and during seasons, where snow loading is not expected. No snow loading value has been applied in this analysis (Ps = 0psf).

If a snow event is expected or is likely to occur while the fabric is still in place, then measures should be provided to ensure snow removal or melting. Furthermore, the prescribed gradient of the roof fabric should be maintained to allow for smooth drainage and to prevent the potential for ponding of melt water.

1.6 Seismic Loads

Due to the low mass of the structure, seismic base shear does not control over wind loading shear and thus has not been included in this analysis.
1.7 Base Reactions

The maximum reactions at the foundations/supports due to the factored load and exposure category are given in the table below, per base plate, per frame.

<table>
<thead>
<tr>
<th>Bay Spacing</th>
<th>Vertical</th>
<th>Horizontal</th>
<th>Guy Strap</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Uplift</td>
<td>Gravity</td>
<td>Perpendicular to Ridge</td>
</tr>
<tr>
<td>10ft</td>
<td>1674 lb</td>
<td>3839 lb</td>
<td>321 lb</td>
</tr>
<tr>
<td>15ft</td>
<td>1873 lb</td>
<td>4954 lb</td>
<td>420 lb</td>
</tr>
</tbody>
</table>

NOTE: Foundations, by others, are required to support column loads. The structure should be set on firm and unyielding ground. This ground should sufficiently contain the bearing pressures of the base plates as well as the tractive forces of the anchors. A foundations engineer must verify ground conditions on a site-by-site basis and provide appropriate bearing plate sizes to accommodate column loads.

1.8 Installation Requirements

It is understood that the responsibility of proper installation according to the plans rests upon the installation contractor. This includes, but is not limited to, ensuring the following:

- that the cables are always held taut,
- that the fabric is stretched tight enough to prevent the development of pockets and to maintain the prescribed roof gradient,
- that purlins are installed securely against rafters to resist calculated loads,
- that base plates are secured to their foundations using anchors. The manufacturer provides a base plate and anchoring plan for the structure as a base starting point for average soil conditions. It is the installer's responsibility to ensure that the anchorage provided will resist the reaction loads as indicated in the tables found in this document.
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2. Project Parameters

The frame tent structure consists of a series of pin-supported interior and end frames made up of custom-designed hollow profiles of structural aluminum alloy spanning the tent hall width. These frames are the main supporting elements for the structure. The aluminum alloy is an equivalent to the American alloy 6005-T5 as detailed in the U.S. Aluminum Construction Manual and is the basis of material property and allowable stress determinations.

The longitudinal stability (parallel to the ridge) of the structure consist of a combined system of braced frames and cantilevered simple connected truss. Intermediate frames and purlins provide relative bracing along the weak axis of the profile. These purlins are located at the eave, peak and, an intermediate purlin. The tension induced windbracing, in conjunction with the axial capacity of the purlins, transmit shear forces to the baseplate. A maximum of six unbraced bays are permitted. In addition, a minimum of two braced bays are assumed for each sidewall of every structure.

Lateral stability is achieved through flexural stiffness of the main profile, in combination with knee braces and ridge brace.

The roof and walls are clad in non-prestressed fabric skin connected to the aluminum frames by edge ropes slid through the aluminum extrusions. Since this fabric is not attached to the purlins, it transmits the effects of suction pressures directly to the supporting frames. Moreover, the structure is attached to base plates anchored securely to the ground against uplift. The fabric is not considered to provide lateral support to the frame.

Building Geometry

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Imperial Dimensions</th>
<th>Metric Dimensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame Width:</td>
<td>L_width = 30 ft</td>
<td>L_width = 9.14 m</td>
</tr>
<tr>
<td>Eave/ Leg height (outside):</td>
<td>h_e = 8 ft</td>
<td>h_e = 2.44 m</td>
</tr>
<tr>
<td>Peak height (outside):</td>
<td>z = 15.69 ft</td>
<td>z = 4.78 m</td>
</tr>
<tr>
<td>Available Bay widths:</td>
<td>L_bay15 = 15 ft</td>
<td>L_bay15 = 4.57 m</td>
</tr>
<tr>
<td></td>
<td>L_bay10 = 10 ft</td>
<td>L_bay10 = 3.05 m</td>
</tr>
<tr>
<td>Purlin length based on 15 ft bay:</td>
<td>L_purlin_length15 = 14.84 ft</td>
<td>L_purlin_length15 = 4.52 m</td>
</tr>
<tr>
<td></td>
<td>L_purlin_length10 = 9.84 ft</td>
<td>L_purlin_length10 = 3 m</td>
</tr>
<tr>
<td>Roof Slope (outside):</td>
<td>θ_r = 27.15 deg</td>
<td></td>
</tr>
<tr>
<td>Length of knee brace:</td>
<td>L_ab1 = 4.67 ft</td>
<td>L_ab1 = 1.42 m</td>
</tr>
<tr>
<td>Length of ridge brace:</td>
<td>L_sb1 = 4.54 ft</td>
<td>L_sb1 = 1.38 m</td>
</tr>
<tr>
<td>Overall length of frame:</td>
<td>Overthrow = 49.71 ft</td>
<td>Overthrow = 15.15 m</td>
</tr>
</tbody>
</table>
3. Determination of Loads

**Dead Load:**

The structure dead loads consist of the self weight of the structure's components with addition of uniform distributed loads for fabric roofing, side wall materials, and minor components. Various calculated weights are shown below for reference and use in the static computer model analysis.

\[
\text{Area} \cdot W_{\text{fabric}} = 24.00 \text{ oz per sq yard} \quad \text{Unit} \cdot W_{\text{fabric}} = 0.208 \text{ pli}
\]

\[
\text{Eaves Purlin, 116mm x 50mm x 2.5mm Alu} : \quad \text{Unit} \cdot W_{\text{eave}} = 0.181 \text{ pli} \quad W_{\text{eave}} = 32.17 \text{ lbf}
\]

\[
\text{Ridge Purlin 116mm x 50mm x 2.5mm Alu} : \quad \text{Unit} \cdot W_{\text{ridge}} = 0.181 \text{ pli} \quad W_{\text{ridge}} = 32.17 \text{ lbf}
\]

The structure is designed to support the loads shown in this calculations. It may, or may not, be capable of supporting additional collateral loads. The owner of the structure shall not hand, or otherwise affix, additional loads to this structure without a review by an engineer qualified to make said review. Additionally, prior to adding load to this structure, the owner shall get a written confirmation by the qualified engineer as to the magnitude and location of the load, or loads, being applied.

**Live Load:**

Live loads loads produced by the use and occupancy of the building are found on Table 1607.1. In the case of this structure, their are no additional live loads.

