

SPECIFICATION

E3 Bolted Connections

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

Bolts, nuts, and washers conforming to one of the following ASTM specifications shall be approved for use under this *Specification*:

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.

The holes for bolts shall not exceed the sizes specified in Table E3a, except that larger holes are permitted to be used in column base details or structural systems connected to concrete walls.

When the bolt hole deformation is considered in design in accordance with Eq. E3.3.2-1, the following restrictions shall be applied:

(a) Standard holes shall be used in bolted connections, except that oversized and slotted

holes shall be permitted to be used as approved by the designer;

(b) The length of slotted holes shall be normal to the direction of the shear load; and

(c) Washers or backup plates shall be installed over oversized or slotted holes in an outer ply unless suitable performance is demonstrated by tests in accordance with Chapter F.

When the bolt hole deformation is not considered in design, oversized holes and short-slotted holes are permitted. The holes for bolts shall not exceed the sizes specified in Table E3a.

TABLE E3a
Maximum Size of Bolt Holes, in inches

Nominal Bolt Diameter, d in.	Standard Hole Diameter, d_h in.	Oversized Hole Diameter, d_h in.	Short-Slotted Hole Dimensions in.	Long-Slotted Hole Dimensions in.	Alternative Short-Slotted Hole* Dimensions in.
$< 1/2$	$d + 1/32$	$d + 1/16$	$(d + 1/32)$ by $(d + 1/4)$	$(d + 1/32)$ by $(2^{1/2} d)$	
$\geq 1/2$	$d + 1/16$	$d + 1/8$	$(d + 1/16)$ by $(d + 1/4)$	$(d + 1/16)$ by $(2^{1/2} d)$	$9/16$ by $7/8$

Note

* The alternative short-slotted hole is only applicable for $d/t = 1/2$ in.

TABLE E3a
Maximum Size of Bolt Holes, in millimeters

Nominal Bolt Diameter, d mm	Standard Hole Diameter, d_h mm	Oversized Hole Diameter, d_h mm	Short-Slotted Hole Dimensions mm	Long-Slotted Hole Dimensions mm	Alternative Short-Slotted Hole* Dimensions mm
< 12.7	$d + 0.8$	$d + 1.6$	$(d + 0.8)$ by $(d + 6.4)$	$(d + 0.8)$ by $(2^{1/2} d)$	
≥ 12.7	$d + 1.6$	$d + 3.2$	$(d + 1.6)$ by $(d + 6.4)$	$(d + 1.6)$ by $(2^{1/2} d)$	14.3 by 22.2

Note

* The alternative short-slotted hole is only applicable for $d/t = 12.7$ mm

Slotted or oversized holes shall be ~~permitted to be used~~ considered taken as standard holes when the hole occurs within the lap of lapped or nested Z-members, subject to the following restrictions:

- (1) 1/2 in. (12.7 mm)-diameter bolts only with or without washers or backup plates
- (2) Maximum slot size is 9/16 in. x 7/8 in. (14.3 mm x 22.2 mm), slotted vertically
- (3) Maximum oversize hole is 5/8 in. (15.9 mm) diameter
- (4) Minimum member thickness is 0.060 in. (1.52 mm) nominal
- (5) Maximum member *yield stress* is 60 ksi (410 MPa, and 4220 kg/cm²)
- (6) Minimum lap length measured from center of frame to end of lap is 1.5 times the member depth.

E3.1 Minimum Spacing

The distance between the centers of fasteners shall not be less than $3d$. In addition, the minimum distance between centers of bolt holes shall provide clearance for bolt heads, nuts, washers and the wrench. For oversized and slotted holes, the clear distance between the edges of two adjacent holes shall not be less than $2d$.

E3.2 Minimum Edge and End Distances

The distance from the center of a fastener to the edge or end of any part shall not be less than $1.5d$. For oversized and slotted holes, the distance between the edge of the hole and the edge or end of the member shall not be less than d .

