Section 5
Steel Resistance
Introduction and Prescriptive Design

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Disclaimer

This investigation was sponsored by TRB under the NCHRP Program. Data reported are work in progress. The contents of this article (presentation) have not been reviewed by the project panel or NCHRP, nor do they constitute a standard, specification, or regulation.
5.1—SCOPE

This Section specifies design provisions for steel structural supports. Fatigue-sensitive steel support structures are further addressed in Section 11. Additional design provisions not addressed in this Section shall be obtained from other references as noted.

Design provisions are provided for round and multi-sided tubular shapes, I-shaped sections, channels, plates, angles, and anchor bolts above the foundation. Anchorage requirements are specified in Section 15.

Laminated structures may be used when the fabrication process is such that adequate shear transfer between the lamina can be achieved. Their use is subject to the approval of the Owner.
5.5—DESIGN LIMIT STATES
5.5.1—General

Structural components and connections shall be proportioned to satisfy the requirements at strength, extreme event, service, and fatigue limit states.

5.5.2—Service Limit State

General service requirements are provided in Section 10.
Design Limit State -- Strength

5.5—DESIGN LIMIT STATES
5.5.3—Strength Limit State
  5.5.3.1—General
    Strength and stability shall be considered using the applicable strength load combinations specified in Table 3.4-1.

5.5.3.2—Resistance Factors
    Resistance factors, $\phi_i$, for the strength limit states shall be taken as follows:

    Flexure $\phi_f = 0.90$
    Shear $\phi_v = 0.90$
    Torsion $\phi_t = 0.95$
    Axial compression, $\phi_c = 0.90$
    Tension, fracture in net section $\phi_u = 0.75$
    Tension, yielding in gross section $\phi_y = 0.90$

C5.5.3.1
    NCHRP project 10-80 developed specific LRFD load and resistance factors using ASCE/SEI 07-2010 loading.

C5.5.3.2
    NCHRP Project Report 796 determined resistance factors specifically for signs, luminaires, and traffic signal supports and these may differ from other specifications. (Puckett et al., 2014)

$$\sum \gamma_i q_i \leq \phi R_n = R_r$$
5.5.4—Extreme Limit State

All applicable load combinations in Table 3.4-1 for the extreme event limit state shall be investigated.

\[ \Sigma \gamma_i Q_i \leq \phi R_n = R_r \]

\[ \Sigma \gamma_i Q_i = \max \left\{ \frac{1.25D}{1.1D + 1.0W} \right\} \]

5.5.5—Fatigue Limit State

Components and details shall be investigated for fatigue as specified in Section 11.

However, Section 5 contains several prescriptive design requirements to mitigate fatigue problems and past poor performance issues.
General Dimension and Details

• Minimum Thickness

<table>
<thead>
<tr>
<th>Component Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum Thickness, in.</td>
</tr>
<tr>
<td>Steel truss-type supports</td>
</tr>
<tr>
<td>Secondary members, such as bracing and truss webs</td>
</tr>
<tr>
<td>Members of pole-type supports and truss-type luminaire arms</td>
</tr>
<tr>
<td>Roadside</td>
</tr>
</tbody>
</table>

• Minimum Number of Side

\[ n \geq \sqrt{5D} \geq 8 \]
General Dimension and Details

• Transverse Plate Thickness

<table>
<thead>
<tr>
<th>Section Diameter or depth D, in.</th>
<th>Minimum Plate Thickness, in.</th>
</tr>
</thead>
<tbody>
<tr>
<td>D ≤ 8</td>
<td>1.5</td>
</tr>
<tr>
<td>D &gt; 8</td>
<td>2.0</td>
</tr>
</tbody>
</table>

• Stiffened Base Connection

  Stiffeners

  Tapered terminating angle 15 deg.  15 degrees
  Minimum Height                      12 in
  Minimum Tube thickness             0.25 in
  Stiffener/Tube Wall Ratio          < 1.25
General Dimension and Details

Details of Holes and Cutouts

Figure 5.6.1-1—Details of Unreinforced Holes and Cutouts

Figure 5.6.1-2—Details of Reinforced Holes and Cutouts

Figure 5.6.1-3—Details of Reinforced Holes and Cutouts for High-Mast Poles
General Dimension and Details