**Roof Live Load:**

The electrical and mechanical fixtures (lighting, HVAC, suspended items, etc.) totaling 500 lbs per frame and suspended symmetrically on the structure are accounted for. These hanging loads have been assumed to be 500 lbf at the peak of the structure for this analysis.

\[
P_{\text{peak}} = 500 \text{ lbf}
\]
**Snow Load:**

**Ground Snow Load:**
- Ground snow load: \( p_g = 0\text{-psf} \)  
  \[ \text{[Fig. 7-1, Table 7-1]} \]

**Flat Roof Snow Load:**
- Exposure Factor: \( C_e = 1 \)  
- Thermal Factor: \( C_t = 1 \)  
- Importance Factor: \( I_s = 0.8 \)  
- \( p_f := 0.7C_eC_tI_sp_g \)  
- \( p_f = 0\text{-psf} \)  
  \[ \text{[Section 7.3.1]} \]

**Minimum Snow Load for Low-Slope Roofs:**
A minimum roof snow load, \( p_m \), shall only apply to monoslope, hip and gable roofs with slopes less than 15°, and to curved roofs where the vertical angle from the eaves to the crown is less than 10°. This minimum roof snow load is a separate uniform load case. It need not be used in determining or in combination with drift, sliding, unbalanced, or partial loads.

\[ p_m := \min(p_g, 20\text{-psf})I_s \Rightarrow p_m = 0\text{-psf} \]  
[**Section 7.3.4**]

**Sloped Roof Snow Load:**
- Roof Slope Factor: \( C_s = 0.66 \)  
- \( p_s := C_s p_f \)  
- \( p_s = 0\text{-psf} \)  
  \[ \text{[Figure 7-2]} \]

**Balanced Snow Load:**
- \( N_1 := p_s L_{bay} \)  
- \( N_1 = 0\text{-pli} \)

**Un-balanced Snow Load:**
\[ W_{\text{Fig 7.5}} := \frac{L_{\text{width}}}{2} \]  
[**Figure 7-5**]

\( S = 1.95 \)  
[**Section 7.1**]

\( \gamma_{\text{snow}} = 0\text{-pcf} \)  
[**Eq. 7-3**]

\( h_d = 0\text{-ft} \)  
[**Figure 7-9**]

\[ \gamma_{\text{snow}} = 0\text{-pcf} \]  
[**Eq. 7-3**]

\( h_d = 0\text{-ft} \)  
[**Figure 7-9**]

- \( N_{2,\text{windward}} = 0.00\text{-pli} \)
- \( N_{2,\text{leeward}} = 0.00\text{-pli} \)
- \( N_{2,\text{leeward}} + \frac{h_d\gamma_{\text{snow}}}{\sqrt{S}}L_{\text{bay}} = 0\text{-pli} \)

**Note:** Unbalanced loads need not be considered for \( \theta > 30.2^\circ \) (7 on 12) or \( \theta \leq 23.5^\circ \) (11/2 on 12)
**Wind Loads.**

**General Requirements**

<table>
<thead>
<tr>
<th>Risk Category</th>
<th>Cat = &quot;I&quot;</th>
</tr>
</thead>
</table>

Use of Building(Cat) = "Buildings and other structures that represent a low risk to human life in the event of failure"

<table>
<thead>
<tr>
<th>Basic wind speed:</th>
<th>V = 125-mph</th>
</tr>
</thead>
</table>

Basic Wind Speed Map(Cat) = "Use Figure 26.5-1C."

<table>
<thead>
<tr>
<th>Wind directionality factor:</th>
<th>K_d = 0.85</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Exposure category:</th>
<th>Exposure = &quot;C&quot;</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Topographic factor:</th>
<th>K_zt = 1</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Gust effect factor:</th>
<th>G = 0.85</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Mean recurrence interval:</th>
<th>MRI = 2-yr</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Reduction factor for 'other' MRI:</th>
<th>R_n = 0.68</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Effective wind speed:</th>
<th>V_r := V * R_n = 85-mph</th>
</tr>
</thead>
</table>

**Envelope Procedure**

ASCE 7-10 Envelope Procedure for low-rise buildings as specified in Chapter 28 is used in this evaluation.

No reduction to the velocity pressure is taken due to apparent shielding.

<table>
<thead>
<tr>
<th>Velocity pressure:</th>
</tr>
</thead>
</table>

\[ q_z = 0.00256 \frac{\text{psf}}{\text{mph}^2} K_d K_zt V_r^2 \]

where:

\[ K_d = 0.85 \quad \text{wind directionality factor} \]

\[ K_zt = 1 \quad \text{topographic factor} \]

\[ K_x = 2.01 \left( \frac{z}{z_g} \right)^2 \quad \text{for } 15\text{ft} \leq z \leq z_g \]

\[ K_x = 2.01 \left( \frac{15\text{ft}}{z_g} \right)^2 \quad \text{for } z \leq 15\text{ft} \]

\[ K_z = 0.86 \quad \text{velocity pressure exposure coefficient} \]

\[ V = 125\text{-mph} \quad \text{basic wind speed} \]

\[ q_z = 13.47 \text{-psf} \quad \text{velocity pressure evaluated at peak height, } z \]

\[ q_h = 13.35 \text{-psf} \quad \text{velocity pressure evaluated at mean roof height, } h \]

The wind load to be used in the design of the MWFRS for an enclosed or partially enclosed building shall not be less than 16 psf multiplied by the wall area of the building and 8 psf multiplied by the roof area of the building projected onto a vertical plane normal to the assumed wind direction.

<table>
<thead>
<tr>
<th>Wall Case windward = 10-qli</th>
<th>Wall Case leeward = 10-qli</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Roof Case windward = 5-qli</th>
<th>Roof Case leeward = 5-qli</th>
</tr>
</thead>
</table>
Internal Pressure Coefficients (GC_{pi})

Openings are considered to be equally distributed around the building. The building qualifies as an enclosed building (see Section 26.10). The value can be both positive (overpressure), and negative (underpressure);

\[
GC_{pi} = \begin{pmatrix}
0.18 \\
-0.18
\end{pmatrix}
\]

[Section 26.11]

External Pressure Coefficients (GC_{pf})

\[2 \cdot a = 6.00\text{-ft} \quad \frac{2 \cdot a}{L_{\text{bay}}} = 40\%\]

Figure 28.4-1 : External Pressure coefficients (GC_{pf})

<table>
<thead>
<tr>
<th>Roof Angle (\theta_t) (degrees)</th>
<th>LOAD CASE A Building Surface</th>
<th>LOAD CASE B Building Surface</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>0-5</td>
<td>0.40</td>
<td>-0.69</td>
</tr>
<tr>
<td>20</td>
<td>0.53</td>
<td>-0.69</td>
</tr>
<tr>
<td>30-45</td>
<td>0.56</td>
<td>0.21</td>
</tr>
<tr>
<td>90</td>
<td>0.56</td>
<td>0.56</td>
</tr>
</tbody>
</table>

Application of Pressures on Building Surfaces 2 and 3

Per note 8 in ASCE 7-10 Fig. 28.4-1, the roof pressure coefficient (GC_{pf}), when negative in Zone 2 and 2E, shall be applied in Zone 2/2E for a distance from the edge of the roof equal to 0.5*horizontal dimension of the building parallel to the direction of the MWFRS being designed or 2.5* the eave height at the windward wall, whichever is less; the remainder of Zone 2/2E extending to the ridge line shall use the pressure coefficient (GC_{pf}) for Zone 3/3E.

\[
\begin{align*}
\text{Zone 2/2E distance}_{\text{CaseA}} &= 15\text{-ft} \\
\text{Zone 2/2E distance}_{\text{CaseB}} &= 20\text{-ft}
\end{align*}
\]
Design Wind Pressures

\[ p = q_h \left[ (G_{pf}) - (G_{pi}) \right] \]

\[ [\text{Equation 28.4-1}] \]

\[
\begin{array}{cccccccc}
\text{p}_A &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} & \text{"1E"} & \text{"2E"} & \text{"3E"} & \text{"4E"} \\
& & 9.76 & 1.78 & -3.53 & -2.76 & 12.03 & 0.90 & -5.28 & -4.61 \\
\text{p}_B &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} & \text{"5"} & \text{"6"} & \text{"1E"} & \text{"2E"} & \text{"3E"} & \text{"4E"} & \text{"5E"} & \text{"6E"} \\
& & -3.6 & -6.81 & -2.54 & -3.6 & 7.74 & -1.47 & -4 & -11.88 & -4.67 & -4 & 10.54 & -3.34 \\
\end{array}
\]

