

For $0.25 \text{ mm} \leq t < 3.56 \text{ mm}$:

$$P_n = 5.51t^{1.47} \quad (\text{Eq. E2.6-3})$$

For $3.56 \text{ mm} \leq t \leq 4.57 \text{ mm}$:

$$P_n = 7.6t + 8.57 \quad (\text{Eq. E2.6-4})$$

When t is in centimeters and P_n is in kg:

For $0.025 \text{ cm} \leq t < 0.356 \text{ cm}$:

$$P_n = 16600t^{1.47} \quad (\text{Eq. E2.6-5})$$

For $0.356 \text{ cm} \leq t \leq 0.457 \text{ cm}$:

$$P_n = 7750t + 875 \quad (\text{Eq. E2.6-6})$$

where t = Thickness of thinnest outside sheet.

USA and Mexico		Canada
$\Omega(\text{ASD})$	$\phi(\text{LRFD})$	$\phi(\text{LSD})$
2.35	0.65	0.55

E2.7 Fracture in Net Section of Members other than Flat Sheets (Shear Lag)

The nominal tensile strength [resistance] of a welded member shall be determined in accordance with Section C2. For fracture and/or yielding in the effective net section of the connected part, the nominal tensile strength [resistance], P_n , shall be determined as follows:

$$P_n = A_e F_u \quad (\text{Eq. E2.7-1})$$

USA and Mexico		Canada
$\Omega(\text{ASD})$	$\phi(\text{LRFD})$	$\phi(\text{LSD})$
2.50	0.60	0.50

F_u = Tensile strength of the connected part as specified in Section A2.1 or A2.3.2

A_e = AU , effective net area with U defined as follows:

When the load is transmitted only by transverse welds:

A = Area of directly connected elements

$U = 1.0$

When the load is transmitted only by longitudinal welds or by longitudinal welds in combination with transverse welds:

A = Gross area of member, A_g

$U = 1.0$ for members when load is transmitted directly to all of the cross sectional elements. Otherwise the reduction coefficient U is determined as follows:

(a) For angle members:

$$U = 1.0 - 1.20 \bar{x}/L < 0.9 \quad (\text{Eq. E2.7-2})$$

but U shall not be less than 0.4.

(b) For channel members

$$U = 1.0 - 0.36 \bar{x}/L < 0.9 \quad (\text{Eq. E2.7-3})$$

but U shall not be less than 0.5.

\bar{x} = Distance from shear plane to centroid of cross section

L = Length of longitudinal weld

E3 Bolted Connections

The following design criteria and the requirements stipulated in Section E3a of Appendix A, B, and C govern bolted connections used for cold-formed steel structural members in which the thickness of the thinnest connected part is less than 3/16 in. (4.76 mm). For bolted connections in which the thickness of the thinnest connected part is equal to or greater than 3/16 in. (4.76 mm), refer to the specifications and standards stipulated in Section E3a of Appendix A, B, or C.

Bolts, nuts, and washers shall generally conform to one of the following specifications:

→ A,B,C

ASTM A194/A194M, Carbon and Alloy Steel Nuts for Bolts for High-Pressure and High-Temperature Service

ASTM A307(Type A), Carbon Steel Bolts and Studs, 60,000 PSI Tensile Strength

ASTM A325, Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength

ASTM A325M, High Strength Bolts for Structural Steel Joints [Metric]

ASTM A354 (Grade BD), Quenched and Tempered Alloy Steel Bolts, Studs, and Other Externally Threaded Fasteners (for diameter of bolt smaller than 1/2 in.)

ASTM A449, Quenched and Tempered Steel Bolts and Studs (for diameter of bolt smaller than 1/2 in.)