E3.3 Bearing

The *available bearing strength [factored resistance]* of bolted *connections* shall be determined in accordance with Sections E3.3.1 and E3.3.2. For conditions not shown, the available bearing strength [factored resistance] of bolted connections shall be determined by tests. ➡ **B**

E3.3.1 Bearing 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 in accordance with Eq. E3.3.1-1. The *safety factor* and *resistance factors* given in this section shall be used to determine the *allowable strength* or *design strength [factored resistance]* in accordance with the applicable design method in Section A4, A5, or A6.

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

$$\Omega = 2.50 \quad (\text{ASD})$$

$$\phi = 0.60 \quad (\text{LRFD})$$

$$= 0.50 \quad (\text{LSD})$$

where

C = Bearing factor, determined in accordance with Table E3.3.1-1

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

d = Nominal bolt diameter

t = Uncoated sheet *thickness*

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

Table E3.3.1-1
Bearing Factor, C

	<u>Connections with Standard Holes</u>		<u>Connections with Oversized or Short-Slotted Holes</u>	
Thickness of Connected Part, t, in. (mm)	Ratio of Fastener Diameter to Member Thickness, d/t	C	Ratio of Fastener Diameter to Member Thickness, d/t	C
0.024 ≤ t < 0.1875 (0.61 ≤ t < 4.76)	d/t < 10	3.0	d/t < 7	3.0
	10 ≤ d/t ≤ 22	4 - 0.1(d/t)	7 ≤ d/t ≤ 18	1+14/(d/t)
	d/t > 22	1.8	d/t > 18	1.8

Note: Oversized or short-slotted holes within the lap of lapped or nested Z-members as ~~restricted defined by~~ in Section E3 ~~shall be~~ is permitted to be considered as standard holes.

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 <u>Using</u> Standard Holes w With Washers Under <u>under</u> Both Bolt Head and Nut	1.00
Single Shear and Outside Sheets of Double Shear Connection <u>Using</u> Standard Holes w Without Washers under Both <u>both</u> Bolt Head and Nut, or With <u>with</u> Only <u>only</u> One Washer	0.75
<u>Single Shear and Outside Sheets of Double Shear Connection Using Oversized or Short-Slotted Holes Parallel to the Applied Load without Washers under both Bolt Head and Nut, or with only One Washer</u>	<u>0.70</u>
<u>Single Shear and Outside Sheets of Double Shear Connection Using Short-Slotted Holes Perpendicular to the Applied Load w</u> without Washers <u>Under B</u> both Bolt Head and Nut, or <u>w</u> with <u>Only One Washer</u>	<u>0.55</u>
Inside Sheet of Double Shear Connection <u>Using</u> Standard Holes w With or Without <u>without</u> Washers	1.33
<u>Inside Sheet of Double Shear Connection Using Oversized or Short-Slotted Holes Parallel to the Applied Load w</u> with or without Washers	<u>1.10</u>
<u>Inside Sheet of Double Shear Connection Using Short-Slotted Holes Perpendicular to the Applied Load with or without Washers</u>	<u>0.90</u>

Note: Oversized or short-slotted holes within the lap of lapped or nested Z-members as defined in Section E3 ~~shall be~~ is permitted to be considered as standard holes.

E3.3.2 Bearing 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 be calculated in accordance with Eq. E3.3.2-1. The *safety factor* and *resistance factors* given in this section shall be used to determine the *available strength [factored resistance]* in accordance with the applicable design method in Section A4, A5, or A6. In addition, the *available strength* shall not exceed the available strength obtained in accordance with Section E3.3.1.

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

$$\Omega = 2.22 \quad (ASD)$$

$$\phi = 0.65 \quad (LRFD)$$

$$= 0.55 \quad (LSD)$$

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)

See Section E3.3.1 for definitions of other variables.