Details of Fillet-Welded Gusseted Box Connections
General Dimension and Details

Details of Fillet-Welded Ring-Stiffened Box Connections
Strength Equations

- Round & Multi-Sided Tubes
  - Modified from Existing ASD Strength Equations
  - Plastic Flexural Capacity for Compact Sections
  - Yield Capacity for Direct Shear & Torsion

- Other Structural Components
  - Mostly AISC Specifications
  - Not all Equations that are Required are Necessarily Included. Other references may be required

- Base Plates
  - General design, detail and material specifications
  - AISC Design Guide 1 & ACI 318-11 Appendix D

- Connections – AASHTO LRFD & AWS

\[ \Sigma \gamma_i Q_i \leq \phi R_n = R_r \]
The provisions of this Article apply to cables and their connections.

The factored tensile resistance, $R_{rt}$, shall be

$$R_{rt} = \phi_{rt} R_{nr}$$  \hspace{1cm} (5.13-1)

where:

$\phi_{rt}$ is the resistance factor as specified in Article 5.5.3.2.

For horizontal supports (wire and connections) of span wire pole structures, the resistance of the cable or connection is the nominal breaking strength of the cable or connection.

Typically manufacturers’ data may be used for the resistances.
Welded Connections

5.14—WELDED CONNECTIONS


Fatigue considerations are provided in Section 11.
Bolted Connections

5.15—BOLTED CONNECTIONS

Design of bolted connections shall be in accordance with the current LRFD Design. Fatigue considerations are provided in Section 11.
Anchor Bolt Connections

5.16—ANCHOR BOLT CONNECTIONS

This Article provides the minimum requirements for design of steel anchor bolts used to transmit loads from attachments into concrete supports or foundations by means of tension, bearing, and shear. A minimum of eight anchor bolts shall be used to connect high-mast lighting towers.

5.16.3—Design Basis

The anchor bolts and their anchorage shall be designed to transmit loads from the attachment into the concrete support or foundation by means of tension, bearing, and shear, or any combination thereof.

C5.16.3

AISC (2006), Design Guide 1: Base Plate and Anchor Rod Design may be used. Concrete anchorages may be designed using ACI 318-11, Appendix D. Resistance factors shall be as specified in ACI 318-11. Loads shall be determined from this Specification.

Figure C5.16-1—Typical Double-Nut Connection

Figure C5.16-2. Typical Single-Nut Connection
Section 5
Steel Resistance
Steel Member Resistances
Section 5 – Steel Design

5.1 SCOPE
5.2 DEFINITIONS
5.3 NOTATION
5.4 MATERIAL
5.5 DESIGN LIMIT STATES
5.6 GENERAL DIMENSIONS AND DETAILS
5.7 SECTION CLASSIFICATION FOR LOCAL BUCKLING
5.8 COMPONENTS IN FLEXURE
5.9 COMPONENTS IN TENSION
5.10 COMPONENTS IN COMPRESSION
5.11 COMPONENTS IN DIRECT SHEAR AND TORSION
5.12 COMBINED FORCES
5.13 CABLES AND CONNECTIONS
5.14 WELDED CONNECTIONS
5.15 BOLTED CONNECTIONS
5.16 ANCHOR BOLT CONNECTIONS
5.17 REFERENCES
Strength Equations

• **Round & Multi-Sided Tubes**
  – Modified from Existing ASD Strength Equations
  – Plastic Flexural Capacity for Compact Sections
  – Yield Capacity for Direct Shear & Torsion

• **Other Structural Components**
  – Mostly AISC Specifications
  – Not all Equations that are Required are Necessarily Included. Other references may be required

• **Base Plates**
  – General design, detail and material specifications
  – AISC Design Guide 1 & ACI 318-11 Appendix D

• **Connections – AASHTO LRFD & AWS**

\[ \Sigma \gamma_i Q_i \leq \phi R_n = R_r \]
Section Classification: Width–Thickness Ratios

5.7.1—Classification of Steel Sections

Steel sections are classified as compact, noncompact, and slender element sections. For a section to qualify as compact or noncompact, the width–thickness ratios of compression elements must not exceed the applicable corresponding limiting $\lambda_p$ or $\lambda_r$ values given in Tables 5.7.2-1 and 5.7.3-1, respectively. If the width–thickness ratios of any compression element section exceed the noncompact limiting value, $\lambda_r$, the section is classified as a slender element section.

