E. CONNECTIONS AND JOINTS

E1 General Provisions

Connections shall be designed to transmit the maximum design forces acting on the connected members. Proper regard shall be given to eccentricity.

In determining the strength of connections ductility is of utmost concern. In AISI design we allow local yielding. By allowing this local yielding we ensure that all fasteners in a group see the same amount of stress. In order for this approach to be accurate adequate ductility is required and is of much more importance than in AISC design.

E2 Welded connections

Welded connections are basically the same design in AISI as in AISC. Minor differences are present and outlined below.

Plug Welds - similar to Arc Spot welds, however, no pre-punched holes are required, rather a hole is burned by the arc into the top sheet and then filler material is added to fuse the two sheets together. When the top sheet is less than 0.028 inches thick a weld washer is required to avoid excessive burning of the sheets. Design is identical to AISC except that by not pre-punching the hole to be plugged, the effective diameter doesn't equal the diameter on the top surface.

Fillet Welds- fillet welds are essentially the same design in AISI and AISC specification, the only difference is in defining the critical section. Since cold formed sections are very thin often the leg of a fillet weld is equal to the thickness of the section. Usually failure of fillet welded joints occurs by the tearing of the sheet adjacent to the weld.

E3 Bolted Connections

For bolted connections in material thicker than 3/16" reference is made to the AISC specification. For materials thinner than 3/16" the AISI specification requires the same checks be made as for the thicker material.

E4 Screw Connections

Results of tests worldwide were analyzed to formulate the AISI specification's screw connection provisions.

Table C-E4-1 Nominal Diameter for Screws

Number Designation	Nominal Diameter, d in.	mm
0	0.060	1.52
1	0.073	1.85
2	0.086	2.18
3	0.099	2.51
4	0.112	2.84
5	0.125	3.18
6	0.138	3.51
7	0.151	3.84
8	0.164	4.17
10	0.190	4.83
12	0.216	5.49
1/4	0.250	6.35

Figure C-E4-1 Nominal Diameter for Screws

Screw connection tests used to formulate the provisions included single fastener as well as multiple fastener patterns. However, it is recommended that at least two screws should be used to connect individual elements. This provides redundancy against under-torquing, over-torquing, etc., and limits lap shear connection distortion of flat unformed members such as straps.

Proper installation of screws is important to achieve satisfactory performance. Power tools with adjustable torque controls and driving depth limitations are usually used.

Unlike bolts that are specified by diameter (e.g. ½″ diameter A325 bolt), screws are specified by a number designation; Table C-E4-1 gives the correlation between the common number designation and the nominal diameter for screws. See Figure C-E4-1 for the measurement of nominal diameters.

All E4 requirements shall apply to screws with 0.08 in. (2.03 mm) ≤d ≤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

Screw connections loaded in shear can fail in one mode or in combination of several modes. These modes are screw shear, edge tearing, tilting and subsequent pull-out of the screw, and bearing of the joined materials.

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These provisions are focused on the tilting and bearing failure modes. Tilting of the screw followed by threads tearing out of the lower sheet reduces the

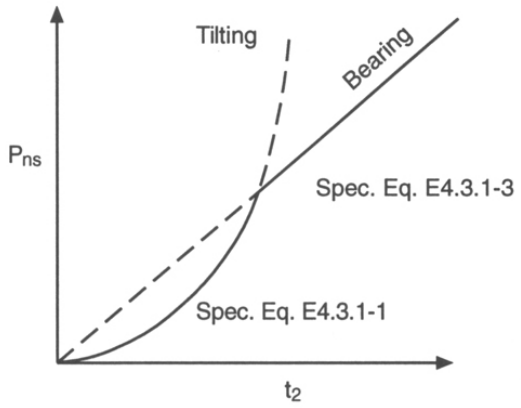


Figure C-E4.3-1 Comparison of Tilting and Bearing

connection shear capacity from that of the typical connection bearing strength (Figure C-E4.3-1). Two cases are given depending on the ratio of thicknesses of the connected members. Normally, the head of the screw will be in contact with the thinner material as shown in Figure C-E4.3-2. However, when both members are the same thickness, or when the thicker member is in contact with the screw head, tilting must also be considered as shown in Figure C-E4.3-3.