Top line = overpressure, bottom line = underpressure

Design Wind Loads

The wind pressure on one bay must be supported by one arch. The total wind load per arch equals:

\[ WL = p \cdot L_{bay} \]

\[
\begin{array}{cccccccc}
\text{WL}_A &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} & \text{"1E"} & \text{"2E"} & \text{"3E"} & \text{"4E"} \\
& & 12.2 & 2.22 & -4.41 & -3.46 & 15.04 & 1.13 & -6.6 & -5.77 \\
\text{WL}_B &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} & \text{"5"} & \text{"6"} & \text{"1E"} & \text{"2E"} & \text{"3E"} & \text{"4E"} & \text{"5E"} & \text{"6E"} \\
\end{array}
\]

Top line = overpressure, bottom line = underpressure

Design Wind Loads - First Arch on End with applied load

\[
\begin{array}{cccc}
\text{WL}_A &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} \\
& = & 4.23 & -2.33 & -6.08 & -5.65 \\
& & 7.24 & 0.67 & -3.08 & -2.65 \\
\text{WL}_B &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} & \text{"5"} & \text{"6"} \\
& = & -5.46 & -9.79 & -5.66 & -5.46 & 3.24 & -4.85 \\
& & -2.45 & -6.79 & -2.65 & -2.45 & 6.24 & -1.85 \\
\end{array}
\]

Design Wind Loads - Second Arch from End with applied load

\[
\begin{array}{cccc}
\text{WL}_A &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} \\
& = & 6.2 & -3.78 & -10.41 & -9.46 \\
& & 12.2 & 2.22 & -4.41 & -3.46 \\
\text{WL}_B &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} & \text{"5"} & \text{"6"} \\
& = & -10.51 & -14.51 & -9.18 & -10.51 & 3.67 & -7.84 \\
& & -4.5 & -8.51 & -3.17 & -4.5 & 9.68 & -1.84 \\
\end{array}
\]

Design Wind Loads - All Other Arches

\[
\begin{array}{cccc}
\text{WL}_A &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} \\
& = & 6.2 & -3.78 & -10.41 & -9.46 \\
& & 12.2 & 2.22 & -4.41 & -3.46 \\
\text{WL}_B &=& \text{"1"} & \text{"2"} & \text{"3"} & \text{"4"} & \text{"5"} & \text{"6"} \\
& = & -10.51 & -14.51 & -9.18 & -10.51 & 3.67 & -7.84 \\
& & -4.5 & -8.51 & -3.17 & -4.5 & 9.68 & -1.84 \\
\end{array}
\]
4. LRFD Load Combinations:

**ASCE 7-10 Section 2.2: SYMBOLS AND NOTATION**

- **D** = dead load
- **D<sub>i</sub>** = weight of ice
- **E** = earthquake load
- **F** = load due to fluids with well-defined pressures and maximum heights
- **F<sub>a</sub>** = flood load
- **H** = load due to lateral earth pressure, ground water pressure, or pressure of bulk materials
- **L** = live load
- **L<sub>r</sub>** = roof live load
- **R** = rain load
- **S** = snow load
- **T** = self-straining force
- **W** = wind load
- **W<sub>i</sub>** = wind-on-ice determined in accordance with Chapter 10

**ASCE Section 2.3: COMBINING FACTORED LOADS USING STRENGTH DESIGN**

Section 2.3.2: Basic Combinations. Structures, components, and foundations shall be designed so that their design strength equals or exceeds the effects of the factored loads in the following combinations:

1. **1.4D**
2. **1.2D + 1.6L + 0.5(L<sub>r</sub> or S or R)**
3. **1.2D + 1.6(L<sub>r</sub> or S or R) + (L or 0.5W)**
4. **1.2D + 1.0W + L + 0.5(L<sub>r</sub> or S or R)**
5. **1.2D + 1.0E + L + 0.2S**
6. **0.9D + 1.0W**
7. **0.9D + 1.0E**
Symbols as used in calculations:

- $D_1$ = dead load;
- $W_1$ = lateral wind (perpendicular to ridge line with overpressure);
- $D_2$ = dead load - ancillary;
- $W_2$ = lateral wind (perpendicular to ridge line with underpressure);
- $L_r$ = roof live load;
- $W_3$ = longitudinal wind (parallel to ridge line with overpressure);
- $S_1$ = balanced snow;
- $W_4$ = longitudinal wind (parallel to ridge line with underpressure);
- $S_2$ = unbalanced snow;
- $W$' = minimum wind per section 28.4.4 (designated at $W_5$).

Combinations as applied in calculations:

1. $1.4D_1 + 1.4D_2$
2. $1.2D_1 + 0.5L_r$
3. $1.2D_1 + 1.6L_r + 0.5W_1$
4. $1.2D_1 + 0.5L_r + 1.0W_1$
5. $1.2D_1 + 0.5S_1 + 1.0W_1$
6. $0.9D_1 + 1.0W_1$
7. $1.2D_1 + 0.5L_r + 1.0W_2$
8. $1.2D_1 + 0.5S_1 + 1.0W_2$
9. $1.2D_1 + 0.5S_1 + 1.0W_3$
10. $1.2D_1 + 0.5S_1 + 1.0W_4$
11. $0.9D_1 + 1.0W_1$
12. $1.2D_1 + 0.5L_r + 1.0W_3$
13. $1.2D_1 + 0.5L_r + 1.0W_4$
14. $1.2D_1 + 0.5S_1 + 1.0W_3$
15. $1.2D_1 + 0.5S_1 + 1.0W_4$
16. $0.9D_1 + 1.0W_1$
17. $1.2D_1 + 0.5L_r + 1.0W_5$
18. $1.2D_1 + 0.5S_1 + 1.0W_5$
19. $1.2D_1 + 0.5S_1 + 1.0W_6$
20. $1.2D_1 + 0.5S_1 + 1.0W_7$
21. $0.9D_1 + 1.0W_1$
22. $1.2D_1 + 0.5L_r + 1.0W_8$
23. $1.2D_1 + 0.5S_1 + 1.0W_8$
24. $1.2D_1 + 0.5S_1 + 1.0W_9$
25. $0.9D_1 + 1.0W_1$
26. $1.2D_1 + 0.5L_r + 1.0W_9$
27. $1.2D_1 + 0.5S_1 + 1.0W_9$
28. $1.2D_1 + 0.5S_1 + 1.0W_10$
29. $0.9D_1 + 1.0W_1$
30. $1.2D_1 + 0.5L_r + 1.0W_{10}$
31. $1.2D_1 + 0.5S_1 + 1.0W_{10}$
32. $1.2D_1 + 0.5S_1 + 1.0W_{11}$
33. $0.9D_1 + 1.0W_1$
34. $1.2D_1 + 0.5L_r + 1.0W_{11}$
35. $1.2D_1 + 0.5S_1 + 1.0W_{11}$
36. $1.2D_1 + 0.5S_1 + 1.0W_{12}$
37. $0.9D_1 + 1.0W_1$
38. $1.2D_1 + 0.5L_r + 1.0W_{12}$
39. $1.2D_1 + 0.5S_1 + 1.0W_{12}$
40. $1.2D_1 + 0.5S_1 + 1.0W_{13}$
41. $0.9D_1 + 1.0W_1$
42. $1.2D_1 + 0.5L_r + 1.0W_{13}$
43. $1.2D_1 + 0.5S_1 + 1.0W_{13}$
44. $1.2D_1 + 0.5S_1 + 1.0W_{14}$
45. $0.9D_1 + 1.0W_1$
46. $1.2D_1 + 0.5L_r + 1.0W_{14}$
47. $1.2D_1 + 0.5S_1 + 1.0W_{14}$
48. $1.2D_1 + 0.5S_1 + 1.0W_{15}$
49. $0.9D_1 + 1.0W_1$
50. $1.2D_1 + 0.5L_r + 1.0W_{15}$
51. $1.2D_1 + 0.5S_1 + 1.0W_{15}$
52. $1.2D_1 + 0.5S_1 + 1.0W_{16}$
53. $0.9D_1 + 1.0W_1$
54. $1.2D_1 + 0.5L_r + 1.0W_{16}$
55. $1.2D_1 + 0.5S_1 + 1.0W_{16}$
56. $1.2D_1 + 0.5S_1 + 1.0W_{17}$
57. $0.9D_1 + 1.0W_1$
58. $1.2D_1 + 0.5L_r + 1.0W_{17}$
59. $1.2D_1 + 0.5S_1 + 1.0W_{17}$
60. $1.2D_1 + 0.5S_1 + 1.0W_{18}$
61. $0.9D_1 + 1.0W_1$
62. $1.2D_1 + 0.5L_r + 1.0W_{18}$
63. $1.2D_1 + 0.5S_1 + 1.0W_{18}$
64. $1.2D_1 + 0.5S_1 + 1.0W_{19}$
65. $0.9D_1 + 1.0W_1$
66. $1.2D_1 + 0.5L_r + 1.0W_{19}$
67. $1.2D_1 + 0.5S_1 + 1.0W_{19}$
68. $1.2D_1 + 0.5S_1 + 1.0W_{20}$
69. $0.9D_1 + 1.0W_1$
70. $1.2D_1 + 0.5L_r + 1.0W_{20}$
71. $1.2D_1 + 0.5S_1 + 1.0W_{20}$
72. $1.2D_1 + 0.5S_1 + 1.0W_{21}$
73. $0.9D_1 + 1.0W_1$
74. $1.2D_1 + 0.5L_r + 1.0W_{21}$
75. $1.2D_1 + 0.5S_1 + 1.0W_{21}$
76. $1.2D_1 + 0.5S_1 + 1.0W_{22}$
77. $0.9D_1 + 1.0W_1$
78. $1.2D_1 + 0.5L_r + 1.0W_{22}$
79. $1.2D_1 + 0.5S_1 + 1.0W_{22}$
80. $1.2D_1 + 0.5S_1 + 1.0W_{23}$
81. $0.9D_1 + 1.0W_1$
82. $1.2D_1 + 0.5L_r + 1.0W_{23}$
83. $1.2D_1 + 0.5S_1 + 1.0W_{23}$
84. $1.2D_1 + 0.5S_1 + 1.0W_{24}$
85. $0.9D_1 + 1.0W_1$
86. $1.2D_1 + 0.5L_r + 1.0W_{24}$
87. $1.2D_1 + 0.5S_1 + 1.0W_{24}$
88. $1.2D_1 + 0.5S_1 + 1.0W_{25}$
89. $0.9D_1 + 1.0W_1$
90. $1.2D_1 + 0.5L_r + 1.0W_{25}$
91. $1.2D_1 + 0.5S_1 + 1.0W_{25}$
92. $1.2D_1 + 0.5S_1 + 1.0W_{26}$
93. $0.9D_1 + 1.0W_1$
94. $1.2D_1 + 0.5L_r + 1.0W_{26}$
95. $1.2D_1 + 0.5S_1 + 1.0W_{26}$
96. $1.2D_1 + 0.5S_1 + 1.0W_{27}$
97. $0.9D_1 + 1.0W_1$
98. $1.2D_1 + 0.5L_r + 1.0W_{27}$
99. $1.2D_1 + 0.5S_1 + 1.0W_{27}$
100. $1.2D_1 + 0.5S_1 + 1.0W_{28}$