E3.4 Shear and Tension in Bolts

See Section E3.4 of Appendix A or B for provisions provided in this section.

⇒ **A.B**

Specification Appendix A:

E3a Bolted Connections

In addition to the design criteria given in Section E3 of the *Specification*, the following design requirements shall also be followed for bolted connections used for *cold-formed steel structural members*, in which the *thickness* of the thinnest connected part is 3/16 in. (4.76 mm) or less. Bolted connections in which the thickness of the thinnest connected part is greater than 3/16 in. (4.76 mm) shall be in accordance with ANSI/AISC-360.

~~The holes for bolts shall not exceed the sizes specified in Table E3a, except that larger holes are permitted to be used in column base details or structural systems connected to concrete walls.~~

~~When the bolt hole deformation is considered in design in accordance with Eq. E3.3.2-1, the following restrictions shall be applied:~~

- ~~(d) Standard holes shall be used in bolted connections, except that oversized and slotted holes shall be permitted to be used as approved by the designer.~~
- ~~(e) The length of slotted holes shall be normal to the direction of the shear load; and.~~
- ~~(f) Washers or backup plates shall be installed over oversized or slotted holes in an outer ply unless suitable performance is demonstrated by tests in accordance with Chapter F.~~

~~When the bolt hole deformation is not considered in design, oversized holes and short slotted holes are permitted. The holes for bolts shall not exceed the sizes specified in Table E3a.~~

TABLE E3a
Maximum Size of Bolt Holes, in inches

Nominal Bolt Diameter, d in.	Standard Hole Diameter, d_h in.	Oversized Hole Diameter, d_h in.	Short Slotted Hole Dimensions in.	Long Slotted Hole Dimensions in.	<u>Alternative Short Slotted Hole* Dimensions in.</u>
$< 1/2$	$d + 1/32$	$d + 1/16$	$(d + 1/32)$ by $(d + 1/4)$	$(d + 1/32)$ by $(2 1/2 d)$	
$\geq 1/2$	$d + 1/16$	$d + 1/8$	$(d + 1/16)$ by $(d + 1/4)$	$(d + 1/16)$ by $(2 1/2 d)$	<u>9/16 by 7/8</u>

Note

* The alternative short slotted hole is only applicable for $d/t = 1/2$ in.

TABLE E3a
Maximum Size of Bolt Holes, in millimeters

Nominal Bolt Diameter, d mm	Standard Hole Diameter, d_h mm	Oversized Hole Diameter, d_h mm	Short-Slotted Hole Dimensions mm	Long-Slotted Hole Dimensions mm	<u>Alternative Short Slotted Hole* Dimensions</u> mm
< 12.7 ≥ 12.7	$d + 0.8$ $d + 1.6$	$d + 1.6$ $d + 3.2$	$(d + 0.8)$ by $(d + 6.4)$ $(d + 1.6)$ by $(d + 6.4)$	$(d + 0.8)$ by $(\frac{1}{2}d)$ $(d + 1.6)$ by $(\frac{1}{2}d)$	<u>14.3 by 22.2</u>

Note

* The alternative short slotted hole is only applicable for $d = 12.7$ mm

Specification Appendix B

E3a Bolted Connections

In addition to the design criteria given in Section E3 of the *Specification*, the following design requirements shall be followed for bolted connections used for *cold-formed steel structural members* in which the *thickness* of the thinnest connected part is 4.76 mm or less, there are no gaps between connected parts, and fasteners are installed with sufficient tightness to achieve satisfactory performance of the connection under anticipated service conditions. Bolted *connections* in which the thickness of the thinnest connected part is greater than 4.76 mm shall be in accordance with CSA Standard S16.

Unless otherwise specified, ~~circular holes~~ the standard hole diameter for bolts shall not be greater than the nominal bolt diameter, d , plus 1 mm for bolt sizes up to 13 mm and plus 2 mm for bolt sizes over 13 mm.