Cold-formed steel beam-column applications in residential and commercial midrise buildings

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Cold-formed steel beam-column applications in residential and commercial midrise buildings and design method comparisons

Abstract

The objective of this report is to summarize the use of beam-columns in common cold-formed steel applications. The cold-formed systems emphasized are trusses and load bearing framing as typically used in residential and commercial mid-rise cold-formed steel buildings and secondary cold-formed steel systems (purlins, girts, etc.) as typically used in metal building systems. Case studies are employed to illustrate typical scenarios. The results are being used to inform the selected sections and testing to be performed as part of a larger AISI and MBMA funded project on direct strength prediction of cold-formed steel beam-columns.

1. Introduction

Residential and commercial cold-formed steel buildings comprise of beam-column components in the majority of applications. The Direct Strength Method study for beam-columns greatly benefits from the survey of these applications in the cold-formed steel industry. In order to assess the current design approaches and increase the industry impact from the implementation of a direct strength beam-column design, a survey of some cold-formed steel applications is undertaken. The objectives of the industry survey centered on understanding

- Typical beam-column design
- Critical load cases and members in the structural system under combined loading
- Sections commonly used as beam-columns
- Unusual sections (particularly un-symmetric sections, e.g., eave strut) used as beam-columns
- End boundary conditions
- Bracing details and connection practices for beam-columns
- Current limitations, needs, areas of opportunity for more efficient beam-column design
- Range of members (shapes, range of thicknesses and dimensions for numerical testing)
- Design examples, current analysis and design approaches, assumptions, context and procedures
- Sections for experimental testing

2. Cold-formed steel beam-column industry applications

Cold-formed steel beam-columns are used in various applications in commercial and mid-rise buildings. From truss to framing they serve an important role in the cold-formed steel industry applications. To aid in understanding current design practice and the development of a new direct strength method for combined loading, industry survey on beam-column applications has been undertaken. The categories chosen for the survey
include those in the framing, truss and metal building industries (Figure 1). A brief summary of the survey of commonly used sections and design details in beam-column industry applications is presented in this section.

Figure 1 Beam-column applications in a) framing-CFS NEES-DEVCO b) truss-NUTRUSS c) metal building-BUTLER

2.1 Truss

Common truss chord industry shapes include those by TrusSteel, Nuconsteel and SSMA C-studs. Examples of the industry truss sections by Nucon and Alpine are shown in Figure 2. Comprehensive sections and their properties are listed in Appendix A.1.

- NUTRUSS sections:
  20TC-(27,33,43); 30TC-(27,33,43,54); 250NTC162-(33,43,54); 350NTC162-(33,43,54); 450NTC162-(33,43,54); 550NTC162-(33,43,54); 250NTCG162-(33,43,54); 350NTCG162-(33,43,54); 450NTCG162-(33,43,54); 550NTCG162-(33,43,54)

- ALPINE/TRUSSTEEL sections:
  (28/33/43) TSC275;(28/33/43/54/68/97) TSC400
2.2 Framing

Common framing industry shapes include those by ADTEK, DEVCO (SSMA sections) and NUCON. Examples of NUCON proprietary framing sections are shown in Figure 3. Comprehensive sections and their properties are listed in Appendix A.2.

- **SSMA Sections by ADTEK, DEVCO**

  SSMA Channel sections: In wall studs commonly used sections include:
  - 362S162-(33,43,54,68,97); 362S200-(33,43,54,68,97); 600S162-(33,43,54,68,97);
  - 800S200-(33,43,54,68,97); 800S250-(43,54,68,97). In roof-rafter: 6-8-12 in. deep SSMA sections are commonly used.
ADTEK DESIGN PRACTICES
Combined axial and bending is common in the framing practice. Even in simple retail storefronts small areas of load bearing walls support high roof feature trusses. In fully load bearing buildings built-up studs are sometimes used to support the end of structural steel beams.

- Unusual sections used as beam columns
  - Stud-framing side: symmetric on the major axis; proprietary truss members can be unsymmetric
- End boundary conditions / connection practices for beam-columns
  - Wall studs: bottom track screwed on each side (same on top, joist laps on side), track preventing rotation; no clips (extra hardware) unless considering blast
- Bracing details
  - Industry rule of thumb: bracing studs on 4ft on center; non-load bearing (5-6 ft.)
- Loading
  - Only wind load in non-load bearing framing on exterior
  - Combined lateral wind and vertical gravity loads if exterior load bearing
  - Combined gravity loads with the 5 PSF interior lateral load for interior load bearing
- Current limitations, needs, areas of opportunity for more efficient beam-column design
  - More efficiency in multistory load bearing design is needed if the industry is to compete against structural steel and wood.

Instead of SSMA sections, NUCON uses mostly proprietary sections. Complete dimension ranges of these sections are given in Appendix A.2. Those that are commonly found in beam-column applications are 350NF150-(21,27,33,43), 550NF150-(21,27,33,43) and 600NF150-(21,27,33,43).

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Figure 3 NUCON beam-column sections used in framing a) 600NF150 b) 550NF150 c) 350NF150

2.3 Metal building
Metal building survey included BUTLER and MESCO. Common metal building shapes by BUTLER and MESCO are shown in Figure 4. Comprehensive sections and their properties are listed in Appendix A.3.
- **BUTLER SECTIONS**
  7C-(060,073,098,113), 8.5C-(060,068,073,079,088,098,113),
  10C(060,068,073,079,088,098,113), 11.5C-(060,073,088,113), 7Z-
  (060,073,098,113), 8.5Z-(060,068,073,079,088,098,113), 10Z-
  (060,068,073,079,088)
- **MESCO SECTIONS**: 8,10,12 in. web, 3.5 in. flange C sections and 8 or
  10 in. deep Z sections

**BUTLER/MESCO DESIGN PRACTICES**

- Unusual sections
  Eave strut used between wall and roof
- End boundary conditions / connection practices for beam-columns
  - Simple: end wall posts, eave struts and cee’s
  - Continuous: overlapping girts, purlins and struts (zee’s)
- Bracing details / connection practices for beam-columns
  Round rod 3/8 to 1-1/2
- Load range
  Wind: Basic wind pressure: Minimum 90 mph Exposure B=12.35 psf; Maximum
  140 mph Exposure D=46.19 psf. 10-50 psf is generally the range (Average 15 psf
  covers 75% or more of the U.S.)
- Load cases, critical load combinations
  - Depends on member locations (corner (higher) or interior (lower)), type of
    wall posts or purlins or on strut lines
  - Depends on whether the dominant load is wind load or hurricane

![Diagram](image)
Figure 4 Beam-column sections used in metal buildings a) MESCO b) BUTLER
3. Comparison of efficiency of sections among current industry beam-column use

This section examines efficiency of industry sections in various applications. In order to study the efficiency of sections used in industry applications a plot of nominal compression and bending capacities normalized with area is given in Figure 3. Sections considered in the plot include SSMA Stud C-sections with lips and no lips, SSMA Track C-sections with no lips, ADTEK sections (part of SSMA Stud C-sections with lips) and NUCON’s NUTRUSS Hat sections used in truss applications. For a fixed angle (direction) as measured from, say the Mn/A axis, the larger the radial distance from the origin the more efficient that section is (either as a column, beam or beam-column) in comparison with shorter radial distance along that line. Hence those sections that form the outer boundary represent the efficient group of sections under the different applications.

![Figure 5 Efficiency of selected industry sections in current applications](image)

4. Design examples in beam-column applications

Summary of design examples in framing, truss and metal building beam-column applications are presented in this section. Detailed designs for combined loading of beam-column applications are given in Appendix B.

4.1 Framing

A typical wall stud design approach for beam-columns in framing (NUCON) is given below. Six load combinations are considered. Using section 550NF150-33, load
Combination 3 (D+W) and load combination 4 (D+0.75(Lr or S)+0.75W) result in combined interaction values of 0.86 and 0.816 respectively.