Note: The combinations are subject to specific design criteria and regulations.
5a. Main Profile Design

**Section Properties:**

- \( E = 10100 \text{ ksi} \) (Table 3.3-1)
- \( n_u = 1.95 \) (Table 3.4-1)

**Main Extrusion**

- \( A_g = 2.069 \text{ in}^2 \) (Cross-sectional area of Shape)
- \( b_w = 5.020 \text{ in} \) (Web length of Shape)
- \( t_w = 0.118 \text{ in} \) (Web thickness)
- \( b_f = 1.970 \text{ in} \) (Flat flange)
- \( t_f = 0.118 \text{ in} \) (Flange thickness)
- \( I_x = 5.75 \text{ in}^4 \) (Moment of inertia about strong axis)
- \( I_y = 1.04 \text{ in}^4 \) (Moment of inertia about weak axis)
- \( S_x = 2.17 \text{ in}^3 \) (Section Modulus about strong axis)
- \( S_y = 1.05 \text{ in}^3 \) (Section Modulus about weak axis)
- \( r_x = 1.67 \text{ in} \) (Radius of Gyration about strong axis)
- \( r_y = 0.71 \text{ in} \) (Radius of Gyration about weak axis)
- \( J = 0.64 \text{ in}^4 \) (Torsional constant)
- \( K_x : = 1.0 \) (For strong axis buckling)
- \( L_x = 96 \text{ in} \) (Length between Inflection Points for strong axis buckling from computer model)
- \( K_y : = 0.7 \) (For weak axis buckling)
- \( L_y = 96 \text{ in} \) (Length for weak axis buckling)
- \( L_b : = L_y \) (Length between Bracing Points (compression flange restrained from twisting or moving laterally))

**Selected Ratios:**

- \( \frac{b_w}{t_w} = 42.5 \)
- \( \frac{b_f}{t_f} = 16.7 \)
- \( \frac{R_b}{r_f} = 0 \)
- \( \frac{K_x \cdot L_x}{r_x} = 57.6 \)
- \( \frac{K_y \cdot L_y}{r_y} = 94.9 \)
- \( \frac{L_b \cdot S_x}{0.5 \sqrt{I_y \cdot J}} = 511.1 \)
Allowable Axial Stress:

**Specification 3.4.1 - Tension, axial:**
Any tension member.

F<sub>3.4.1</sub> = 32.3 ksi  \quad F<sub>3.4.1</sub> = 222.7 MPa

**Specification 3.4.7 - Compression in Columns:**
All columns.

F<sub>3.4.7x</sub> = 19.5 ksi  \quad F<sub>3.4.7x</sub> = 134.4 MPa
F<sub>3.4.7y</sub> = 9.18 ksi  \quad F<sub>3.4.7y</sub> = 63.3 MPa
F<sub>3.4.9</sub> = 19.14 ksi  \quad F<sub>3.4.9</sub> = 131.9 MPa

**Specification 3.4.9 - Compression in Column Elements:**
Flat elements supported on both edges.

F<sub>3.4.10</sub> = 33.25 ksi  \quad F<sub>3.4.10</sub> = 229.3 MPa

**Specification 3.4.10 - Compression in Column Elements:**
Curved elements supported on both edges.

Allowable Axial Stress:

Use in Eq. 4.1.1-1
F<sub>a</sub> = 9.18 ksi  \quad F<sub>a</sub> = 63.3 MPa
F<sub>a0</sub> = 19.14 ksi  \quad F<sub>a0</sub> = 131.9 MPa
F<sub>ex</sub> = 23.24 ksi  \quad F<sub>ex</sub> = 160.2 MPa
F<sub>ey</sub> = 9.18 ksi  \quad F<sub>ey</sub> = 63.3 MPa

Use in Eq. 4.1.1-2

**Allowable Bending Stress:**

**Specification 3.4.2 - Tension in Beams, extreme fibre, net section:**
Flat elements in uniform tension (flanges).

F<sub>3.4.2</sub> = 32.3 ksi  \quad F<sub>3.4.2</sub> = 222.7 MPa

**Specification 3.4.14 - Compression in Beams, gross section:**
Tubular shapes.

F<sub>3.4.14</sub> = 25.9 ksi  \quad F<sub>3.4.14</sub> = 178.6 MPa

**Specification 3.4.16 - Compression in Beams, gross section:**
Flat elements supported on both edges.

F<sub>3.4.16</sub> = 31.46 ksi  \quad F<sub>3.4.16</sub> = 216.9 MPa

**Specification 3.4.16.1 - Compression in Beams, gross section:**
Curved elements supported on both edges.

F<sub>3.4.16.1</sub> = 38.9 ksi  \quad F<sub>3.4.16.1</sub> = 268.2 MPa

**Specification 3.4.19 - Compression in Beams, elements:**
Flat elements supported on both edges with longitudinal stiffening.

