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AISI Specification Provisions for Screw Connections

The following design provisions for screw connections were prepared by Subcommittee 3 on Connections of the AISI Committee on Specifications. It was approved by the AISI Committee on Specifications at its Feb. 6, 1993, meeting held in Nashville, Tenn. and will be included in future editions of the AISI Specifications.

A. *Provisions for Screw Connections—AISI Specification for the Design of Cold-Formed Steel Structural Members*

E4 Screw Connections

The following notation applies to this section:

d = nominal screw diameter
Ω = factor of safety = 3.0
P_{as} = allowable shear force per screw
P_{ns} = nominal shear strength per screw
P_{at} = allowable tension force per screw
P_{nt} = nominal tension strength per screw
P_{not} = pull-out force per screw
P_{nov} = pull-over force per screw
t_1 = thickness of member in contact with the screw head
t_2 = thickness of member not in contact with the screw head
F_{u1} = tensile strength of member in contact with the screw head
F_{u2} = tensile strength of member not in contact with the screw head

All E4 requirements shall apply to self-tapping screws with 0.08 in. $\leq d \leq$ 0.25 in. The screws shall be thread-forming or thread-cutting, with or without a self-drilling point. Alternatively, design values for a particular application shall be permitted to be based on tests according to Section F.* For diaphragm applications, Section D5* shall be used.

Screws shall be installed and tightened in accordance with the manufacturer's recommendations.

The tension force on the net section of each member joined by a screw connection shall not exceed T_a from Section C2* or P_a from Section E3.2.*

E4.1 Minimum Spacing

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

E4.2 Minimum Edge and End Distance

The distance from the center of a fastener to the edge of any part shall not be less than 3d. If the connection is subjected to shear force in one direction only, the minimum edge distance shall be reduced to 1.5d in the direction perpendicular to the force.

E4.3 Shear

E4.3.1 Connection Shear

The shear force per screw shall not exceed P_{as} calculated as follows:
$$P_{as} = P_{ns} / \Omega$$

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

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

$$P_{ns} = 2.7 \, t_1 \, d \, F_{u1} \qquad \text{(Eq. E4.3.2)}$$

$$P_{ns} = 2.7 \, t_2 \, d \, F_{u2} \qquad \text{(Eq. E4.3.3)}$$

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

$$P_{ns} = 2.7 \, t_1 \, d \, F_{u1} \qquad \text{(Eq. E4.3.4)}$$

$$P_{ns} = 2.7 \, t_2 \, d \, F_{u2} \qquad \text{(Eq. E4.3.5)}$$

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

*See AISI Specification, 1986 ed. with 1989 Addendum

E4.3.2 Shear in Screws

The shear capacity of the screw shall be determined by test according to Section F1(a).* The shear capacity of the screw shall not be less than 1.25 P_{ns}.

E4.4 Tension

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

The tension force per screw shall not exceed P_{at}, calculated as follows:

$$P_{at} = P_{nt} / \Omega \qquad \text{(Eq. E4.4.1)}$$

P_{nt} shall be taken as the lesser of P_{not} and P_{nov} as determined in Sections E4.4.1 and E4.4.2.

E4.4.1 Pull-Out

The pull-out force, P_{not}, shall be calculated as follows:

$$P_{not} = 0.85 \, t_c \, d \, F_{u2} \qquad \text{(Eq. E4.4.1.1)}$$

where t_c is the lesser of the depth of the penetration and the thickness, t_2.

E4.4.2 Pull-Over

The pull-over force, P_{nov}, shall be calculated as follows:

$$P_{nov} = 1.5 \, t_1 \, d_w \, F_{u1} \qquad \text{(Eq. E4.4.2.1)}$$

where d_w is the larger of the screw head diameter or the washer diameter, and shall be taken not larger than 1/2 in.

E4.4.3 Tension in Screws

The tensile capacity of the screw shall be determined by test according to Section F1(a)*. The tensile capacity of the screw shall not be less than 1.25 P_{nt}.