Wall Stud Design Example

**Design Assumptions**
- Stud Height = 9 ft
- Wall Tributary Width = 5 ft
- Stud Spacing = 5 ft
- Wall Deflection Criteria = L/180

**Design Loads**
- Roof Live Load = 20 psf
- Roof Dead Load = 3 psf
- Exposure Factor (C_e) = 1.0 Partially Exposed
- Thermal Factor (C_t) = 1.2 Unheated Structure
- Snow Imp. Factor = 0.8 per Table 7-4
- Ground Snow Load = 30 psf
- Design snow load = 0.7 C_e C_t P
- Roof Snow Load = 0.7 * 1.0 * 1.2 * 0.8 (30 psf) = 20.16 psf

Per ASCE 7 - 05
- Wind Speed = 100 mph, Exposure = E
- Wind Imp. Factor (I_w) = 0.87 per Table 6-1
- K_s = 0.7 Velocity pressure exposure coefficient defined in Section 6.5.6.8 & Table 6-3
- K_d = 0.85 Wind directionality factor defined in Section 6.5.4.4 & Table 6-4
- K_a = 1 Topographic factor defined in Section 6.5.7.2 & Figure 6-4

**Velocity Pressure**

\[
\alpha_v = 0.00256 K_s K_a K_v^{2/3} = 0.00256 \times 0.7 \times 1 \times 0.85 \times (100)^{2/3} \times 0.87
\]

Wall OC_{w} = -0.994 External pressure coefficient given in Figures 6-11A

\[
OC_{w} = -0.18 \text{ Internal pressure coefficient given in Figure 6-5}
\]

**Wind Pressure**

\[
P = \alpha_v [(OC_{w}) - (OC_{w})]
\]

Wall OC_{w} = -13.252 - 0.994 - (-0.18) = -15.56 psf

**Load Combinations**

1. D No lateral
2. D + (Lr or S) No lateral
3. D + W Combined Bending and Axial
4. D + 0.75(Lr or S) + 0.75W Combined Bending and Axial
5. W Wind Bending Only
6. 0.7W used to check Deflections

Use 550NF150-33 Section

The below section properties and allowable capacities of this section are calculated using CFS computer program with bracing at stud mid-height.

**Allowable Moment (M_{a})** = 0.751 ft-kips

**Allowable Axial (P_{a})** = 2.371 kips

**moment of inertia (I)** = 1.299 in.⁴

**Affective Area (A_{a})** = 0.301 in.²
Load Combination 3: Dead Load + Wind Load

Dead Load (P) = 3 psf (5 ft x 5 ft)
   = 0.075 kips

Wind Load = 15.56 psf (5 ft)
   = 77.8 plf

Wind Bending (Mx) = wL^2/8
   = (77.8 plf)(8 ft)^2/8
   = 622.4 ft-lb
   = 0.622 ft-kips

Per AISI Section C5.2 Combined compressive Axial Load and Bending

\[ [\Omega_c, P/P_n] + [\Omega_b, M/M_n] \leq 1.0 \quad \text{Eq. C5.2.1-1} \]

\[ [\Omega_c, P/P_n] + [\Omega_b, M/M_n] \leq 1.0 \quad \text{Eq. C5.2.1-2} \]

When \( \Omega_c, P/P_n \leq 0.15 \) the following equation shall be permitted to be used in lieu of the above equations:

\[ [\Omega_c, P/P_n] + [\Omega_b, M/M_n] \leq 1.0 \quad \text{Eq. C5.2.1-3} \]

\[ P_a = P_c / \Omega_c \quad \text{>>>} \quad \Omega_c / P_n = 1 / P_a \]
\[ M_a = M_{c0} / \Omega_b \quad \text{>>>} \quad \Omega_b / M_{c0} = 1 / M_a \]

\[ P_{c0} = F_y * A_e \]
   = 50 ksi (0.301 in^2)
   = 15.05 kips

\[ \Omega_c, P/P_n = 0.075/2.371 \]
   = 0.03 \leq 0.15 used Eq. C5.2.1-3

\[ [\Omega_c, P/P_n] + [\Omega_b, M/M_n] = [0.075/2.371] + [0.622/0.751] \]
   = 0.86 \leq 1.00, Therefore the section is adequate

Load Combination 4: D + 0.75(Lr or S) + 0.75W

\[ D + 0.75S = [3 \text{ psf} + 0.75(20.16 \text{ psf})] (5 \text{ ft} x 5 \text{ ft}) \]
   = 0.453 kips

\[ 0.75W = [0.75*15.56 \text{ psf}] (5 \text{ ft}) \]
   = 58.35 plf

Wind Bending (Mx) = wL^2/8
   = (58.35 plf)(8 ft)^2/8
   = 466.8 ft-lb
   = 0.467 ft-kips
Combined loading critical member design results for CFS-NEES (DEVCO) at the first and second level framed openings are presented next. Combined interaction values observed are 1.00 and 0.90 at the second level and first level framed openings respectively. Sections used at the second level are (2) 600S162-33 back-to-back C studs; a single 600S200-68 single C stud is used at the first level. Table 1 gives a summary of framing beam-column applications (DEVCO (CFS-NEES), ADTEK and NUCON), design load combinations and traditional beam-column design interaction values.
2007 NASPEC

Project: CFS-NEES
Model: 2nd Level Framed Openings - Jams (Long Sides)

<table>
<thead>
<tr>
<th>Point Loads</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load (lb)</td>
<td>196</td>
<td>196</td>
<td>476</td>
<td>-476</td>
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<tr>
<td>X-Dist. (ft)</td>
<td>6.50</td>
<td>2.50</td>
<td>8.00</td>
<td>9.00</td>
</tr>
</tbody>
</table>

Section: (2) 600S102-33 Back-to-Back C Stud (X-X Axis)
Fy = 33.0 ksi
V_a = 1276.1 lb
Maxo = 1901.3 ft-lb
Moment of Inertia, I = 3.566 in^4

Combined Bending and Axial Load

<table>
<thead>
<tr>
<th>Span</th>
<th>Axial Ld (lb)</th>
<th>Bracing (in)</th>
<th>Max K-phi (in-lb/ft)</th>
<th>Lm Brac (in)</th>
<th>Allow Ld (lb)</th>
<th>P/Pa</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Span</td>
<td>1912.0 (c)</td>
<td>Mid-Pl</td>
<td>79</td>
<td>108.0</td>
<td>5256.1 (c)</td>
<td>0.36</td>
<td>1.00</td>
</tr>
</tbody>
</table>

2007 NASPEC

Project: CFS-NEES
Model: 1st Floor Openings - Jams Case 1 ALT

<table>
<thead>
<tr>
<th>Point Loads</th>
<th>P1</th>
<th>P2</th>
<th>P3</th>
<th>P4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load (lb)</td>
<td>180</td>
<td>210</td>
<td>814</td>
<td>-814</td>
</tr>
<tr>
<td>X-Dist. (ft)</td>
<td>7.00</td>
<td>3.00</td>
<td>8.00</td>
<td>9.00</td>
</tr>
</tbody>
</table>

Section: 600S200-68 Single C Stud (X-X Axis)
Fy = 50.0 ksi
V_a = 5350.3 lb
Maxo = 3544.4 ft-lb
Moment of Inertia, I = 4.101 in^4

Loads have not been modified for strength checks
Loads have not been modified for deflection calculations

Combined Bending and Axial Load

<table>
<thead>
<tr>
<th>Span</th>
<th>Axial Ld (lb)</th>
<th>Bracing (in)</th>
<th>Max K-phi (in-lb/ft)</th>
<th>Lm Brac (in)</th>
<th>Allow Ld (lb)</th>
<th>P/Pa</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center Span</td>
<td>5036.0 (c)</td>
<td>45.0</td>
<td>46.0</td>
<td>66</td>
<td>108.0</td>
<td>0.51</td>
<td>0.90</td>
</tr>
</tbody>
</table>
Table 1 Summary of framing beam-column applications