ASTM A490, Heat-Treated Steel Structural Bolts, 150 ksi Minimum Tensile Strength

ASTM A490M, High Strength Steel bolts, Classes 10.9 and 10.9.3, for Structural Steel Joints [Metric]

ASTM A563, Carbon and Alloy Steel Nuts

ASTM A563M, Carbon and Alloy Steel Nuts [Metric]

ASTM F436, Hardened Steel Washers

ASTM F436M, Hardened Steel Washers [Metric]

ASTM F844, Washers, Steel, Plain (Flat), Unhardened for General Use

ASTM F959, Compressible Washer-Type Direct Tension Indicators for Use with Structural Fasteners

ASTM F959M, Compressible Washer-Type Direct Tension Indicators for Use with Structural Fasteners [Metric]

When other than the above are used, drawings shall indicate clearly the type and size of fasteners to be employed and the nominal strength [resistance] assumed in design.

Bolts shall be installed and tightened to achieve satisfactory performance of the connections.

E3.1 Shear, Spacing and Edge Distance

The provisions of this section are given in Section E3.1 of the Appendices.

→ A,B,C

E3.2 Fracture in Net Section (Shear Lag)

The provisions of this section are given in Section E3.2 of the Appendices.

E3.3 Bearing

→ A,B,C

The design bearing strength [factored resistance] of bolted connections shall be determined according to Sections E3.3.1 and E3.3.2. For conditions not shown, the design bearing strength [factored resistance] of bolted connections shall be determined by tests.

→ B

E3.3.1 Strength [Resistance] without Consideration of Bolt Hole Deformation

When deformation around the bolt holes is not a design consideration, the nominal bearing strength [resistance], P_n of the connected sheet for each loaded bolt shall be determined as follows:

$$P_n = m_f C d t F_u \quad (\text{Eq. E3.3.1-1})$$

USA and Mexico		Canada
$\Omega(\text{ASD})$	$\phi(\text{LRFD})$	$\phi(\text{LSD})$
2.50	0.60	0.50

where

C =Bearing factor, which shall be determined according to Table E3.3.1-1

d =Nominal bolt diameter

t =Uncoated sheet thickness

F_u =Tensile strength of sheet as defined in Section A2.1 or A2.2

m_f =Modification factor for type of bearing connection, which shall be determined according to Table E3.3.1-2

Table E3.3.1-1
Bearing Factor, C

Thickness of Connected Part, t , in. (mm)	Ratio of Fastener Diameter to Member Thickness, d/t	C
$0.024 \leq t < 0.1875$ ($0.61 \leq t < 4.76$)	$d/t < 10$	3.0
	$10 \leq d/t \leq 22$	$4 - 0.1(d/t)$
	$d/t > 22$	1.8

Table E3.3.1-2
Modification Factor, m_f , for Type of Bearing Connection

Type of Bearing Connection	m_f
Single Shear and Outside Sheets of Double Shear Connection with Washers under Both Bolt Head and Nut	1.00
Single Shear and Outside Sheets of Double Shear Connection without Washers under Both Bolt Head and Nut, Or with only One Washer	0.75
Inside Sheet of Double Shear Connection with or without Washers	1.33

E3.3.2 Strength [Resistance] with Consideration of Bolt Hole Deformation

When deformation around a bolt hole is a design consideration, the nominal bearing strength [resistance], P_n , shall also be limited by the following values:

$$P_n = (4.64\alpha t + 1.53)dtF_u \quad (\text{Eq. E3.3.2-1})$$

USA and Mexico		Canada
$\Omega(\text{ASD})$	$\phi(\text{LRFD})$	$\phi(\text{LSD})$
2.22	0.65	0.55

where

- α = Coefficient for conversion of units
 = 1 for US customary units (with t in inches)
 = 0.0394 for SI units (with t in mm)
 = 0.394 for MKS units (with t in cm)
 Other symbols are defined in Section E3.3.1.

E3.4 Shear and Tension in Bolts

The provisions under this section are provided in Section E3.4 of the Appendices.

 **A,B,C**

E4 Screw Connections

All E4 requirements shall apply to screws with 0.08 in. (2.03 mm) $\leq d \leq 0.25$ in. (6.35 mm). The screws shall be thread-forming or thread-cutting, with or without a self-drilling point. Screws shall be installed and tightened in accordance with the manufacturer's recommendations.

The nominal screw connection strengths [resistances] shall also be limited by Section C2.

For diaphragm applications, Section D5 shall be used.

The following factor of safety or resistance factor shall be used for the sub-sections of Chapter E4.

