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Wei-Wen Yu Center for Cold-Formed Steel Structures

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AISI Specification Changes

This Technical Bulletin summarizes recently approved changes to Section J4 Screw Connections of the *North American Specification for the Design of Cold-Formed Steel Structural Members*, AISI S100. These approved Committee on Specifications changes will be published in the next edition of AISI S100. They are being summarized here to enable users of the specification to implement the new provisions with approval of the local building official. This information is printed with permission from the American Iron and Steel Institute.

J4 Screw Connections

In 2020, a research study (Stevens, Sputo, and Bridge, 2020) was undertaken to review the data available at that time on *connections* loaded in both shear and tension. The result of this research permitted the revision of *safety factors* and *resistance factors.*

Also in 2020, the research study by Stevens, et al.) indicated that an empirical modifier ($1.63\alpha t_c^{0.18}$) could be added to the resistance equation to better fit the available experimental data. Pull-out strength is related to the ratio of sheet *thickness* to thread pitch, but in the interest of practicality, instead of thread pitch, the sheet *thickness* alone was used in the calibration.

Stevens, et al. indicated that the existing pull-over equation adequately predicted the pull-over strength, except for low ductility sheets which are covered by *Specification* Section A3.1.3 (Elongation ≤ 3%) with *thickness* less than 0.023 inches (0.58 mm), where a reduction of 40% was warranted. For these thin sheets, it appears that the magnitude of the clamping force, and the geometry of the *connection* (including distance from the screw to adjacent stiffeners) is a factor (Kreiner and Ellifritt, 1998).

J4 Screw Connections

The provisions of this section shall apply to steel-to-steel screw *connections* within specified limitations used for *cold-formed steel structural members*. All provisions in Section J4 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 Chapter D.

For *diaphragm* applications, Section I2 shall be used.

The *safety factor* or *resistance factor* used to determine the *available strength* [*factored resistance*] in accordance with the applicable design method in Section B3.2.1, B3.2.2, or B3.2.3 shall be as indicated for the specific limit state.

Alternatively, design values for a particular application are permitted to be based on tests, with the *safety factor*, Ω, and the *resistance factor*, ϕ, determined in accordance with Section K2.

The following notation shall apply to Section J4:

d = Nominal screw diameter
d_h = Screw head diameter or hex washer head integral washer diameter
d_w = Steel washer diameter
d'_w = Effective pull-over resistance diameter
P_{nv} = *Nominal shear strength* [*resistance*] of sheet per screw
P_{nvs} = *Nominal shear strength* [*resistance*] of screw as reported by manufacturer or determined by independent laboratory testing
P_{not} = *Nominal pull-out strength* [*resistance*] of sheet per screw
P_{nov} = *Nominal pull-over strength* [*resistance*] of sheet per screw
P_{nts} = *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 or washer
t_2 = *Thickness* of member not in contact with screw head or washer
t_c = Lesser of depth of penetration and *thickness* t_2
F_{u1} = *Tensile strength* of member in contact with screw head or washer
F_{u2} = *Tensile strength* of member not in contact with screw head or washer

J4.1 Minimum Spacing

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

J4.2 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.

J4.3 Shear

J4.3.1 Shear Strength Limited by Tilting and Bearing

The *nominal shear strength* [*resistance*] of sheet per screw, P_{nv}, shall be determined in accordance with this section.

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

$$P_{nv} = 4.2\,(t_2^3 d)^{1/2} F_{u2} \quad \text{(Eq. J4.3.1-1)}$$

$$P_{nv} = 2.7\,t_1\,d\,F_{u1} \quad \text{(Eq. J4.3.1-2)}$$

$$P_{nv} = 2.7\,t_2\,d\,F_{u2} \quad \text{(Eq. J4.3.1-3)}$$

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

$P_{nv} = 2.7\, t_1\, d\, F_{u1}$ (*Eq.* J4.3.1-4)

$P_{nv} = 2.7\, t_2\, d\, F_{u2}$ (*Eq.* J4.3.1-5)

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

The following *safety* and *resistance factors* shall be used to determine the *available strength* [*factored resistance*]:

$\Omega = 2.80$ (*ASD*)

$\phi = 0.55$ (*LRFD*)

$= 0.45$ (*LSD*)

J4.3.2 Shear in Screws

The *nominal shear strength* [*resistance*] of the screw shall be taken as P_{nvs}. The following *safety* and *resistance factors* shall be used to determine the *available strength* [*factored resistance*]:

$\Omega = 3.00$ (*ASD*)

$\phi = 0.50$ (*LRFD*)

$= 0.40$ (*LSD*)

Alternatively, the *safety factor* or the *resistance factor* is permitted to be determined in accordance with Section K2.1 and shall be taken as $1.25\Omega \leq 3.0$ (*ASD*), $\phi/1.25 \geq 0.5$ (*LRFD*), or $\phi/1.25 \geq 0.4$ (*LSD*).