<table>
<thead>
<tr>
<th>Framing Member</th>
<th>Location</th>
<th>Fy (ksi)</th>
<th>L (ft)</th>
<th>W (psf)</th>
<th>P (lb)</th>
<th>Mmax (ft-lb)</th>
<th>Fa (lb)</th>
<th>Ma (lb-ft)</th>
<th>Interaction</th>
<th>Load Combination</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEVCO 600S162-54</td>
<td>Lower level</td>
<td>50</td>
<td>9</td>
<td>15</td>
<td>2576</td>
<td>536</td>
<td>5098</td>
<td>1947</td>
<td>0.887</td>
<td>D+H+L</td>
</tr>
<tr>
<td>ADTEK 600S200-54</td>
<td>Exterior bearing wall-3rd fl</td>
<td>50</td>
<td>11.5</td>
<td>22</td>
<td>4000</td>
<td>475.4</td>
<td>7093</td>
<td>2326.6</td>
<td>0.81</td>
<td>D+H+L+W</td>
</tr>
<tr>
<td>600S250-68</td>
<td>Exterior bearing wall-2nd fl</td>
<td>50</td>
<td>10.42</td>
<td>22</td>
<td>8300</td>
<td>393.6</td>
<td>10711.2</td>
<td>3251.2</td>
<td>0.92</td>
<td>D+H+L+W</td>
</tr>
<tr>
<td>600S250-97</td>
<td>Exterior bearing wall-1st fl</td>
<td>50</td>
<td>10.42</td>
<td>22</td>
<td>2600</td>
<td>393.6</td>
<td>17891.1</td>
<td>4821.3</td>
<td>0.83</td>
<td>D+H+L+W</td>
</tr>
<tr>
<td>NUCON 550NF150-43</td>
<td>1st exterior end wall</td>
<td>50</td>
<td>10</td>
<td>25.17</td>
<td>1840</td>
<td>629</td>
<td>3540</td>
<td>1068</td>
<td>0.92</td>
<td>D+H+0.75L+0.75W</td>
</tr>
<tr>
<td>550NF150-43</td>
<td>1st exterior wall</td>
<td>50</td>
<td>10</td>
<td>25.17</td>
<td>2383</td>
<td>418</td>
<td>3540</td>
<td>1068</td>
<td>0.92</td>
<td>D+H+0.75L+0.75W</td>
</tr>
<tr>
<td>550NF150-43</td>
<td>1st interior wall</td>
<td>50</td>
<td>10</td>
<td>5</td>
<td>2329</td>
<td>83</td>
<td>2592</td>
<td>588</td>
<td>0.9</td>
<td>D+H+0.75L+0.75W</td>
</tr>
<tr>
<td>550NF150-43</td>
<td>1st interior wall</td>
<td>50</td>
<td>10</td>
<td>5</td>
<td>2329</td>
<td>83</td>
<td>2592</td>
<td>588</td>
<td>0.9</td>
<td>D+H+0.75L+0.75W</td>
</tr>
</tbody>
</table>

4.2 Truss

Truss design example for an ALPINE truss is shown in Figure 6. Critical chord member #6 (section 54TSC4.00) is selected for demonstrating the beam-column design application for trusses. The combined stress indices for positive bending and negative bending are 0.81 and 0.97 respectively.
Figure 6 TrusSteel truss design example a) truss b) loading case considered c) critical member
TrusSteel Chord Compression + Flexure

Calculate combined compression + flexure CSI for positive and negative moment:

**Positive Moment:**

\[ \frac{P}{P_a} + \frac{C_{mx} M_x}{M_{ax} \alpha_x} \leq 1.0 = 0.80890085 \]

Where \( \Omega_c = 1.80 \)

Combined Compression + Flexure CSI:

\[ P \text{ (at max pos M) / } P_a = 0.38856899 \]

For \( P \text{ (at max M) / } P_a > 0.15: \)

\[ \left( \frac{P}{P_a} \right) + \left( \frac{C_{mx} M_x}{M_{ax} \alpha_x} \right) \leq 1.0 = 0.80890085 \]

\[ C_{mx} = 0.85 \]

\[ \left( \frac{P}{P_a} \right) + \left( \frac{M_x}{M_{ax}} \right) \leq 1.0 = 0.72696963 \]

Where: \( A_e \times F_y = 0.63216951 \text{ in}^2 \)

(Reference page CF3 for calculation of \( A_e \times F_y \))

\[ P_{ao} = \frac{(A_e \times F_y) \times F_y \times Z_y}{\Omega_c} = 19316.2905 \]

For \( P \text{ (at max M) / } P_a \leq 0.15: \)

\[ \left( \frac{P}{P_a} \right) + \left( \frac{M_x}{M_{ax}} \right) \leq 1.0 = \text{N/A} \]

\[ CSI = 0.808900853 \text{ for positive moment} \]

**Negative Moment:**

\[ \frac{P}{P_a} + \frac{C_{mx} M_x}{M_{ax} \alpha_x} \leq 1.0 = 0.98313789 \]

Where \( \Omega_c = 1.80 \)

Combined Compression + Flexure CSI:

\[ P \text{ (at max neg M) / } P_a = 0.41064512 \]

For \( P \text{ (at max M) / } P_a > 0.15: \)

\[ \left( \frac{P}{P_a} \right) + \left( \frac{C_{mx} M_x}{M_{ax} \alpha_x} \right) \leq 1.0 = 0.9494788 \]

\[ C_{mx} = 0.85 \]

\[ \left( \frac{P}{P_a} \right) + \left( \frac{M_x}{M_{ax}} \right) \leq 1.0 = 0.96635479 \]

Where: \( A_e \times F_y = 0.63216951 \text{ in}^2 \)

(Reference page CF3 for calculation of \( A_e \times F_y \))

\[ P_{ao} = \frac{(A_e \times F_y) \times F_y \times Z_y}{\Omega_c} = 19316.2905 \]

For \( P \text{ (at max M) / } P_a \leq 0.15: \)

\[ \left( \frac{P}{P_a} \right) + \left( \frac{M_x}{M_{ax}} \right) \leq 1.0 = \text{N/A} \]

\[ CSI = 0.966354786 \text{ for negative moment} \]

Negative moment controls

**Compression + Flexure CSI** = 0.96635479
4.3 Metal building
A typical CFS beam-column design example in secondary members in a metal building (BUTLER) shown in Figure 7a is presented. For the loading case shown in Figure 7b, the critical member is an 8.5in Eave strut shown in Figure 7c that sustains a combined stress ratio of 0.94. Design details can be found in Appendix B3.

Rafter Loading Example
- Code = 2006 IBC
- Occupancy = Standard
- Roof Live Load = 20 psf Reducible
- Collateral Gravity = 5 psf (Projected) - Collateral Uplift = 2 psf
- Ground Snow Load = 30 psf (with system Defaults)
- Wind Speed = 100 mph, Exp D Enclosed
- Seismic - Seismic Design Base Shear Coefficient for Exterior Walls = 0.22, S1 = 11 (with system Defaults)

Concrete:
- Wall = B3
- Roof = B3
Figure 7 Butler metal building design example a) metal building b) loading case considered c) critical member
5. Conclusions

This report summarizes examples of current industry practices in cold-formed steel applications, and examines efficiency of sections used in beam-column applications. Selected critical loads are presented to aid in decision making of test matrix development. This will serve in the comparison of the new Direct Strength Method implementation with traditional beam-column design and identify critical members to investigate the potential development of an efficient beam-column direct design.
APPENDIX
A.1 TRUSS CROSS-SECTIONS
A.1.1 NUTRUSS
Figure 1
ALPINE TRUSSTEEL SECTION - SERIES 1

Figure 2
ALPINE TRUSSTEEL SECTION - SERIES 2

Figure 3
ALPINE TRUSSTEEL SPLICE SECTION - SERIES 3

Figure 4
ALPINE TRUSSTEEL SPLICE SECTION - SERIES 4

Notes:
1. All dimensions indicated in Figures 1 to 4 are in inches.
2. 28, 33, 43 and 54 denote the uncoated minimum steel thickness in thousands of an inch, as delivered to the job site.
<table>
<thead>
<tr>
<th>SECTION NAME</th>
<th>T</th>
<th>WEIGHT</th>
<th>GROSS SECTION PROPERTIES</th>
<th>EFFECTIVE SECTION PROPERTIES</th>
<th>TORSIONAL SECTION PROPERTIES</th>
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<tbody>
<tr>
<td></td>
<td>in</td>
<td>lbs/ft</td>
<td>A_x in^2</td>
<td>A_r in^2</td>
<td>x_e in</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>l_x in^4</td>
<td>l_r in^4</td>
<td>y_e in</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>r_x in</td>
<td>r_r in</td>
<td>J_{xx} in^4</td>
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<td></td>
<td>S_x in^3</td>
<td>S_r in^3</td>
<td>C_x in</td>
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<td></td>
<td></td>
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<tr>
<td>21TS/2C.75</td>
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<tr>
<td>33TS/2C.75</td>
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<tr>
<td>43TS/4C.00</td>
<td>0.0451</td>
<td>1.93</td>
<td>0.5763</td>
<td>1.1902</td>
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<td>0.5763</td>
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<td>54TS/4C.00</td>
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<td>2.5X4.00-5/8X3/4 SI G60</td>
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<td></td>
<td>0.7022</td>
<td>1.4660</td>
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<tr>
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<td>0.75</td>
<td>0.2193</td>
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<td></td>
<td>0.2193</td>
<td>0.1368</td>
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<tr>
<td>43TS/5C.25</td>
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<td></td>
<td></td>
<td>0.5181</td>
<td>1.0399</td>
<td>1.0399</td>
</tr>
</tbody>
</table>

**NOTE:** Effective moment of inertia and section moduli are equal to the gross values when stress in extreme fiber is at yield stress.