Allowable Bending Stress:

Use in Eq. 4.1.1-1
F<sub>bx</sub> = 25.9 ksi  \quad F<sub>bx</sub> = 178.6 MPa
F<sub>by</sub> = 25.9 ksi  \quad F<sub>by</sub> = 178.6 MPa

& Eq. 4.1.1-2

**Allowable Shear Stress:**

**Specification 3.4.20 - Shear in Elements, gross section:**
Unstiffened flat elements supported on both edges.

F<sub>3.4.20</sub> = 17.16 ksi  \quad F<sub>3.4.20</sub> = 118.3 MPa
**Actual Stress (un-reinforced extrusion):**

Member ID = "M102"  
Mx = 32.95-kip-in  
My = 0-kip-in  
C = −0.9-kip

Load Case = "6c - 0.9D1±1.0W3"

\[ C_{max} := 0.85 \]

\[ C_{my} := 0.85 \]

\[ f_{bx} := \frac{Mx}{S_x} \]

\[ f_{by} := \frac{My}{S_y} \]

\[ f_{ac} := \frac{C}{A_g} \]

\[ f_{bx} = 15.2\text{-ksi} \]

\[ f_{by} = 0.0\text{-ksi} \]

\[ f_{ac} = 0.4\text{-ksi} \]

\[ f_{bx} = 104.5\text{MPa} \]

\[ f_{by} = 0.0\text{MPa} \]

\[ f_{ac} = 3.0\text{MPa} \]

**Eq. 4.1.1-1**

\[ Eq1 := \frac{f_{ac}}{F_a} + \frac{C_{max}f_{bx}}{\left(1 - \frac{f_{ac}}{F_{ex}}\right)f_{bx}} + \frac{C_{my}f_{by}}{\left(1 - \frac{f_{ac}}{F_{ey}}\right)f_{by}} \]

Eq1 = 0.55  
Eq1 is less than or equal to 1.0 = "OK"

**Eq. 4.1.1-2**

\[ Eq2 := \frac{f_{ac}}{F_{ao}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \]

Eq2 = 0.61  
Eq2 is less than or equal to 1.0 = "OK"

Member ID = "M101"  
Mx = 32.95-kip-in  
My = 0-kip-in  
T = 1.5-kip

Load Case = "6c - 0.9D1±1.0W3"

\[ f_{bx} := \frac{Mx}{S_x} \]

\[ f_{by} := \frac{My}{S_y} \]

\[ f_{at} := \frac{T}{A_g} \]

\[ f_{bx} = 15.2\text{-ksi} \]

\[ f_{by} = 0\text{-ksi} \]

\[ f_{at} = 0.7\text{-ksi} \]

\[ f_{bx} = 104.5\text{MPa} \]

\[ f_{by} = 0\text{MPa} \]

\[ f_{at} = 5\text{MPa} \]

**Eq. 4.1.2-1**

\[ Eq3 := \frac{f_{at}}{F_{3.4.1}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \]

Eq3 = 0.61  
Eq3 is less than or equal to 1.0 = "OK"
5b. Eave Brace Profile Design

**Section Properties:**

\[ E = 10100 \text{ ksi} \]
\[ n_a = 1.95 \]

**main extrusion**

- \[ A_g = 0.736 \text{ in}^2 \] Cross-sectional area of Shape
- \[ b_w = 2.000 \text{ in} \] Web length of Shape
- \[ t_w = 0.125 \text{ in} \] Web thickness
- \[ b_f = 2.000 \text{ in} \] Flat flange
- \[ t_f = 0.125 \text{ in} \] Flange thickness
- \[ I_x = 0.32 \text{ in}^4 \] Moment of inertia about strong axis
- \[ I_y = 0.32 \text{ in}^4 \] Moment of inertia about weak axis
- \[ S_x = 0.32 \text{ in}^3 \] Section Modulus about strong axis
- \[ S_y = 0.32 \text{ in}^3 \] Section Modulus about weak axis
- \[ r_x = 0.66 \text{ in} \] Radius of Gyration about strong axis
- \[ r_y = 0.66 \text{ in} \] Radius of Gyration about weak axis
- \[ J = 0.65 \text{ in}^4 \] Torsional constant
- \[ K_x := 1.0 \] For strong axis buckling
- \[ L_x = 56.04 \text{ in} \] Length between Inflection Points for strong axis buckling from computer model
- \[ K_y := 0.7 \] For weak axis buckling
- \[ L_y = 56.04 \text{ in} \] Length for weak axis buckling
- \[ L_b := L_y \] Length between Bracing Points (compression flange restrained from twisting or moving laterally)

**Selected Ratios:**

\[ \frac{b_w}{t_w} = 16 \quad \frac{b_f}{t_f} = 16 \quad \frac{R_b}{t_f} = 0 \quad \frac{K_x \cdot L_x}{r_x} = 84.4 \quad \frac{K_y \cdot L_y}{r_y} = 59.1 \quad \frac{L_b \cdot S_x}{0.5 \sqrt{I_y \cdot J}} = 79.2 \]
The following allowable stresses are based on values from the "2005 Aluminum Design Manual"

**Allowable Axial Stress:**

**Specification 3.4.1 - Tension, axial:**
Any tension member.

**Specification 3.4.7 - Compression in Columns:**
All columns.

**Specification 3.4.9 - Compression in Column Elements:**
Flat elements supported on both edges.

**Specification 3.4.10 - Compression in Column Elements:**
Curved elements supported on both edges.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.1</td>
<td>$F_{3.4.1} = 32.3 \text{ ksi}$ $F_{3.4.1} = 222.7 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.7x</td>
<td>$F_{3.4.7x} = 11.22 \text{ ksi}$ $F_{3.4.7x} = 77.4 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.7y</td>
<td>$F_{3.4.7y} = 30.01 \text{ ksi}$ $F_{3.4.7y} = 206.9 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.9</td>
<td>$F_{3.4.9} = 31.74 \text{ ksi}$ $F_{3.4.9} = 218.8 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.10</td>
<td>$F_{3.4.10} = 33.25 \text{ ksi}$ $F_{3.4.10} = 229.3 \text{ MPa}$</td>
</tr>
</tbody>
</table>

**Allowable Axial Stress:**
Use in Eq. 4.1.1-1

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.1</td>
<td>$F_a = 11.22 \text{ ksi}$ $F_a = 77.4 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.7x</td>
<td>$F_{ao} = 31.74 \text{ ksi}$ $F_{ao} = 218.8 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.7y</td>
<td>$F_{ex} = 11.22 \text{ ksi}$ $F_{ex} = 77.4 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.9</td>
<td>$F_{ey} = 21.94 \text{ ksi}$ $F_{ey} = 151.3 \text{ MPa}$</td>
</tr>
</tbody>
</table>