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*See AISI Specification, 1986 ed. with 1989 Addendum

B. Commentary on Section E4

E4. Screw Connections

Results of over 3500 tests worldwide were analyzed to formulate screw connection provisions (Reference R1). European Recommendations (Reference R2) and British Standards (Reference R3) were considered and modified as appropriate. Since the provisions apply to many different screw connections and fastener details, a greater degree of conservatism is implied than is otherwise typical within this Specification. These provisions are intended for use when a sufficient number of test results is not available for the particular application. A higher degree of accuracy can be obtained by testing any particular application (Reference R4).

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

Screw connection tests used to formulate the provisions included single fastener specimens as well as multiple fastener specimens. 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.

For the convenience of designers, Table 1 gives the correlation between the common number designation and the nominal diameter for screws.

Table 1

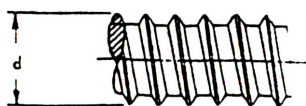| Number Designation	Nominal Diameter, d, in.*
0	0.0600
1	0.0730
2	0.0860
3	0.0990
4	0.1120
5	0.1250
6	0.1380
7	0.1510
8	0.1640
10	0.1900
12	0.2160
1/4	0.2500

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*See Figure 1.

Fig. 1

E4.1 Minimum Spacing

Minimum Spacing is the same as specified for bolts.

E4.2 Minimum Edge and End Distance

Tests have shown that screw connections loaded in shear will almost always exhibit edge failure when the distance from the center of the screw to the free edge is less than three times the diameter of the screw.

E4.3 Shear

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.

Tilting of the screw followed by threads tearing out of the lower sheet reduces the connection shear capacity from that of the typical connection bearing strength.
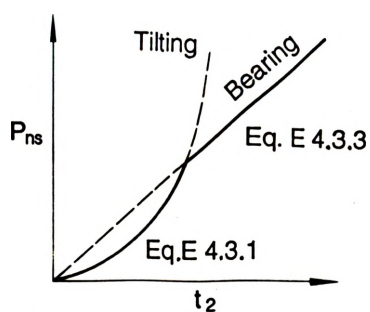

Fig. 2

These provisions are focused on the tilting and bearing failure modes. 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 3. However, when both members are the same thickness, or when the thicker member is in contact with the screw head, Equations E4.3.1, E4.3.2 and E4.3.3 apply as shown in Figure 4.

a) $t_2/t_1 \geq 2.5$
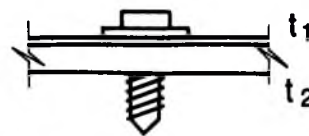
tilting   N/A

bearing $P_{ns} = 2.7\, t_1 d F_{u1}$ or

bearing $P_{ns} = 2.7\, t_2 d F_{u2}$

Fig. 3

b) $t_2/t_1 \leq 1.0$

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

Fig. 4

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

Shear capacity of the screw fastener itself should be known and documented from testing. Screw strength should be well established and published by the manufacturer.

E4.4 Tension

Screw connections loaded in tension can fail either by pulling out of the screw from the plate (pull-out) or pulling of material over the screw head and the washer, if a washer is present, (pull-over) or by tensile fracture of the screw. The serviceability concerns of gross distortion are not covered by the formulas given in E4.4.

Diameter and rigidity of the fastener head assembly as well as sheet thickness and tensile strength have a significant effect on the pull-over failure load of a connection.

There are a variety of washers and head styles in use. Washers must be at least .050 in. thick to withstand bending forces with little or no deformation.

References

R1.   Pekoz, T., "Design of Cold-Formed Steel Screw Connections," Proceedings of the Tenth International Specialty Conference on Cold-Formed Steel Structures, Oct. 23-24, 1990, University of Missouri-Rolla, Mo.

R2.   European Convention for Constructional Steelwork, "European Recommendations for the Design of Light Gage Steel Members," First Edition, 1987, Brussels, Belgium.

R3.   British Standards Institution, "British Standard-Structural Use of Steelwork in Building—Part 5. Code of Practice for Design of Cold-Formed Sections," BS 5950: Part 5:1987.

R4.   American Iron and Steel Institute, "Test Methods for Mechanically Fastened Cold-Formed Steel Connections", Research Report CF92-2, February 1992.

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