1 inch = 25.4 mm, 1 lb = 4.448 N

**Notes for Table 1:**
- T = Design steel thickness,
- A_x = Gross sectional area,
- l_x = Moment of inertia about x-axis,
- r_x = Gross radius of gyration about x-axis,
- A_r = Effective sectional area with stress in extreme fiber at yield stress (F_y),
- S_x = Minimum effective section modulus about major x-axis. +S_x is for positive bending (compression at the closed end of the section) and -S_x is for negative bending (compression at the open end of the section),
- x_e, y_e = Distance from shear center to centroid along the principal x and y axes,
- J = St. Venant torsional constant,
- C_p = Torsional warping constant of the cross section,
- r_e = Polar radius of gyration about shear center.
<table>
<thead>
<tr>
<th>SECTION NAME</th>
<th>ALLOWABLE VALUES</th>
</tr>
</thead>
<tbody>
<tr>
<td>TENSION Ta</td>
<td>COMPRESSION Pa</td>
</tr>
<tr>
<td>8283</td>
<td>8931</td>
</tr>
<tr>
<td>5787</td>
<td>5787</td>
</tr>
<tr>
<td>9530</td>
<td>8203</td>
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<tr>
<td>8807</td>
<td>6607</td>
</tr>
<tr>
<td>12083</td>
<td>10863</td>
</tr>
<tr>
<td>8354</td>
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</tr>
<tr>
<td>12568</td>
<td>8849</td>
</tr>
<tr>
<td>12768</td>
<td>11467</td>
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<tr>
<td>14486</td>
<td>10551</td>
</tr>
<tr>
<td>14645</td>
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</tr>
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<td>18722</td>
<td>14442</td>
</tr>
<tr>
<td>18718</td>
<td>18718</td>
</tr>
<tr>
<td>23272</td>
<td>18907</td>
</tr>
<tr>
<td>22577</td>
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<td>7238</td>
<td>4317</td>
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<td>3049</td>
<td>1408</td>
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<tr>
<td>17098</td>
<td>10307</td>
</tr>
<tr>
<td>9735</td>
<td>2295</td>
</tr>
</tbody>
</table>

Ta = Allowable axial tension assuming no screw holes
Pa = Allowable axial compression for a fully braced section
Ma = Allowable bending moment about major x-axis. If bending stress only exists with lateral buckling precluded. Positive moment causes compression at the closed end of the section and negative moment causes compression at the open end of the section.

NOTE: 1 lb = 4.448 N, 1 in-lb = 11.2985 N-mm
A.2 FRAMING CROSS-SECTIONS
NUCON FRAMING

600NF150

550NF150

350NF150

FIGURE 1—NUFRAME® STUD PROFILES
<table>
<thead>
<tr>
<th>Section</th>
<th>Design Thickness (in)</th>
<th>Full Properties</th>
<th>Torsional Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>350NF-105-21</td>
<td>0.0216</td>
<td>0.6489</td>
<td>0.31</td>
</tr>
<tr>
<td>350NF-105-27</td>
<td>0.0202</td>
<td>0.761</td>
<td>0.85</td>
</tr>
<tr>
<td>350NF-150-35</td>
<td>0.0346</td>
<td>0.222</td>
<td>0.70</td>
</tr>
<tr>
<td>350NF-150-43</td>
<td>0.0451</td>
<td>0.301</td>
<td>1.02</td>
</tr>
<tr>
<td>500NF-150-21</td>
<td>0.0216</td>
<td>0.192</td>
<td>0.85</td>
</tr>
<tr>
<td>500NF-150-27</td>
<td>0.0283</td>
<td>0.301</td>
<td>1.02</td>
</tr>
<tr>
<td>500NF-150-33</td>
<td>0.0346</td>
<td>0.280</td>
<td>1.33</td>
</tr>
<tr>
<td>600NF-170-21</td>
<td>0.0216</td>
<td>0.211</td>
<td>0.72</td>
</tr>
<tr>
<td>600NF-170-27</td>
<td>0.0283</td>
<td>0.282</td>
<td>0.92</td>
</tr>
<tr>
<td>600NF-170-33</td>
<td>0.0346</td>
<td>0.321</td>
<td>1.12</td>
</tr>
<tr>
<td>800NF-200-21</td>
<td>0.0216</td>
<td>0.345</td>
<td>1.40</td>
</tr>
</tbody>
</table>

1. Section properties comply with the 2001 AASHTO-NASPG with 2004 Supplement for recognition under 2008 IRC and 2006 IRC.
2. Full properties are based on the full, uncracked cross section of the members, away from wall punch-outs.
3. Web-height to thickness ratio exceeds 200 therefore, when used as flexural members, web stiffeners are required at all support points and concentrated loads per Section B1.2(k) of 2001 AASHTO-NASPG with 2004 Supplement.
4. Effective Moment of inertia about the X-X axis is used for deflection calculations.
5. Effective section properties of 33 ksi members are not permitted to be used with the 50 ksi or 70 ksi members and effective section properties of 50 ksi members are not permitted to be used with 70 ksi members.
6. Effective properties of all sections are based on punched sections.
7. Effective properties include the strength increase from cold work of forming per AASHTO-NASPG section A7.2 where applicable.
# A.3 METAL BUILDING CROSS-SECTIONS

## A.3.1 BUTLER

### Secondary

**Standard Shapes:**

<table>
<thead>
<tr>
<th>Shape</th>
<th>Size</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zee</td>
<td>7&quot;, 8 1/2&quot;, 10&quot;, 11 1/2&quot;</td>
<td>7&quot; Purlins not allowed with floating roofs.</td>
</tr>
<tr>
<td>Cee</td>
<td>7&quot;, 8 1/2&quot;, 10&quot;, 11 1/2&quot;</td>
<td>7&quot; Purlins not allowed with floating roofs.</td>
</tr>
<tr>
<td>Eave Purlin</td>
<td>7&quot;, 8 1/2&quot;, 10&quot;, 11 1/2&quot;</td>
<td>7&quot; Purlins not allowed with floating roofs.</td>
</tr>
<tr>
<td>Back to Back Cee (Galvanized)</td>
<td>8 1/2&quot;, 10&quot; 17 - 11 Gage</td>
<td></td>
</tr>
<tr>
<td>Face to Face Cee ( Primer)</td>
<td>8 1/2&quot;, 10&quot; 14 &amp; 11 Gage</td>
<td></td>
</tr>
<tr>
<td>Face to Back Cee (Primer)</td>
<td>8 1/2&quot;, 10&quot; 14 &amp; 11 Gage</td>
<td></td>
</tr>
<tr>
<td>Truss Purlin</td>
<td>2 1/2&quot; &amp; 8 1/2&quot; Seat Depth 1&quot;-8 1/2&quot; &amp; 2&quot;-5 1/2&quot; Depths</td>
<td>Truss Purlins must be used with floating roofs.</td>
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<tr>
<td>Bar Joist</td>
<td>Buyout Floating Roof (typical) 5&quot; Seat Depth SSJ 3 1/2&quot; Gage, 1/2&quot; Bolts LSJ 4&quot; Gage, 3/4&quot; Bolts Mezzanine (typical) 2 1/2&quot; Seat Depth</td>
<td>Notes: Bar Joist must be used with floating roofs.</td>
</tr>
<tr>
<td>Depth</td>
<td>Z Leg</td>
<td>C Leg</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>7&quot;</td>
<td>2 1/4&quot;</td>
<td>2 3/8&quot;</td>
</tr>
<tr>
<td>6 1/2&quot;</td>
<td>2 1/2&quot;</td>
<td>2 5/8&quot;</td>
</tr>
<tr>
<td>10&quot;</td>
<td>2 3/4&quot;</td>
<td>2 7/8&quot;</td>
</tr>
<tr>
<td>11 1/2&quot;</td>
<td>3 1/2&quot;</td>
<td>3 5/8&quot;</td>
</tr>
</tbody>
</table>