**Allowable Bending Stress:**

**Specification 3.4.2 - Tension in Beams, extreme fibre, net section:**
Flat elements in uniform tension (flanges).

**Specification 3.4.14 - Compression in Beams, gross section:**
Tubular shapes.

**Specification 3.4.16 - Compression in Beams, gross section:**
Flat elements supported on both edges.

**Specification 3.4.16.1 - Compression in Beams, gross section:**
Curved elements supported on both edges.

**Specification 3.4.19 - Compression in Beams, elements:**
Flat elements supported on both edges with longitudinal stiffening.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.2</td>
<td>$F_{3.4.2} = 32.3 \text{ ksi}$ $F_{3.4.2} = 222.7 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.14</td>
<td>$F_{3.4.14} = 30.49 \text{ ksi}$ $F_{3.4.14} = 210.2 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.16</td>
<td>$F_{3.4.16} = 31.74 \text{ ksi}$ $F_{3.4.16} = 218.8 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.16.1</td>
<td>$F_{3.4.16.1} = 38.9 \text{ ksi}$ $F_{3.4.16.1} = 268.2 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.19</td>
<td>$F_{3.4.19} = 43.22 \text{ ksi}$ $F_{3.4.19} = 298 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.20</td>
<td>$F_{bx} = 30.49 \text{ ksi}$ $F_{bx} = 210.2 \text{ MPa}$</td>
</tr>
<tr>
<td>3.4.20</td>
<td>$F_{by} = 30.49 \text{ ksi}$ $F_{by} = 210.2 \text{ MPa}$</td>
</tr>
</tbody>
</table>

**Allowable Shear Stress:**

**Specification 3.4.20 - Shear in Elements, gross section:**
Unstiffened flat elements supported on both edges.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.20</td>
<td>$F_{3.4.20} = 19.2 \text{ ksi}$ $F_{3.4.20} = 132.4 \text{ MPa}$</td>
</tr>
</tbody>
</table>
Actual Stress:

Member ID = "Eb101"
Mx = 0.02-kip-in      My = 0-kip-in      C = −1.59-kip
Load Case = "4b - 1.2D1±0.5Lr±1.0W2"

Cmx := 0.85
Cmy := 0.85
f_{bx} := \frac{M_x}{S_x}           f_{by} := \frac{M_y}{S_y}           f_{ac} := \frac{C}{A_{g}}

f_{bx} = 0.1\text{-ksi}            f_{by} = 0.0\text{-ksi}            f_{ac} = 2.2\text{-ksi}
f_{bx} = 0.5\text{-MPa}            f_{by} = 0.0\text{-MPa}            f_{ac} = 14.9\text{-MPa}

Eq. 4.1.1-1 : \quad Eq1 := \frac{f_{ac}}{F_{ao}} + \frac{C_{mx}f_{bx}}{F_{bx}} + \frac{C_{my}f_{by}}{F_{by}}

Eq1 := \frac{f_{ac}}{F_{ao}} + \frac{C_{mx}f_{bx}}{F_{bx}} + \frac{C_{my}f_{by}}{F_{by}} \quad Eq1 = 0.2

Eq1 is less than or equal to 1.0 = "OK"

Eq. 4.1.1-2 : \quad Eq2 := \frac{f_{ac}}{F_{ao}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}}

Eq2 := \frac{f_{ac}}{F_{ao}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \quad Eq2 = 0.07

Eq2 is less than or equal to 1.0 = "OK"

Member ID = "Eb101"
Mx = 0.02-kip-in      My = 0-kip-in      T = 3.48-kip
Load Case = "6c - 0.9D1±1.0W3"

f_{bx} := \frac{M_x}{S_x}           f_{by} := \frac{M_y}{S_y}           f_{at} := \frac{T}{A_{g}}

f_{bx} = 0.1\text{-ksi}            f_{by} = 0.0\text{-ksi}            f_{at} = 4.7\text{-ksi}
f_{bx} = 0.4\text{-MPa}            f_{by} = 0.0\text{-MPa}            f_{at} = 32.6\text{-MPa}

Eq. 4.1.2-1 : \quad Eq3 := \frac{f_{at}}{F_{34.1}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}}

Eq3 := \frac{f_{at}}{F_{34.1}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \quad Eq3 = 0.15

Eq3 is less than or equal to 1.0 = "OK"
5c. Ridge Brace Profile Design

Section Properties:

\[ E = 10100 \text{ ksi} \]
\[ n_u = 1.95 \]

main extrusion
\[ A_g = 0.736 \text{ in}^2 \]
\[ b_w = 2.000 \text{ in} \]
\[ t_w = 0.125 \text{ in} \]
\[ b_f = 2.000 \text{ in} \]
\[ t_f = 0.125 \text{ in} \]
\[ I_x = 0.32 \text{ in}^4 \]
\[ I_y = 0.32 \text{ in}^4 \]
\[ S_x = 0.32 \text{ in}^3 \]
\[ S_y = 0.32 \text{ in}^3 \]
\[ r_x = 0.66 \text{ in} \]
\[ r_y = 0.66 \text{ in} \]
\[ J = 0.65 \text{ in}^4 \]
\[ K_x := 1.0 \]
\[ L_x = 54.5 \text{ in} \]
\[ K_y := 0.7 \]
\[ L_y = 54.5 \text{ in} \]

Selected Ratios:

\[ \frac{b_w}{t_w} = 16 \quad \frac{b_f}{t_f} = 16 \quad \frac{R_b}{t_f} = 0 \quad \frac{K_x \cdot L_x}{r_x} = 82 \quad \frac{K_y \cdot L_y}{r_y} = 57.4 \quad \frac{L_b \cdot S_x}{0.5 \sqrt{I_y \cdot J}} = 77.1 \]
The following allowable stresses are based on values from the "2005 Aluminum Design Manual"

**Allowable Axial Stress:**

**Specification 3.4.1 - Tension, axial:**
Any tension member.

**Specification 3.4.7 - Compression in Columns:**
All columns.

**Specification 3.4.9 - Compression in Column Elements:**
Flat elements supported on both edges.

**Specification 3.4.10 - Compression in Column Elements:**
Curved elements supported on both edges.

**Allowable Axial Stress:**
Use in Eq. 4.1.1-1

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Axial Stress in ksi</th>
<th>Allowable Axial Stress in MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.1</td>
<td>$F_{3.4.1} = 32.3$</td>
<td>$F_{3.4.1} = 222.7$</td>
</tr>
<tr>
<td>3.4.7x</td>
<td>$F_{3.4.7x} = 11.78$</td>
<td>$F_{3.4.7x} = 81.2$</td>
</tr>
<tr>
<td>3.4.7y</td>
<td>$F_{3.4.7y} = 30.26$</td>
<td>$F_{3.4.7y} = 208.7$</td>
</tr>
<tr>
<td>3.4.9</td>
<td>$F_{3.4.9} = 31.74$</td>
<td>$F_{3.4.9} = 218.8$</td>
</tr>
<tr>
<td>3.4.10</td>
<td>$F_{3.4.10} = 33.25$</td>
<td>$F_{3.4.10} = 229.3$</td>
</tr>
</tbody>
</table>

**Specification 3.4.14 - Compression in Beams, gross section:**
Tubular shapes.

**Specification 3.4.16 - Compression in Beams, gross section:**
Flat elements supported on both edges.

**Specification 3.4.16.1 - Compression in Beams, gross section:**
Curved elements supported on both edges.

**Specification 3.4.19 - Compression in Beams, elements:**
Flat elements supported on both edges with longitudinal stiffening.