C5.7.1

Cross section elements with width–thickness ratios greater than the limits in Tables 5.7.2-1 and 5.7.3-1 may experience local buckling. Flexural members may be subject to local buckling when the width–thickness ratio exceeds $\lambda_p$. Members in compression may be subject to local buckling when the width–thickness ratio exceeds $\lambda_r$.

Flexure: If slenderness $\leq \lambda_p$, compact and no local buckling

Axial Compression: If slenderness $\leq \lambda_r$, not slender and no local buckling
# Width–Thickness Ratios for Round and Multi-Sided Tubular Sections

<table>
<thead>
<tr>
<th>Shape</th>
<th>Ratio</th>
<th>$\lambda_p$</th>
<th>$\lambda_r$</th>
<th>$\lambda_{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round</td>
<td>$D/t$</td>
<td>0.07 $\frac{E}{F_y}$</td>
<td>$0.11 \frac{E}{F_y}$ (compression)</td>
<td>0.45 $\frac{E}{F_y}$</td>
</tr>
<tr>
<td>Hexadecagonal (16)</td>
<td>$b/t$</td>
<td>1.12 $\sqrt{\frac{E}{F_y}}$</td>
<td>1.26 $\sqrt{\frac{E}{F_y}}$</td>
<td>2.14 $\sqrt{\frac{E}{F_y}}$</td>
</tr>
<tr>
<td>Dodecagonal (12)</td>
<td>$b/t$</td>
<td>1.12 $\sqrt{\frac{E}{F_y}}$</td>
<td>1.41 $\sqrt{\frac{E}{F_y}}$</td>
<td>2.14 $\sqrt{\frac{E}{F_y}}$</td>
</tr>
<tr>
<td>Octagonal (8)</td>
<td>$b/t$</td>
<td>1.12 $\sqrt{\frac{E}{F_y}}$</td>
<td>1.53 $\sqrt{\frac{E}{F_y}}$</td>
<td>2.14 $\sqrt{\frac{E}{F_y}}$</td>
</tr>
<tr>
<td>Flanges of Square/Rectangle</td>
<td>$b/t$</td>
<td>1.12 $\sqrt{\frac{E}{F_y}}$</td>
<td>1.53 $\sqrt{\frac{E}{F_y}}$</td>
<td>2.14 $\sqrt{\frac{E}{F_y}}$</td>
</tr>
</tbody>
</table>

$b = \tan\left(\frac{180}{n}\right)\left[D' - 2t - \text{minimum}\left(2r_b, 8t\right)\right]$

$D'$ = the outside distance from flat side to flat side of multi-sided tubes and $180/n$ is in degrees.
**TUBES IN FLEXURE**

\[ M_r = \phi_f M_n \quad \phi_f = 0.9 \]