USA and Mexico		Canada
Ω (ASD)	ϕ (LRFD)	ϕ (LSD)
3.00	0.50	0.40

Alternatively, design values for a particular application shall be permitted to be based on tests, with the factor of safety, Ω , and the resistance factor, ϕ , determined according to Chapter F.

The following notation applies to this section:

- d = Nominal screw diameter
- d_w = Larger of screw head diameter or washer diameter
- P_{ns} = Nominal shear strength [resistance] per screw
- P_{ss} = Nominal shear strength [resistance] of screw as reported by manufacturer or determined by independent laboratory testing
- P_{nt} = Nominal tension strength [resistance] per screw
- P_{not} = Nominal pull-out strength [resistance] per screw
- P_{nov} = Nominal pull-over strength [resistance] per screw
- P_{ts} = Nominal tension strength [resistance] of screw as reported by manufacturer or determined by independent laboratory testing
- t_1 = Thickness of member in contact with screw head
- t_2 = Thickness of member not in contact with screw head
- t_c = Lesser of depth of penetration and thickness t_2
- F_{u1} = Tensile strength of member in contact with screw head
- F_{u2} = Tensile strength of member not in contact with screw head

E4.1 Minimum Spacing

The distance between the centers of fasteners shall not be less than $3d$.

E4.2 Minimum Edge and End Distances

The distance from the center of a fastener to the edge of any part shall not be less than $1.5d$. If the end distance is parallel to the force on the fastener, the nominal shear strength per screw, P_{ns} , shall be limited by Section E4.3.2.

E4.3 Shear

E4.3.1 Connection Shear Limited by Tilting and Bearing

The nominal shear strength [resistance] per screw, P_{ns} , shall be determined as follows:

For $t_2/t_1 \leq 1.0$, P_{ns} shall be taken as the smallest of

$$P_{ns} = 4.2 (t_2^3 d)^{1/2} F_{u2} \quad (\text{Eq. E4.3.1-1})$$

$$P_{ns} = 2.7 t_1 d F_{u1} \quad (\text{Eq. E4.3.1-2})$$

$$P_{ns} = 2.7 t_2 d F_{u2} \quad (\text{Eq. E4.3.1-3})$$

For $t_2/t_1 \geq 2.5$, P_{ns} shall be taken as the smaller of

$$P_{ns} = 2.7 t_1 d F_{u1} \quad (\text{Eq. E4.3.1-4})$$

$$P_{ns} = 2.7 t_2 d F_{u2} \quad (\text{Eq. E4.3.1-5})$$

For $1.0 < t_2/t_1 < 2.5$, P_{ns} shall be determined by linear interpolation between the above two cases.

E4.3.2 Connection Shear Limited by End Distance

The provisions of this section are given in Section E4.3.2 of the Appendices.

→ A,B,C

E4.3.3 Shear in Screws

The nominal shear strength [resistance] of the screw shall be calculated as follows:

$$P_{ns} = 0.8 P_{ss} \quad (\text{Eq. E4.3.3-1})$$

E4.4 Tension

For screws which carry tension, the head of the screw or washer, if a washer is provided, shall have a diameter d_w not less than 5/16 in. (7.94 mm). Washers shall be at least 0.050 in. (1.27 mm) thick.

E4.4.1 Pull-Out

The nominal pull-out strength [resistance], P_{not} , shall be calculated as follows:

$$P_{not} = 0.85 t_c d F_{u2} \quad (\text{Eq. E4.4.1-1})$$

E4.4.2 Pull-Over

The nominal pull-over strength [resistance], P_{nov} , shall be calculated as follows:

$$P_{nov} = 1.5 t_1 d_w F_{u1} \quad (\text{Eq. E4.4.2-1})$$

where d_w shall be taken not larger than 1/2 in. (12.7 mm).

E4.4.3 Tension in Screws

The nominal tension strength [resistance], P_{nt} , per screw shall be calculated as follows:

$$P_{nt} = 0.8 P_{ts} \quad (\text{Eq. E4.4.3-1})$$

E5 Rupture

The provisions provided under this section are given in Section E5 of the Appendices.

→ A,B,C