**Allowable Axial Stress:**
Use in Eq. 4.1.1-1 & Eq. 4.1.1-2

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Axial Stress in ksi</th>
<th>Allowable Axial Stress in MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.2</td>
<td>$F_{3.4.2} = 32.3$</td>
<td>$F_{3.4.2} = 222.7$</td>
</tr>
<tr>
<td>3.4.14</td>
<td>$F_{3.4.14} = 30.53$</td>
<td>$F_{3.4.14} = 210.5$</td>
</tr>
<tr>
<td>3.4.16</td>
<td>$F_{3.4.16} = 31.74$</td>
<td>$F_{3.4.16} = 218.8$</td>
</tr>
<tr>
<td>3.4.16.1</td>
<td>$F_{3.4.16.1} = 38.9$</td>
<td>$F_{3.4.16.1} = 268.2$</td>
</tr>
<tr>
<td>3.4.19</td>
<td>$F_{3.4.19} = 43.22$</td>
<td>$F_{3.4.19} = 298$</td>
</tr>
</tbody>
</table>

**Specification 3.4.20 - Shear in Elements, gross section:**
Unstiffened flat elements supported on both edges.

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Shear Stress in ksi</th>
<th>Allowable Shear Stress in MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.20</td>
<td>$F_{3.4.20} = 19.2$</td>
<td>$F_{3.4.20} = 132.4$</td>
</tr>
</tbody>
</table>

**Allowable Bending Stress:**

**Specification 3.4.2 - Tension in Beams, extreme fibre, net section:**
Flat elements in uniform tension (flanges).

**Specification 3.4.14 - Compression in Beams, gross section:**
Tubular shapes.

**Specification 3.4.16 - Compression in Beams, gross section:**
Flat elements supported on both edges.

**Specification 3.4.16.1 - Compression in Beams, gross section:**
Curved elements supported on both edges.

**Specification 3.4.19 - Compression in Beams, elements:**
Flat elements supported on both edges with longitudinal stiffening.

**Allowable Bending Stress:**
Use in Eq. 4.1.1-1 & Eq. 4.1.1-2

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Bending Stress in ksi</th>
<th>Allowable Bending Stress in MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.2</td>
<td>$F_{bx} = 30.53$</td>
<td>$F_{bx} = 210.5$</td>
</tr>
<tr>
<td>3.4.19</td>
<td>$F_{by} = 30.53$</td>
<td>$F_{by} = 210.5$</td>
</tr>
</tbody>
</table>

**Allowable Shear Stress:**

<table>
<thead>
<tr>
<th>Specification</th>
<th>Allowable Shear Stress in ksi</th>
<th>Allowable Shear Stress in MPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.4.20</td>
<td>$F_{3.4.20} = 19.2$</td>
<td>$F_{3.4.20} = 132.4$</td>
</tr>
</tbody>
</table>
**Actual Stress:**

Member ID = "Pb101"

Load Case = "1a - 1.4D1"

Cmx := 0.85

Cmy := 0.85

\( f_{bx} := \frac{Mx}{S_x} \)

\( f_{by} := \frac{My}{S_y} \)

\( f_{ac} := \frac{C}{A_g} \)

\( f_{bx} = 0.1\text{-ksi} \)

\( f_{by} = 0\text{-ksi} \)

\( f_{ac} = 0.3\text{-ksi} \)

\( f_{bx} = 0.8\text{MPa} \)

\( f_{by} = 0\text{MPa} \)

\( f_{ac} = 1.8\text{MPa} \)

**Eq. 4.1.1-1**

\[ Eq1 := \frac{f_{ac}}{F_a} + \frac{Cmx f_{bx}}{\left(1 - \frac{f_{ac}}{F_{ex}}\right) F_{bx}} + \frac{Cmy f_{by}}{\left(1 - \frac{f_{ac}}{F_{ey}}\right) F_{by}} \]

Eq1 = 0.03

Eq1 is less than or equal to 1.0 = "OK"

**Eq. 4.1.1-2**

\[ Eq2 := \frac{f_{ac}}{F_{ao}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \]

Eq2 = 0.01

Eq2 is less than or equal to 1.0 = "OK"

Member ID = "Pb101"

Load Case = "4c - 1.2D1\pm0.5Lr\pm1.0W3"

\( f_{bx} := \frac{Mx}{S_x} \)

\( f_{by} := \frac{My}{S_y} \)

\( f_{at} := \frac{T}{A_g} \)

\( f_{bx} = 0.1\text{-ksi} \)

\( f_{by} = 0\text{-ksi} \)

\( f_{at} = 5.3\text{-ksi} \)

\( f_{bx} = 0.7\text{MPa} \)

\( f_{by} = 0\text{MPa} \)

\( f_{at} = 36.6\text{MPa} \)

**Eq. 4.1.2-1**

\[ Eq3 := \frac{f_{at}}{F_{3.4.1}} + \frac{f_{bx}}{F_{bx}} + \frac{f_{by}}{F_{by}} \]

Eq3 = 0.17

Eq3 is less than or equal to 1.0 = "OK"
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6. Cables

**Bracing Cables**

- The bracing cables are constructed of 1/4" 7x19 Galvanized Improved Plow IWRC wire rope.

Nominal Strength of Cable : Cable Capacity = 6800 lbf
Recommended Safety Factor is : Safety Factor = 2
The maximum force in the wind bracing is \( T_{\text{max}} = 934 \text{ lbf}. \)

\[
T_{\text{max}} \text{ is less than or equal to } \left[ \frac{0.75 \times \text{Cable Capacity}}{\text{Safety Factor}} \right] = "OK"
\]
APPENDIX A

COMPUTER MODEL INPUT
Table of Contents
Model Summary
Nodes
Material Properties
OneWay Members
Nodal Supports
Service Load Cases
Load Cases
Load Combination Summary

Model Summary
Structure Type: Plane Frame
14 Nodes, and 34 Degrees of Freedom
17 Member Elements
The model is non-linear.
The size of the model is:
444 in, in the X direction
188.25 in, in the Y direction

Nodes

<table>
<thead>
<tr>
<th>Node</th>
<th>X</th>
<th>Y</th>
<th>Fix DX</th>
<th>Fix DY</th>
<th>Fix RZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>G101</td>
<td>-222.00</td>
<td>0.000</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>G102</td>
<td>222.00</td>
<td>0.000</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>N101</td>
<td>-180.00</td>
<td>78.000</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N102</td>
<td>-180.00</td>
<td>96.000</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N103</td>
<td>-139.51</td>
<td>116.750</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N104</td>
<td>-27.25</td>
<td>174.280</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N105</td>
<td>0.000</td>
<td>188.250</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N106</td>
<td>27.25</td>
<td>174.280</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N107</td>
<td>139.51</td>
<td>116.750</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N108</td>
<td>180.00</td>
<td>96.000</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N109</td>
<td>180.00</td>
<td>78.000</td>
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<td>No</td>
<td>No</td>
</tr>
<tr>
<td>N110</td>
<td>-19.811</td>
<td>178.094</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>S101</td>
<td>-180.00</td>
<td>0.000</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>S102</td>
<td>180.00</td>
<td>0.000</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

Material Properties

<table>
<thead>
<tr>
<th>Material</th>
<th>Strength</th>
<th>Elasticity</th>
<th>Poisson</th>
<th>Density</th>
<th>Therm. Coeff.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>psi</td>
<td>psi</td>
<td></td>
<td>lb/in^3</td>
<td>in/in/deg-F</td>
</tr>
<tr>
<td>6005-T5-E</td>
<td>35000.000</td>
<td>10100000.000</td>
<td>0.33000</td>
<td>0.0970</td>
<td>0.0000</td>
</tr>
<tr>
<td>Weightless Steel (Fy = 50ksi)</td>
<td>50000.000</td>
<td>29000000.000</td>
<td>0.29000</td>
<td>0.0000</td>
<td>6.3890e-006</td>
</tr>
</tbody>
</table>

OneWay Members

<table>
<thead>
<tr>
<th>Member</th>
<th>One Way</th>
<th>Section</th>
<th>Material</th>
<th>(1)Node</th>
<th>(2)Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cb101</td>
<td>Tension</td>
<td>Round</td>
<td>Weightless Steel (Fy = 50ksi)</td>
<td>N102</td>
<td>N108</td>
</tr>
<tr>
<td>Gy101</td>
<td>Tension</td>
<td>Round</td>
<td>Weightless Steel (Fy = 50ksi)</td>
<td>G101</td>
<td>N102</td>
</tr>
<tr>
<td>Gy102</td>
<td>Tension</td>
<td>Round</td>
<td>Weightless Steel (Fy = 50ksi)</td>
<td>N108</td>
<td>G102</td>
</tr>
</tbody>
</table>