Table 5.8.2-1— Nominal Bending Strength, \( M_n \), for Tubular Members

<table>
<thead>
<tr>
<th>Shape</th>
<th>Compact</th>
<th>NonCompact</th>
<th>Slender</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \lambda \leq \lambda_p )</td>
<td>( \lambda_p &lt; \lambda \leq \lambda_r )</td>
<td>( \lambda &gt; \lambda_r )</td>
</tr>
<tr>
<td>Round</td>
<td>( M_n = M_p = Z_x F_y )</td>
<td>( M_n = M_p \left[ 0.77 + \frac{0.016(E/F_y)}{D/t} \right] )</td>
<td>( M_n = M_p \left[ \frac{0.25(E/F_y)}{D/t} \right] )</td>
</tr>
<tr>
<td>Hexadecagonal</td>
<td>( M_n = M_p = Z_x F_y )</td>
<td>( M_n = M_p \left[ 2.59 - \frac{1.43(b/t)}{\sqrt{(E/F_y)}} \right] )</td>
<td>( M_n = M_p \left[ 1.12 - \frac{0.26(b/t)}{\sqrt{(E/F_y)}} \right] )</td>
</tr>
<tr>
<td>Dodocagonal</td>
<td>( M_n = M_p = Z_x F_y )</td>
<td>( M_n = M_p \left[ 1.77 - \frac{0.69(b/t)}{\sqrt{(E/F_y)}} \right] )</td>
<td>( M_n = M_p \left[ 1.15 - \frac{0.25(b/t)}{\sqrt{(E/F_y)}} \right] )</td>
</tr>
<tr>
<td>Octagonal</td>
<td>( M_n = M_p = Z_x F_y )</td>
<td>( M_n = M_p \left[ 1.50 - \frac{0.45(b/t)}{\sqrt{(E/F_y)}} \right] )</td>
<td>( M_n = M_p \left[ 1.14 - \frac{0.22(b/t)}{\sqrt{(E/F_y)}} \right] )</td>
</tr>
<tr>
<td>Flanges of Square/Rectangle (Webs Compact)</td>
<td>( M_n = M_p = Z_x F_y )</td>
<td>( M_n = M_p \left[ 1.37 - \frac{0.33(b/t)}{\sqrt{(E/F_y)}} \right] )</td>
<td>( M_n = M_p \left[ 1.23 - \frac{0.23(b/t)}{\sqrt{(E/F_y)}} \right] )</td>
</tr>
</tbody>
</table>
MULTI-SIDED TUBES IN FLEXURE

\[ M_r = \phi_f M_n \quad \phi_f = 0.9 \]
Tension

5.9.1—General

The provisions of this Article apply to tension of rolled open, tubular, and built-up plate sections. The factored tensile resistance, \( P_{rt} \), shall be

\[
P_{rt} = \min \left[ \phi_Y P_{ny}, \phi_u P_{nu} \right]
\]  

(5.9.1-1)

5.9.2—Nominal Tensile Strength

The nominal tensile strength for yield on the gross section shall be:

\[
P_{ny} = A_g F_y
\]

(5.9.2-1)

where:

\( A_g \) = the gross section area (in.\(^2\)), and

\( F_y \) = yield strength (ksi).

The tensile strength for the fracture on the effective net area shall be:

\[
P_{nu} = A_e F_u
\]

(5.9.2-2)

where:

\( A_e \) = net effective area (in.\(^2\)), and

\( F_u \) = tensile strength (ksi).
Tension

5.9.3—Effective Net Area

\[ A_e = UA_n \]  

(5.9.3-1)

where:

\[ U = \text{shear-lag reduction coefficient} \]

For tension members, except plates and hollow structural shapes, connected by fasteners or longitudinal welds or with longitudinal welds in combination with transverse welds:

\[ U = \left(1 - \frac{x}{L}\right) \leq 0.9 \]  

(5.9.3-2)

where:

\[ x = \text{connection eccentricity, defined as the distance from the connection plane, or face of the member, to the centroid of the section resisting the connection force, (in.)} \]

\[ L = \text{length of connection in the direction of loading (in.), and} \]

In lieu of the calculated value for \( U \), the following values may be used for bolted connections:

\[ U = 0.80 \] (single or double angles with four or more bolts per line in the direction of load)

\[ U = 0.60 \] (single or double angles with three bolts per line in the direction of load)

\[ U = 0.90 \] (with three or more bolts per line in the direction of load and \( b_f \geq \frac{2}{3}d \))

\[ U = 0.85 \] (flange connection I-shaped or tees with three or more bolts per line in the direction of load and \( b_f < \frac{2}{3}d \))
Compression

5.10.1—General

The provisions of this article apply to compression of rolled open, tubular, and built-up plate sections.

The factored compressive resistance, \( P_{rc} \), shall be:

\[
P_{rc} = \phi_c P_{nc} \tag{5.10.1-1}
\]

where:

\( \phi_c \) = resistance factor as specified in Article 5.5.3.2, and

\( P_{nc} \) = minimum nominal compressive strength defined in Article 5.10.2.