### 7" and 8 1/2"
- 17 Gage (0.060)
- 15 Gage (0.073)
- 12 Gage (0.098)
- 11 Gage (0.113)

### 10" and 11 1/2"
- 17 Gage (0.060)
- 16 Gage (0.073)
- 15 Gage (0.088)
- 14 Gage (0.098)
- 12 Gage (0.098)
- 11 Gage (0.113)
### A.3.2 MESCO

#### GENERAL DATA

<table>
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<tr>
<th>Section Name</th>
<th>DIMENSIONAL PROPERTIES</th>
<th>ALLOWABLES</th>
<th>AXIS X-X</th>
<th>AXIS Y-Y</th>
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<td>Gauge</td>
<td>Thickness (in)</td>
<td>Weight (lb/ft)</td>
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<td>16</td>
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</table>

**NOTES:**
- Section properties and allowable loads are computed in accordance with the 1984 edition of the AISC specifications with 1989 addendum.
- $L_x$ and $L_y$ are for deflection determinations.
- $S_x$ and $S_y$ are for bending.
- $F_y = 50,000$ PSI
- $F_u = 70,000$ PSI
B. BEAM-COLUMN DESIGN EXAMPLES IN INDUSTRY APPLICATIONS

B.1 TRUSS

MEMBER #5

MEMBER #6

TrusSteel®

CSI Calculator for TrusSteel Chord Members
TrusSteel Chord Compression

Determine $F_n$.

**Method A - C4.1 - For Sections Not Subject to Torsional or Torsional-Flexural Buckling**

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<th>Out of Plane</th>
<th>In Plane</th>
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<tbody>
<tr>
<td>$K_{x1}L_x$</td>
<td>$K_{x2}L_x$</td>
</tr>
<tr>
<td>$r_y$</td>
<td>$r_y$</td>
</tr>
<tr>
<td>$K_{y1}L_y$</td>
<td>$K_{y2}L_y$</td>
</tr>
<tr>
<td>$r_y$</td>
<td>$r_y$</td>
</tr>
</tbody>
</table>

$F_n = \frac{\pi^2E}{(KL/r)^2} = 107128.767 \text{ psi}$

**Method B - C4.2 - For Singly-Symmetric Sections Subject to Torsional or Torsional-Flexural Buckling**

$\sigma_x = \frac{1}{A} \left[ GJ + \frac{\pi^2EC_M}{(KL/r)^2} \right] = 392734.335 \text{ psi}$

$\sigma_{xy} = \frac{\pi^2E}{(KL/r)^2} = 2927730.95 \text{ psi}$

$\beta = 1 - \left( \frac{Y_x}{r_y} \right)^2 = 0.17100427$

$F_n = \frac{1}{2\beta} \left[ \sigma_{xy} + \sigma_x \right] - \sqrt{\left( \sigma_{xy} + \sigma_x \right)^2 - 4\beta\sigma_{xy}\sigma_x} = 352689.008 \text{ psi}$

Choose smallest $F_n$ from Method A and Method B:

$F_n = 107128.767 \text{ psi}$

$\lambda_c = \sqrt{\frac{F_n}{F_x}} = 0.71651996$

For $\lambda_c \leq 1.5$:

$F_n = \frac{0.658}{\lambda_c^2} \frac{\lambda_c^2}{F_x} Y_x Z_y$

$F_n = 44364.9206 \text{ psi}$

For $\lambda_c > 1.5$:

$F_n = \frac{0.877}{\lambda_c^2} \frac{\lambda_c^2}{F_x} Y_x Z_y$

$F_n = \text{N/A} \text{ psi}$

$F_n = 44364.9206 \text{ psi}$

$Ae = 0.65484499 \text{ in}^2$

See page P2 for calculation of $Ae$

$P_n = AeF_n = 29052.1461 \text{ lbs}$

$P_n = \frac{P_n}{\Omega_c}$

Where $\Omega_c = 1.80$

$P_c = 16140.0812 \text{ lbs}$

$P = 6627.84562 \text{ lbs}$

Compression Stress index $= \frac{P}{P_c} = 0.410645$
### TrusSteel Chord Compression

#### 2001 NASpec Design Criteria

<table>
<thead>
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<th>Chord</th>
<th>Determine $Ae @ Fn$ for</th>
<th>$54TSC4.00$</th>
<th>$F_n$ in ksi</th>
<th>$44.3649206$</th>
</tr>
</thead>
<tbody>
<tr>
<td>28TSC2.75</td>
<td>$0 &lt; F_n \leq 36$ ksi</td>
<td>$Ae = 0.24480 in^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$36 &lt; F_n \leq 48$ ksi</td>
<td>$Ae = -0.0004025(F_n)+0.25929$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$48 &lt; F_n \leq 57.75$ ksi</td>
<td>$Ae = -0.03408(ln(F_n))+0.37208$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>33TSC2.75</td>
<td>$0 &lt; F_n \leq 53$ ksi</td>
<td>$Ae = 0.028074 in^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$53 &lt; F_n \leq 59.4$ ksi</td>
<td>$Ae = -0.01875(ln(F_n))+0.35539$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>43TSC2.75</td>
<td>$0 &lt; F_n \leq 57.75$ ksi</td>
<td>$Ae = 0.36418 in^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>28TSC4.00</td>
<td>$0 &lt; F_n \leq 7$ ksi</td>
<td>$Ae = -0.38095 in^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$7 &lt; F_n \leq 51$ ksi</td>
<td>$Ae = 0.47076*F_n^{-0.001627}$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$51 &lt; F_n \leq 55$ ksi</td>
<td>$Ae = -0.05924(ln(F_n))+0.54196$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>33TSC4.00</td>
<td>$0 &lt; F_n \leq 10$ ksi</td>
<td>$Ae = 0.43880 in^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$10 &lt; F_n \leq 45$ ksi</td>
<td>$Ae = 0.56616*F_n^{-0.001622}$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>43TSC4.00</td>
<td>$0 &lt; F_n \leq 19$ ksi</td>
<td>$Ae = 0.5671 ln^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$19 &lt; F_n \leq 55$ ksi</td>
<td>$Ae = 0.7674*F_n^{-0.001623}$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>54TSC4.00</td>
<td>$0 &lt; F_n \leq 31$ ksi</td>
<td>$Ae = 0.7036 ln^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$31 &lt; F_n \leq 55$ ksi</td>
<td>$Ae = 0.101650*F_n^{-0.001700}$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>68TSC4.00</td>
<td>$0 &lt; F_n \leq 27$ ksi</td>
<td>$Ae = 0.8558 ln^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$27 &lt; F_n \leq 45$ ksi</td>
<td>$Ae = -0.0012099(F_n)+0.887854$</td>
<td>N/A</td>
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</tr>
<tr>
<td></td>
<td>$45 &lt; F_n \leq 50$ ksi</td>
<td>$Ae = -0.002508(F_n)+0.949024$</td>
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<tr>
<td>97TSC4.00</td>
<td>$0 &lt; F_n \leq 50$ ksi</td>
<td>$Ae = 1.1957 ln^2$</td>
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#### 2004 & 2007 NASpec Design Criteria