Nodal Supports

<table>
<thead>
<tr>
<th>Node</th>
<th>Fix DX</th>
<th>Fix DY</th>
<th>Fix RZ</th>
</tr>
</thead>
<tbody>
<tr>
<td>G101</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>G102</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>S101</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>S102</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Service Load Cases

<table>
<thead>
<tr>
<th>Load Case</th>
<th>Self Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>D1</td>
<td>Standard</td>
</tr>
<tr>
<td>Lr</td>
<td>None</td>
</tr>
<tr>
<td>W1</td>
<td>None</td>
</tr>
<tr>
<td>W2</td>
<td>None</td>
</tr>
<tr>
<td>W3</td>
<td>None</td>
</tr>
<tr>
<td>W4</td>
<td>None</td>
</tr>
<tr>
<td>W5</td>
<td>None</td>
</tr>
</tbody>
</table>

Load Cases

<table>
<thead>
<tr>
<th>Load Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>( 1)D1</td>
</tr>
<tr>
<td>(17)Lr</td>
</tr>
<tr>
<td>(28)W1</td>
</tr>
<tr>
<td>(29)W2</td>
</tr>
<tr>
<td>(30)W3</td>
</tr>
<tr>
<td>(31)W4</td>
</tr>
<tr>
<td>(32)W5</td>
</tr>
<tr>
<td>(39)1a - 1.4D1</td>
</tr>
<tr>
<td>(40)2a - 1.2D1±0.5Lr</td>
</tr>
<tr>
<td>(41)2b - 1.2D1±0.5S1</td>
</tr>
<tr>
<td>(42)3a - 1.2D1±1.6Lr±0.5W1</td>
</tr>
<tr>
<td>(43)3b - 1.2D1±1.6Lr±0.5W2</td>
</tr>
<tr>
<td>(44)3c - 1.2D1±1.6Lr±0.5W3</td>
</tr>
<tr>
<td>(45)3d - 1.2D1±1.6Lr±0.5W4</td>
</tr>
<tr>
<td>(46)3e - 1.2D1±1.6Lr±0.5W5</td>
</tr>
<tr>
<td>(47)3f - 1.2D1±0.5W1</td>
</tr>
<tr>
<td>(48)3g - 1.2D1±0.5W2</td>
</tr>
<tr>
<td>(49)3h - 1.2D1±0.5W3</td>
</tr>
<tr>
<td>(50)3i - 1.2D1±0.5W4</td>
</tr>
<tr>
<td>(51)3j - 1.2D1±0.5W5</td>
</tr>
<tr>
<td>(52)4f - 1.2D1±1.0W1</td>
</tr>
<tr>
<td>(53)4a - 1.2D1±0.5Lr±1.0W1</td>
</tr>
<tr>
<td>(54)4b - 1.2D1±0.5Lr±1.0W2</td>
</tr>
<tr>
<td>(55)4c - 1.2D1±0.5Lr±1.0W3</td>
</tr>
<tr>
<td>(56)4d - 1.2D1±0.5Lr±1.0W4</td>
</tr>
<tr>
<td>(57)4e - 1.2D1±0.5Lr±1.0W5</td>
</tr>
<tr>
<td>(58)4g - 1.2D1±1.0W2</td>
</tr>
<tr>
<td>(59)4h - 1.2D1±1.0W3</td>
</tr>
<tr>
<td>(60)4i - 1.2D1±1.0W4</td>
</tr>
<tr>
<td>(61)4j - 1.2D1±1.0W5</td>
</tr>
<tr>
<td>(62)6a - 0.9D1±1.0W1</td>
</tr>
<tr>
<td>(63)6b - 0.9D1±1.0W2</td>
</tr>
<tr>
<td>(64)6c - 0.9D1±1.0W3</td>
</tr>
<tr>
<td>(65)6d - 0.9D1±1.0W4</td>
</tr>
<tr>
<td>(66)6e - 0.9D1±1.0W5</td>
</tr>
</tbody>
</table>

Load Combination Summary

Factored Combination: 1a - 1.4D1
  Scale factor = 1.00
  Factor: Service Case
  1.40 x D1

Factored Combination: 2a - 1.2D1±0.5Lr
  Scale factor = 1.00
  Factor: Service Case
  1.20 x D1
  0.50 x Lr

Factored Combination: 2b - 1.2D1±0.5S1
Project: Future Trac-30 ft

Scale factor = 1.00
Factor : Service Case
1.20 x D1

Factored Combination: 3a - 1.2D1±1.6Lr±0.5W1
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.60 x Lr
0.50 x W1

Factored Combination: 3b - 1.2D1±1.6Lr±0.5W2
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.60 x Lr
0.50 x W2

Factored Combination: 3c - 1.2D1±1.6Lr±0.5W3
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.60 x Lr
0.50 x W3

Factored Combination: 3d - 1.2D1±1.6Lr±0.5W4
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.60 x Lr
0.50 x W4

Factored Combination: 3e - 1.2D1±1.6Lr±0.5W5
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.60 x Lr
0.50 x W5

Factored Combination: 3f - 1.2D1±0.5W1
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x W1

Factored Combination: 3g - 1.2D1±0.5W2
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x W2

Factored Combination: 3h - 1.2D1±0.5W3
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x W3

Factored Combination: 3i - 1.2D1±0.5W4
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x W4

Factored Combination: 3j - 1.2D1±0.5W5
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x W5

Factored Combination: 4f - 1.2D1±1.0W1
Scale factor = 1.00
Factor : Service Case
1.20 x D1
Project: Future Trac-30 ft

1.00 x W1
Factored Combination: 4a - 1.2D1±0.5Lr±1.0W1
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x Lr
1.00 x W1

Factored Combination: 4b - 1.2D1±0.5Lr±1.0W2
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x Lr
1.00 x W2

Factored Combination: 4c - 1.2D1±0.5Lr±1.0W3
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x Lr
1.00 x W3

Factored Combination: 4d - 1.2D1±0.5Lr±1.0W4
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x Lr
1.00 x W4

Factored Combination: 4e - 1.2D1±0.5Lr±1.0W5
Scale factor = 1.00
Factor : Service Case
1.20 x D1
0.50 x Lr
1.00 x W5

Factored Combination: 4g - 1.2D1±1.0W2
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.00 x W2

Factored Combination: 4h - 1.2D1±1.0W3
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.00 x W3

Factored Combination: 4i - 1.2D1±1.0W4
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.00 x W4

Factored Combination: 4j - 1.2D1±1.0W5
Scale factor = 1.00
Factor : Service Case
1.20 x D1
1.00 x W5

Factored Combination: 6a - 0.9D1±1.0W1
Scale factor = 1.00
Factor : Service Case
0.90 x D1
1.00 x W1

Factored Combination: 6b - 0.9D1±1.0W2
Scale factor = 1.00
Factor : Service Case
0.90 x D1
1.00 x W2

Factored Combination: 6c - 0.9D1±1.0W3
Project: Future Trac-30 ft

Scale factor = 1.00
Factor : Service Case
0.90 x D1
1.00 x W3
Factored Combination: 6d - 0.9D1±1.0W4
Scale factor = 1.00
Factor : Service Case
0.90 x D1
1.00 x W4
Factored Combination: 6e - 0.9D1±1.0W5
Scale factor = 1.00
Factor : Service Case
0.90 x D1
1.00 x W5
APPENDIX B

COMPUTER MODEL OUTPUT
Load Cases

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Member Extreme Results

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### Project: Future Trac 30 ft

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