5.10.2—Nominal Compressive Strength

5.10.2.1—Flexural Buckling

The nominal compressive strength shall be calculated as follows:

\[
P_{nc} = A_g F_{cr} \tag{5.10.2.1-1}
\]

when

\[
\frac{KL}{r} \leq 4.71 \sqrt{\frac{E}{QF_y}} \tag{5.10.2.1-2}
\]

\[
F_{cr} = Q \left( 0.658 \right)^{\frac{QF_y}{F_{cr}}} F_y \]

when

\[
\frac{KL}{r} > 4.71 \sqrt{\frac{E}{QF_y}} \tag{5.10.2.1-3}
\]

\[
F_{cr} = 0.877 F_e \tag{5.10.2.1-4}
\]

\[
F_e = \frac{\pi^2 E}{\left( \frac{KL}{r} \right)^2} \tag{5.10.2.1-4}
\]

If all section elements \( \lambda \leq \lambda_r \)

\[
Q = 1.0 \tag{5.10.2.1-5}
\]
Shear & Torsion

5.11.1—General

The provisions of this article apply to direct shear and torsion of rolled open, tubular, and built-up plate sections. The factored direct shear resistance, $V_r$, shall be:

$$ V_r = \phi_v V_n $$  \hspace{1cm} (5.11.1-1)

And the factored torsional shear resistance, $T_r$, shall be:

$$ T_r = \phi_t T_n $$  \hspace{1cm} (5.11.1-2)

where:

$V_n$ = nominal direct shear capacity,

$T_n$ = nominal torsion capacity, and

$\phi_v$ and $\phi_t$ = the resistance factor as specified in Article 5.5.3.2.
5.11.2—Nominal Direct Shear Strength

The nominal direct shear strength due to shear shall be:

\[ V_n = A_v F_{nv} \]  \hspace{1cm} (5.11.2-1)

where:

- \( F_{nv} \) is the nominal shear stress capacity (ksi)
- \( A_v \) is the shear area (in\(^2\)), as defined in Articles 5.11.2.1 and 5.11.2.2.
5.11.2.1-Nominal Shear Stress Capacity for Tubular Members

5.11.2.1.1—Round Tubular Members

The nominal shear stress capacity for round tubular shapes shall be:

\[
F_{nv} = \max \left[ \left( \frac{1.60E}{\sqrt{L_v \left( \frac{D}{t} \right)^{\frac{3}{4}}} \right) \right] \leq 0.6F_y \tag{5.11.2.1.1-1}
\]

where:

\[L_v = \text{distance from the maximum to zero shear force}\]

\[A_v = \frac{A_g}{2} \tag{5.11.2.1.1-2}\]

5.11.2.1.2—Multisided Tubular Members

The nominal direct shear stress capacity for multisided non-square and rectangular tubular shapes shall be:

\[F_{nv} = 0.6F_y \tag{5.11.2.1.2-1}\]

\[A_v = \frac{A_g}{2} \tag{5.11.2.1.2-2}\]
5.11.3—Nominal Torsion Strength

The nominal torsional strength due to torsion shall be:

\[ T_n = C_t F_{nt} \]  \hspace{1cm} (5.11.3-1)

where

\[ T_n = \text{nominal torsion strength} \quad \text{and} \quad C = \text{the torsional constant}. \]
**5.11.3.1.1—Round Tubular Members**

The nominal torsion stress capacities for round tubular shapes shall be the greater of:

\[
F_{nt} = \frac{1.23E}{\sqrt{L \left( \frac{D}{t} \right)^{5/4}}} \quad (5.11.3.1.1-1)
\]

and

\[
F_{nt} = \frac{0.6E}{\left( \frac{D}{t} \right)^{3/2}} \quad (5.11.3.1.1-2)
\]

but shall not exceed \(0.6F_y\).