<table>
<thead>
<tr>
<th>Chord</th>
<th>Determine $Ae @ Fn$ for</th>
<th>$54TSC4.00$</th>
<th>$F_n$ in ksi</th>
<th>$44.3649206$</th>
</tr>
</thead>
<tbody>
<tr>
<td>28TSC2.75</td>
<td>$0 &lt; F_n \leq 35$ ksi</td>
<td>$Ae = 0.25101 ln^2$</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
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<td>$35 &lt; F_n \leq 50$ ksi</td>
<td>$Ae = -0.0004(F_n)+0.2658$</td>
<td>N/A</td>
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<tr>
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<td>$50 &lt; F_n \leq 57.75$ ksi</td>
<td>$Ae = -0.0006(F_n)+0.2749$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>33TSC2.75</td>
<td>$0 &lt; F_n \leq 49$ ksi</td>
<td>$Ae = 0.28879 ln^2$</td>
<td>N/A</td>
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<td>$49 &lt; F_n \leq 59.4$ ksi</td>
<td>$Ae = -0.0219(ln(F_n))+0.3735$</td>
<td>N/A</td>
<td>N/A</td>
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<td>$0 &lt; F_n \leq 57.75$ ksi</td>
<td>$Ae = 0.37159 ln^2$</td>
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<td>$0 &lt; F_n \leq 7$ ksi</td>
<td>$Ae = 0.38076 ln^2$</td>
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<td>$7 &lt; F_n \leq 55$ ksi</td>
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<td>$Ae = 0.43894 ln^2$</td>
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<td>$10 &lt; F_n \leq 55$ ksi</td>
<td>$Ae = -0.063(ln(F_n))-0.5917$</td>
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<td>$0 &lt; F_n \leq 18$ ksi</td>
<td>$Ae = 0.5673 ln^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$18 &lt; F_n \leq 55$ ksi</td>
<td>$Ae = 0.9276*F_n^{0.00164}$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>54TSC4.00</td>
<td>$0 &lt; F_n \leq 25$ ksi</td>
<td>$Ae = 0.70517 ln^2$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$25 &lt; F_n \leq 28$ ksi</td>
<td>$Ae = 0.8026*F_n^{-0.00161}$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>$28 &lt; F_n \leq 55$ ksi</td>
<td>$Ae = 1.2197*F_n^{0.00164}$</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>68TSC4.00</td>
<td>$0 &lt; F_n \leq 27$ ksi</td>
<td>$Ae = 0.85573 ln^2$</td>
<td>N/A</td>
<td>N/A</td>
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<td>$27 &lt; F_n \leq 45$ ksi</td>
<td>$Ae = -0.0012(F_n)+0.8883$</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td></td>
<td>$45 &lt; F_n \leq 50$ ksi</td>
<td>$Ae = -0.0025(F_n)+0.9508$</td>
<td>N/A</td>
<td>N/A</td>
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<tr>
<td>97TSC4.00</td>
<td>$0 &lt; F_n \leq 50$ ksi</td>
<td>$Ae = 1.1957 ln^2$</td>
<td>N/A</td>
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</table>

For 2007 NASpec effective area, $Ae = 0.65484499 ln^2$
TrusSteel®

TrusSteel Chord Flexure

Positive Moment:

\[ M_{ax} = \frac{S_{awp} \cdot F_y \cdot t}{\Omega_f} \rightarrow 38292.1 \text{ in}^*\text{lbs} \]

\[ M_{ax} = \frac{M_{ps}}{\Omega_f} \quad \text{where } \Omega_f = 1.67 \]

\[ M_{ps} = 2292.4012 \text{ in}^*\text{lbs} \]

\[ M_{ps} = 9224.3532 \text{ in}^*\text{lbs} \]

Positive Moment Stress Index, \( \frac{M_{ps}}{M_{ax}} = 0.402294 \)

Negative Moment:

Negative Moment Equations for TrusSteel Chord Members

<table>
<thead>
<tr>
<th>Member</th>
<th>Negative Moment Equations</th>
<th>( \frac{F_y \cdot S_{awp}}{\Omega_f} )</th>
<th>Min value</th>
<th>Max value</th>
</tr>
</thead>
<tbody>
<tr>
<td>28TSC2.75</td>
<td>( M_{aw} = (80774*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>35074.9258</td>
<td>N/A</td>
</tr>
<tr>
<td>33TSC2.75</td>
<td>( M_{aw} = (107268*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>45630.5511</td>
<td>N/A</td>
</tr>
<tr>
<td>43TSC2.75</td>
<td>( M_{aw} = (112714*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>47745.1519</td>
<td>N/A</td>
</tr>
<tr>
<td>28TSC4.00</td>
<td>( M_{aw} = (86390*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>32617.0986</td>
<td>N/A</td>
</tr>
<tr>
<td>33TSC4.00</td>
<td>( M_{aw} = (179438*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>38475.4533</td>
<td>N/A</td>
</tr>
<tr>
<td>43TSC4.00</td>
<td>( M_{aw} = (184848*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>38378.162</td>
<td>N/A</td>
</tr>
<tr>
<td>54TSC4.00</td>
<td>( M_{aw} = (101044*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>37602.0355</td>
<td>37602.0355</td>
</tr>
<tr>
<td>68TSC4.00</td>
<td>( M_{aw} = (101044*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>37602.0355</td>
<td>N/A</td>
</tr>
<tr>
<td>97TSC4.00</td>
<td>( M_{aw} = (101044*10^{0.0327}\text{rt}^3) \times S_{awp} \leq (F_y \cdot t) \times S_{awp} )</td>
<td>38292.1</td>
<td>37602.0355</td>
<td>N/A</td>
</tr>
</tbody>
</table>

\[ M_{ax} = \frac{M_{ax}}{\Omega_f} \quad \text{where } \Omega_f = 1.67 \]

\[ M_{ax} = 22516.1889 \text{ in}^*\text{lbs} \]

\[ M_{ax} = 14032.8255 \text{ in}^*\text{lbs} \]

Negative Moment Stress Index, \( \frac{M_{ax}}{M_{ax}} = 0.623233 \)

Flexure stress index is the larger of positive moment stress index and negative moment stress index:

\[ \text{Flexure Stress Index} = 0.623233 \]
TruSteel Chord Compression + Flexure

Determine $K_{xf}$ ($K_{ef}$ is called $K_{ef}$ in program)

- $E_m$ (psi) = 29500000 Modulus of Elasticity of member for which $K$ is being determined
- $E_a$ (psi) = 29500000 Modulus of Elasticity of member adjacent (to side "a") of member for which $K$ is being determined
- $E_b$ (psi) = 29500000 Modulus of Elasticity of member adjacent (to side "b") of member for which $K$ is being determined
- $I_m$ (in^4) = 1.466 Moment of inertia of member for which $K$ is being determined
- $I_a$ (in^4) = 1.466 Moment of inertia of member adjacent (to side "a") of member for which $K$ is being determined
- $I_b$ (in^4) = 1.466 Moment of inertia of member adjacent (to side "b") of member for which $K$ is being determined
- $L_m$ (in) = 100.2124 Length of member for which $K$ is being determined
- $L_a$ (in) = 3.93919 Length of adjacent member to side "a"
- $L_{na}$ (in) = 110.20356 Length of next adjacent member to side "a"
- $L_{ab}$ (in) = 1.42538 Length of adjacent member to side "b"
- $L_{nb}$ (in) = 0 Length of next adjacent member to side "b"

Choose largest for $L_a$:

| a. | 3.93919 |
| b. | 80.16992 |
| c. | 110.20356 |
| d. | 0 |
| e. | 0 |

Choose largest for $L_b$:

- a. 1.42538
- b. $80.16992$
- c. 0
- d. 0
- e. 1E+10

actual length of the adjacent member

0.8 x the length of the member under consideration

actual length of the next adjacent member

if no adjacent member, use 1E+10

if ($a_1 < b$), and there is no adjacent member, use 1E+10

$$Na = \frac{4 \times E_a \times I_a}{L_a} = 3.63735618$$

$$Nb = \frac{4 \times E_b \times I_b}{L_b} = 4.0085E-08$$

$$K_{ef} = \sqrt{\frac{(\pi^2 + 2Na) \times (\pi^2 + 2Nb)}{(\pi^2 + 4Na) \times (\pi^2 + 4Nb)}} = 0.83790714$$

$$K_{ef1} = 1.00$$

For Positive Moment:

$$P_{of} = \frac{\pi^2 E_i L_x}{(K_{ef} L_x)^2} = 60537.0173 \text{ lbs}$$

For Negative Moment:

$$P_{of} = \frac{\pi^2 E_i L_x}{(K_{ef1} L_x)^2} = 707510.764 \text{ lbs}$$

Where $L_x = 24.561865 \text{ inches}$
# TrusSteel Chord Compression + Flexure

## 2001 NASpec Design Criteria

<table>
<thead>
<tr>
<th>Determine $A_e$ @ $F_{y Zy}$ for</th>
<th>$S4TSC4.00$</th>
<th>$F_n$ in ksi = $F_{y Zy} = 55$</th>
</tr>
</thead>
<tbody>
<tr>
<td>28TSC2.75</td>
<td>$0 &lt; F_n \leq 36$ ksi</td>
<td>$A_e = A_g = 0.24480 \text{in}^2$</td>
</tr>
<tr>
<td>$36 &lt; F_n \leq 48$ ksi</td>
<td>$A_e = -0.0004025(F_n)+0.25929$</td>
<td>N/A</td>
</tr>
<tr>
<td>$48 &lt; F_n \leq 57.75$ ksi</td>
<td>$A_e = -0.03408(ln(F_n))+0.37208$</td>
<td>N/A</td>
</tr>
<tr>
<td>33TSC2.75</td>
<td>$0 &lt; F_n \leq 53$ ksi</td>
<td>$A_e = A_g = 0.28074 \text{in}^2$</td>
</tr>
<tr>
<td>$53 &lt; F_n \leq 59.4$ ksi</td>
<td>$A_e = -0.01875(ln(F_n))+0.35539$</td>
<td>N/A</td>
</tr>
<tr>
<td>43TSC2.75</td>
<td>$0 &lt; F_n \leq 57.75$ ksi</td>
<td>$A_e = A_g = 0.36418 \text{in}^2$</td>
</tr>
<tr>
<td>28TSC4.00</td>
<td>$0 &lt; F_n \leq 7$ ksi</td>
<td>$A_e = A_g = 0.38095 \text{in}^2$</td>
</tr>
<tr>
<td>$7 &lt; F_n \leq 51$ ksi</td>
<td>$A_e = 0.47076*F_n(-0.03667)$</td>
<td>N/A</td>
</tr>
<tr>
<td>$51 &lt; F_n \leq 55$ ksi</td>
<td>$A_e = -0.05924(ln(F_n))+0.54196$</td>
<td>N/A</td>
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<td>33TSC4.00</td>
<td>$0 &lt; F_n \leq 10$ ksi</td>
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<td>$0 &lt; F_n \leq 27$ ksi</td>
<td>$A_e = A_g = 0.8558 \text{in}^2$</td>
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<td>$A_e = -0.012099(F_n)+0.887854$</td>
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<td>$A_e = A_g = 0.85573 \text{in}^2$</td>
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For 2007 NASpec effective Area, $A_e = 0.63216951 \text{ in}^2$
### TrusSteel Chord Compression + Flexure

**Calculate combined compression + flexure CSI for positive and negative moment:**

#### Positive Moment:

\[
\alpha_x = 1 - \left( \frac{\Omega_x P}{P_{cr}} \right) = 0.81352297
\]

Where \( \Omega_x = 1.80 \)

**Combined Compression + Flexure CSI:**

\[
P (\text{at max pos M}) / Pa = 0.38856899
\]

For \( P(\text{at max M})/Pa > 0.15: \)

\[
\left( \frac{P}{P_a} \right) + \left( \frac{C_{mx} M_x}{M_{ax} \alpha_x} \right) \leq 1.0 = \frac{0.80890085}{C_{mx} = 0.85}
\]

Where: \( A_y @ F_y = 0.63216951 \text{ in}^2 \)

(Reference page CF3 for calculation of \( A_y @ F_y \))

\[
P_{ao} = \left( \frac{A_e @ F_y}{\Omega_C} \right) \times F_y \times Z_y = 19316.2905
\]

For \( P(\text{at max M})/Pa \leq 0.15: \)

\[
\left( \frac{P}{P_a} \right) + \left( \frac{M_x}{M_{ax}} \right) \leq 1.0 = \text{N/A}
\]

**CSI = 0.808900853 for positive moment**

#### Negative Moment:

\[
\alpha_x = 1 - \left( \frac{\Omega_x P}{P_{cr}} \right) = 0.98313789
\]

Where \( \Omega_x = 1.80 \)

**Combined Compression + Flexure CSI:**

\[
P (\text{at max neg M}) / Pa = 0.41064512
\]

For \( P(\text{at max M})/Pa > 0.15: \)

\[
\left( \frac{P}{P_a} \right) + \left( \frac{C_{mx} M_x}{M_{ax} \alpha_x} \right) \leq 1.0 = \frac{0.9494788}{C_{mx} = 0.85}
\]

Where: \( A_y @ F_y = 0.63216951 \text{ in}^2 \)

(Reference page CF3 for calculation of \( A_y @ F_y \))

\[
P_{ao} = \left( \frac{A_e @ F_y}{\Omega_C} \right) \times F_y \times Z_y = 19316.2905
\]

For \( P(\text{at max M})/Pa \leq 0.15: \)

\[
\left( \frac{P}{P_a} \right) + \left( \frac{M_x}{M_{ax}} \right) \leq 1.0 = \text{N/A}
\]

**CSI = 0.966354786 for negative moment**

**Negative moment controls**

**Compression + Flexure CSI = 0.96635479**
<table>
<thead>
<tr>
<th>Member # 6</th>
<th>Chord T1</th>
<th>54750.40 0.00 2.534 00.00-56-55821</th>
<th>(Results are per ply)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>n-rpts</td>
<td>Axial</td>
<td>Shear</td>
</tr>
<tr>
<td>(inches)</td>
<td>(lbs)</td>
<td>(lbs-in)</td>
<td>(lbs-in)</td>
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<tr>
<td>0.0000</td>
<td>662.75</td>
<td>465.95</td>
<td>0.0000</td>
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<tr>
<td>1.9045</td>
<td>661.36</td>
<td>369.89</td>
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<td>2.9990</td>
<td>660.68</td>
<td>361.72</td>
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<td>3.9945</td>
<td>659.96</td>
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<tr>
<td>4.9800</td>
<td>659.22</td>
<td>347.35</td>
<td>0.0000</td>
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<tr>
<td>5.9655</td>
<td>658.49</td>
<td>340.15</td>
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<tr>
<td>6.9510</td>
<td>657.76</td>
<td>333.04</td>
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<tr>
<td>7.9365</td>
<td>656.93</td>
<td>326.08</td>
<td>0.0000</td>
</tr>
<tr>
<td>8.9220</td>
<td>656.10</td>
<td>319.13</td>
<td>0.0000</td>
</tr>
<tr>
<td>9.9075</td>
<td>655.27</td>
<td>312.23</td>
<td>0.0000</td>
</tr>
<tr>
<td>10.8930</td>
<td>654.44</td>
<td>305.48</td>
<td>0.0000</td>
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<tr>
<td>11.8785</td>
<td>653.61</td>
<td>298.87</td>
<td>0.0000</td>
</tr>
<tr>
<td>12.8640</td>
<td>652.78</td>
<td>292.38</td>
<td>0.0000</td>
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<tr>
<td>13.8505</td>
<td>651.95</td>
<td>285.99</td>
<td>0.0000</td>
</tr>
<tr>
<td>14.8370</td>
<td>651.12</td>
<td>279.71</td>
<td>0.0000</td>
</tr>
<tr>
<td>15.8235</td>
<td>650.29</td>
<td>273.45</td>
<td>0.0000</td>
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<tr>
<td>16.8100</td>
<td>649.46</td>
<td>267.21</td>
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<tr>
<td>17.7965</td>
<td>648.62</td>
<td>261.00</td>
<td>0.0000</td>
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<td>18.7830</td>
<td>647.79</td>
<td>254.81</td>
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<tr>
<td>19.7695</td>
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<td>248.65</td>
<td>0.0000</td>
</tr>
<tr>
<td>20.7560</td>
<td>646.11</td>
<td>242.50</td>
<td>0.0000</td>
</tr>
<tr>
<td>21.7425</td>
<td>645.27</td>
<td>236.38</td>
<td>0.0000</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Load Case #1</th>
<th>STD.AUTO LOAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pc Mem</td>
<td>---Axial</td>
</tr>
<tr>
<td>T1</td>
<td>0.220</td>
</tr>
</tbody>
</table>
B.2 FRAMING

B.2.1 ADTEK
**PROJECT NAME**: EMU Residence Hall

**LOAD DETERMINATION**

**Code**: IBC 2003

**Wind Speed**: $V = 90$ mph

**Importance Factor**, $I_w = 1.0$

**Exposure** → B

**Mean Roof Ht.** = 42 ft.

**Least Building Width** = 72 ft.

**Corner Spacing**

$(i)(LOW) = 7.2$ ft.