It is necessary to determine the lower bearing capacity of the two members based on the product of their respective thicknesses and tensile strengths.

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

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

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

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

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

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

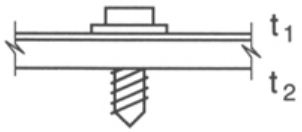
$P_{ns} = 2.7\,t_1\,d\,F_{u1}$ (*Eq.* E4.3.1-4)

$P_{ns} = 2.7\,t_2\,d\,F_{u2}$ (*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.

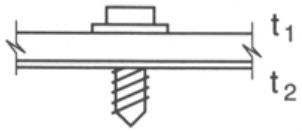
E4.3.2 Connection Shear Limited by End Distance

The nominal shear per fastener as limited by edge distance is the same as that specified for bolts.



tilting	N/A
bearing	$P_{ns} = 2.7\ t_1 d F_{u1}$ or
bearing	$P_{ns} = 2.7\ t_2 d F_{u2}$

Figure C-E4.3-2 Design Equations for $t_2/t_1 \geq 2.5$



tilting	$P_{ns} = 4.2\ (t_2^3 d)^{1/2} F_{u2}$ or
bearing	$P_{ns} = 2.7\ t_1 d F_{u1}$ or
bearing	$P_{ns} = 2.7\ t_2 d F_{u2}$

Figure C-E4.3-3 Design Equations for $t_2/t_1 \leq 1.0$

The nominal shear strength per screw, Pns shall not exceed that calculated as follows when the distance to an end of the connected part is parallel to the line of the applied force.

$P_{ns} = teF_u$ (Eq. E4.3.2-1)

Ω =3.00 (ASD)

ϕ =0.50 (LRFD)

where

t = Thickness of part in which end distance is measured

e = Distance measured in line of force from center of a standard hole to nearest end of connected part.

F_u = Tensile strength of part in which end distance is measured

E4.3.3 Shear in Screws

Shear strength [resistance] of the screw fastener itself should be known and documented from testing. Screw strength should be established and published by the manufacturer. In order to avoid the brittle and sudden shear fracture of the screw, the *Specification* limits the shear strength [resistance] to 0.80 times the shear strength of the screw as reported by the manufacturer or determined by independent laboratory testing.

The nominal shear strength [resistance] of the screw shall be taken as Pss.

In lieu of the value provided in Section E4, the factor of safety or resistance factor shall be permitted to be determined in accordance with Section F1 and shall be taken as $1.25\Omega \leq 3.0$ (ASD), or $\phi / 1.25 \geq 0.5$ (LRFD).

E4.4 Tension

Screw connections loaded in tension can fail either by pulling out of the screw from the sheet t_2 (pull-out) or pulling of material, t_1, over the screw head and the washer, if a washer is present, (pull-over) or by tensile fracture of the screw.

There are a variety of washers and head styles in use. Washers must be at least 0.050 inch (1.27 mm) thick to withstand bending forces with little or no deformation.

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

For the limit state of pull-out of the fastener from material t_2, *Specification* Equation E4.4.1-1 was derived

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

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

E4.4.2 Pull-Over

For the limit state of pull-over of material t_1, Specification Equation E4.4.2-1 was derived.

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

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

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

E4.4.3 Tension in Screws

Tensile strength [resistance] of the screw fastener itself should be known and documented from testing. Screw strength [resistance] should be established and published by the manufacturer.

The nominal tension strength [resistance] of the screw shall be taken as P_{nt}.

In lieu of the value provided in Section E4, the factor of safety or resistance factor shall be permitted to be determined in accordance with Section F1 and shall be taken as $1.25\Omega \leq 3.0$ (ASD), or $\phi / 1.25 \geq 0.5$ (LRFD).