**5.11.3.1.2—Multi-Sided Tubular Members**

The nominal torsion stress capacity for multi-sided non-square and rectangular tubular shapes shall be:

\[
F_{nt} = 0.6F_y \quad (5.11.3.1.2-1)
\]

Torsion Strength
### Appendix B

**Section Properties**

<table>
<thead>
<tr>
<th>Property</th>
<th>Round Tube</th>
<th>Hexagonal Tube</th>
<th>Dodecagonal Tube</th>
<th>Octagonal Tube</th>
<th>Square Tube</th>
<th>Square Tube (Axis on Diagonal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moment of inertia, $I$</td>
<td>$3.14R^3t$</td>
<td>$3.22R^3t$</td>
<td>$3.29R^3t$</td>
<td>$3.50R^3t$</td>
<td>$5.33R^3t$</td>
<td>$5.33R^3t$</td>
</tr>
<tr>
<td>Section modulus, $S$</td>
<td>$3.14R^2t$</td>
<td>$3.22R^2t$</td>
<td>$3.29R^2t$</td>
<td>$3.50R^2t$</td>
<td>$5.33R^2t$</td>
<td>$3.77R^2t$</td>
</tr>
<tr>
<td>Area, $A$</td>
<td>$6.28Rt$</td>
<td>$6.37Rt$</td>
<td>$6.43Rt$</td>
<td>$6.63Rt$</td>
<td>$8.00Rt$</td>
<td>$8.00Rt$</td>
</tr>
<tr>
<td>Shape factor, $K_p = Z/S$</td>
<td>1.27</td>
<td>1.27</td>
<td>1.26</td>
<td>1.24</td>
<td>1.12</td>
<td>—</td>
</tr>
<tr>
<td>Radius of gyration, $r$</td>
<td>$0.707R$</td>
<td>$0.711R$</td>
<td>$0.715R$</td>
<td>$0.727R$</td>
<td>$0.816R$</td>
<td>$0.816R$</td>
</tr>
<tr>
<td>Cross-sectional constant, $C$</td>
<td>3.14</td>
<td>3.22</td>
<td>3.29</td>
<td>3.50</td>
<td>5.33</td>
<td>—</td>
</tr>
</tbody>
</table>

**Notation:**

- $C =$ cross-sectional constant used in Table B.3-1
- $R =$ radius measured to the mid-thickness of the wall
- $t =$ wall thickness
- $Z =$ plastic section modulus
<table>
<thead>
<tr>
<th>Stress</th>
<th>Round Tube</th>
<th>Hexdecagonal Tube</th>
<th>Dodecagonal Tube</th>
<th>Octagonal Tube</th>
<th>Square Tube</th>
<th>Square Tube (Axis on Diagonal)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum bending stress, $f_b$</td>
<td>$\sqrt{f_x^2 + f_y^2}$</td>
<td>$0.199f_x + f_y$</td>
<td>$0.732(f_x + f_y)$</td>
<td>$f_x + f_y$</td>
<td>$f_x$</td>
<td>$f_x$</td>
</tr>
<tr>
<td></td>
<td>or</td>
<td>or</td>
<td>or</td>
<td>or</td>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td></td>
<td>$0.567f_x + 0.848f_y$</td>
<td>$f_x + 0.268f_y$</td>
<td>$0.414f_x + f_y$</td>
<td>$0.414f_x + f_y$</td>
<td>or</td>
<td>or</td>
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<td></td>
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<tr>
<td></td>
<td>$0.848f_x + 0.567f_y$</td>
<td>$0.268f_x + f_y$</td>
<td>or</td>
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<tr>
<td></td>
<td>$f_x + 0.199f_y$</td>
<td>or</td>
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<td>or</td>
<td>or</td>
<td>or</td>
</tr>
<tr>
<td>Maximum shear stress due to transverse loads, $f_{sb}$</td>
<td>$2.0V_z/A$</td>
<td>$2.02V_z/A$</td>
<td>$2.025V_z/A$</td>
<td>$2.05V_z/A$</td>
<td>$2.25V_z/A$</td>
<td>$2.12V_z/A$</td>
</tr>
<tr>
<td>Maximum shear stress due to torsion, $f_{st}$</td>
<td>$M_z/6.28R^2t$</td>
<td>$M_zk_t/6.37R^2t$</td>
<td>$M_zk_t/6.43R^2t$</td>
<td>$M_zk_t/6.63R^2t$</td>
<td>$M_zk_t/8.0R^2t$</td>
<td>$M_zk_t/8.00R^2t$</td>
</tr>
<tr>
<td>Torsional constant for stress computation, e.g., $C_t$ in 5.11.3</td>
<td>$6.28R^2t$</td>
<td>$6.37R^2t/k_t$</td>
<td>$6.43R^2t/k_t$</td>
<td>$6.63R^2t/k_t$</td>
<td>$8.00R^2t/k_t$</td>
<td>$8.00R^2t/k_t$</td>
</tr>
</tbody>
</table>