$(i)(HIGH) = 17$ ft.

$\frac{i_j}{f_j} 7.2$ ft.

**Other Loads**:

* - Loads shown taken from Structural Notes - Loads are bigger than code generated [ ]

 Loading (see attached) - and therefore are controlling []

**Dead Loading**
- 0' Concrete plank - @ 116 psf - 77 psf
- 3' Gypsum Topping slab @ 14B psf - 56 psf
- Total Dead Load - 113 psf

**Live Loading**
- Corridor - 80 psf
- Study - 60 psf
- Lobby/Lounge - 100 psf
- Storage - 126 psf
- Private Rooms - 40 psf

**B.2.2 DEVCO**
B.3 METAL BUILDING

BUTLER

Secondary - Expanded Report

<table>
<thead>
<tr>
<th>Loads and Codes - Shape: Unit 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>City:</td>
</tr>
<tr>
<td>County:</td>
</tr>
<tr>
<td>Building Use: Standard Occupancy Structure</td>
</tr>
<tr>
<td>State: 05AISC - ASD</td>
</tr>
<tr>
<td>Cold Form: 07AISI - ASD</td>
</tr>
<tr>
<td>Rainfall: 3.00 inches per hour</td>
</tr>
</tbody>
</table>

Dead and Collateral Loads:
- Collateral Gravity: 0.00 psf
- Collateral Uplift: 0.00 psf

Wind Load:
- Wind Speed: 90.00 mph
- The Low Rise Method is Used
- Wind Exposure Factor: C (0.902)
- Wind Enclosure Type: Enclosed
- Wind Importance Factor: 1.000

Seismic Load:
- Mapped Spectral Response - Sa: 0.250 %g
- Seismic Performance / Design Category: B
- Seismic Importance: 1.000

Snow Load:
- Ground Snow Load: 10.00 psf
- Flat Roof Snow: 7.00 psf
- Design Snow Sloped: 7.00 psf
- Snow Exposure Category (Factor): 2 Partially Exposed (1.00)
- Snow Importance: 1.000
- Thermal Category (Factor): Heated (1.00)
- Ground / Roof Conversion: 0.70
- % Snow Used in Seismic: 0.00
- Seismic Snow Load: 0.00 psf
- Obstructed or Not Slippery Roof

Deflection Conditions:
- Frames are vertically supporting Metal Roof Purlins and Panels
- Frames are laterally supporting Metal Wall Girts and Panels
- Purlins are supporting Metal Roof Panels
- Girts are supporting Metal Wall Panels

Design Load Combinations - Partial

<table>
<thead>
<tr>
<th>No.</th>
<th>Origin</th>
<th>Factor</th>
<th>Application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 L</td>
<td>D + CG + L</td>
</tr>
<tr>
<td>2</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 S</td>
<td>D + CG + S</td>
</tr>
<tr>
<td>3</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 US1</td>
<td>D + CG + US1</td>
</tr>
<tr>
<td>4</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 *US1</td>
<td>D + CG + *US1</td>
</tr>
<tr>
<td>5</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 PP1</td>
<td>D + CG + PP1 (Span 1)</td>
</tr>
<tr>
<td>6</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 PH1</td>
<td>D + CG + PH1 (Span 1)</td>
</tr>
<tr>
<td>7</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 PP2</td>
<td>D + CG + PP2 (Span 2)</td>
</tr>
<tr>
<td>8</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 PH2</td>
<td>D + CG + PH2 (Span 2)</td>
</tr>
<tr>
<td>9</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 PP2</td>
<td>D + CG + PP2 (Span 3 and 4)</td>
</tr>
<tr>
<td>10</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 W1</td>
<td>D + CG + W1</td>
</tr>
<tr>
<td>11</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 W2</td>
<td>D + CG + W2</td>
</tr>
<tr>
<td>12</td>
<td>System</td>
<td>1.000</td>
<td>D + 0.600 CU + 1.0 W1</td>
<td>D + CU + W1</td>
</tr>
<tr>
<td>13</td>
<td>System</td>
<td>1.000</td>
<td>D + 0.600 CU + 1.0 W2</td>
<td>D + CU + W2</td>
</tr>
<tr>
<td>14</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 0.750 L + 0.750 W1</td>
<td>D + CG + L + W1</td>
</tr>
<tr>
<td>15</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 0.750 L + 0.750 W2</td>
<td>D + CG + L + W2</td>
</tr>
<tr>
<td>16</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 0.750 S + 0.750 W1</td>
<td>D + CG + S + W1</td>
</tr>
<tr>
<td>17</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 0.750 S + 0.750 W2</td>
<td>D + CG + S + W2</td>
</tr>
<tr>
<td>18</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 0.750 L + 0.750 WPA1</td>
<td>D + CG + WPA1</td>
</tr>
<tr>
<td>19</td>
<td>System</td>
<td>1.000</td>
<td>D + 1.0 CG + 0.750 S + 0.750 WPA1</td>
<td>D + CG + S + WPA1</td>
</tr>
<tr>
<td>20</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 0.600 CU + 1.0 WPA1</td>
<td>D + CU + WPA1</td>
</tr>
<tr>
<td>21</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 1.0 CG + 0.750 L + 0.750 WPA1</td>
<td>D + CG + L + WPA1</td>
</tr>
<tr>
<td>22</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 1.0 CG + 0.750 S + 0.750 WPA1</td>
<td>D + CG + S + WPA1</td>
</tr>
<tr>
<td>23</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 WPA1</td>
<td>D + CG + WPA1</td>
</tr>
<tr>
<td>24</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 WPA1</td>
<td>D + CG + WPA1</td>
</tr>
<tr>
<td>25</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 WPA1</td>
<td>D + CG + WPA1</td>
</tr>
<tr>
<td>26</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 WPA1</td>
<td>D + CG + WPA1</td>
</tr>
<tr>
<td>27</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 WPA1</td>
<td>D + CG + WPA1</td>
</tr>
<tr>
<td>28</td>
<td>System Derived</td>
<td>1.000</td>
<td>D + 1.0 CG + 1.0 WPA2</td>
<td>D + CG + WPA2</td>
</tr>
</tbody>
</table>
Design Load Combinations - Girt

<table>
<thead>
<tr>
<th>No.</th>
<th>Origin</th>
<th>Factor</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>System</td>
<td>1.000</td>
<td>W1-</td>
</tr>
<tr>
<td>2</td>
<td>System</td>
<td>1.000</td>
<td>W2</td>
</tr>
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</table>

Deflection Load Combinations - Purlins

<table>
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<tr>
<th>No.</th>
<th>Origin</th>
<th>Factor</th>
<th>Deflection</th>
<th>Application</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>System</td>
<td>1.000</td>
<td>150</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>System</td>
<td>1.000</td>
<td>180</td>
<td>0.700 W1-</td>
<td>W1-</td>
</tr>
<tr>
<td>3</td>
<td>System</td>
<td>1.000</td>
<td>180</td>
<td>0.700 -W2</td>
<td>W2</td>
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Deflection Load Combinations - Girt

<table>
<thead>
<tr>
<th>No.</th>
<th>Origin</th>
<th>Factor</th>
<th>Deflection</th>
<th>Application</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>System</td>
<td>1.000</td>
<td>90</td>
<td>0.700 W1-</td>
<td>W1-</td>
</tr>
<tr>
<td>2</td>
<td>System</td>
<td>1.000</td>
<td>90</td>
<td>0.700 -W2</td>
<td>W2</td>
</tr>
</tbody>
</table>

Roof: A