Values of $k_t$, stress

See Figure B.2-1

**Appendix B Stress Formulas**
Example: Strength for Octagonal Tube

- **Compression**: \( P_{rc} = \phi_c P_{nc} \quad \phi_c = 0.90 \)
  
  \[ P_{nc} = A_g F_{cr} \quad (F_{cr} \text{ buckling eqn}) \quad A_g = 6.63Rt \]

- **Flexure**: \( M_r = \phi_f M_n = \phi_f M_p \text{ if compact} \)
  
  \[ M_y = SF_y = 3.50R^2tF_y \quad \phi_f = 0.90 \]
  
  \[ M_p = SF*M_y = 1.24[3.50R^2tF_y] \]

- **Direct Shear**: \( V_r = \phi V_n = \phi A_v F_{nv} \quad \phi_v = 0.90 \)
  
  \[ A_v = A_g/2 = 6.63Rt/2 \quad F_{nv} = 0.60F_y \]

- **Torsion**: \( T_r = \phi T_n = \phi C_t F_{nt} \quad \phi_T = 0.95 \)
  
  \[ C_t = 6.63R^2t \quad F_{nt} = 0.60F_y \]
5.12—COMBINED FORCES

5.12.1—Combined Force Interaction Requirements

Members subjected to combined bending, axial compression or tension, shear, and torsion shall be proportioned to meet the following:

\[
\frac{P_u}{P_r} + \frac{BM_u}{M_r} + \left(\frac{V_u}{V_r} + \frac{T_u}{T_r}\right)^2 \leq 1.0 \quad (5.12.1-1)
\]

If \(\frac{T_u}{T_r} \leq 0.20\) torsional and shear effects can be ignored, and when:

\[
\frac{P_u}{P_r} \geq 0.20
\]

\[
\frac{P_u}{P_r} + \frac{8BM_u}{9M_r} \leq 1.0 \quad (5.12.1-2)
\]

when \(\frac{P_u}{P_r} < 0.20\)

\[
\frac{P_u}{2P_r} + \frac{BM_u}{M_r} \leq 1.0 \quad (5.12.1-3)
\]

For round and multi-sided tubular members,

\[
M_u = \sqrt{M_{ux}^2 + M_{uy}^2} \quad (5.12.1-4)
\]

and

\[
V_u = \sqrt{V_{ux}^2 + V_{uy}^2} \quad (5.12.1-5)
\]
For members with biaxial bending about geometric or principal axes, the term $\frac{BM_u}{M_r}$ may be expanded to:

$$B_x \frac{M_{ux}}{M_{rx}} + B_y \frac{M_{uy}}{M_{ry}}$$  \hspace{1cm} (5.12.1-6)

where:

$$\frac{V_u}{V_r} = \text{the greater of } \frac{V_{ux}}{V_{rx}} \text{ or } \frac{V_{uy}}{V_{ry}}$$  \hspace{1cm} (5.12.1-7)

Moment Magnifier $B$:

For prismatic members:

Compression: \quad $B = \frac{1}{1 - \frac{P_u}{P_e}}$  \hspace{1cm} (5.12.1-10)

Tension:

$$B = 1.0$$  \hspace{1cm} (5.12.1-12)

For non-prismatic members, Tension:

$$B = 1.0$$  \hspace{1cm} (5.12.1-13)

Compression: $B$ shall be computed according to Section 4.
Section 5 Steel Design

• Prescriptive Design
  – Sections 5.1-5.6, 5.13-5.16

• Steel Strength Equations
  – Sections 5.7-5.12

\[ \sum \gamma_i Q_i \leq \phi R_n = R_r \]

• Division II – Fabrication and Construction
  – Section 14 Materials, Detailing and Fabrication
  – Section 15 Construction