J4.4 Tension

For screws that carry tension, the head of the screw or washer, if a washer is provided, shall have a diameter d_h or d_w not less than 5/16 in. (7.94 mm). The nominal washer thickness shall be at least 0.050 in. (1.27 mm) for t_1 greater than 0.027 in. (0.686 mm) and at least 0.024 in. (0.610 mm) for t_1 equal to or less than 0.027 in. (0.686 mm). The washer shall be at least 0.063 in. (1.60 mm) thick when 5/8 in. (15.9 mm) $< d_w \leq$ 3/4 in. (19.1 mm).

J4.4.1 Pull-Out Strength

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

$P_{not} = 0.85\, t_c\, d\, F_{u2}\, [1.63(\alpha t_c)^{0.18}]$ (*Eq.* J4.4.1-1)

where

$\alpha = 1$ for t_c in inches

$= 0.0394$ for t_c in millimeters

The following *safety* and *resistance factors* shall be used to determine the *available strength* [*factored resistance*]:

$\Omega = 2.80$ (*ASD*)

$\phi = 0.55$ (*LRFD*)

$= 0.45$ (*LSD*)

J4.4.2 Pull-Over Strength

The *nominal pull-over strength* [*resistance*] of sheet per screw, P_{nov}, shall be calculated as

follows:

$$P_{nov} = 1.5t_1 d'_w F_{u1} \quad \text{(Eq. J4.4.2-1)}$$

Exception: For steel included in Section A3.1.3 (Elongation < 3%) with thickness of less than 0.023 in. (0.58 mm), the *nominal strength* [*resistance strength*] shall be calculated as follows:

$$P_{nov} = 0.90t_1 d'_w F_{u1} \quad \text{(Eq. J4.4.2-2)}$$

where

d'_w = Effective pull-over diameter determined in accordance with (a), (b), or (c) as follows:

(a) For a round head, hex head (Figure J4.4.2-1(1)), pancake screw washer head (Figure J4.4.2-1(2)), or hex washer head (Figure J4.4.2-1(3)) screw with an independent and solid steel washer beneath the screw head:

$$d'_w = d_h + 2t_w + t_1 \le d_w \quad \text{(Eq. J4.4.2-3)}$$

where

t_w = Steel washer thickness

(b) For a round head, a hex head, or a hex washer head screw without an independent washer beneath the screw head:

$d'_w = d_h$ but not larger than 3/4 in. (19.1 mm)

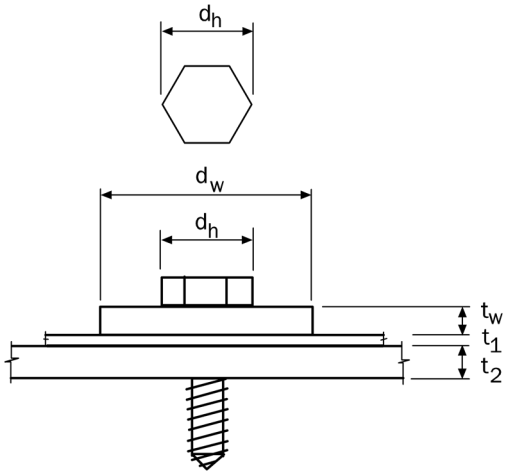
(c) For a domed (non-solid and either independent or integral) washer beneath the screw head (Figure J4.4.2-1(4)), it is permitted to use d'_w as calculated in Eq. J4.4.2-3, where t_w is the thickness of the domed washer. In the equation, d'_w shall not exceed 3/4 in. (19.1 mm).

The following *safety* and *resistance factors* shall be used to determine the *available strength* [*factored resistance*]:

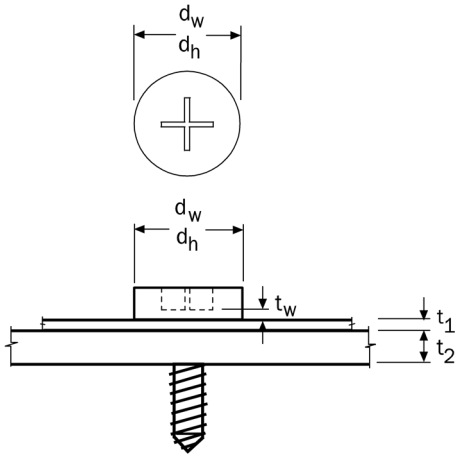
Ω = 2.90 (*ASD*)

ϕ = 0.55 (*LRFD*)

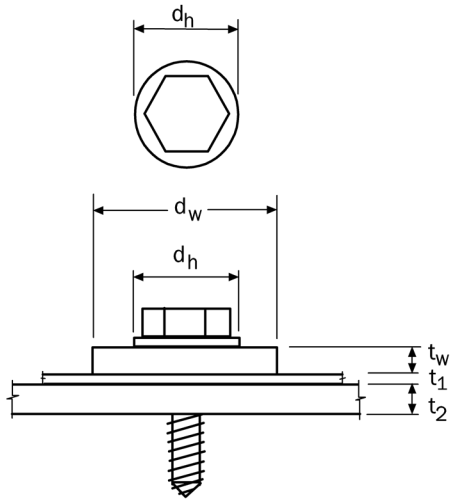
= 0.40 (*LSD*)



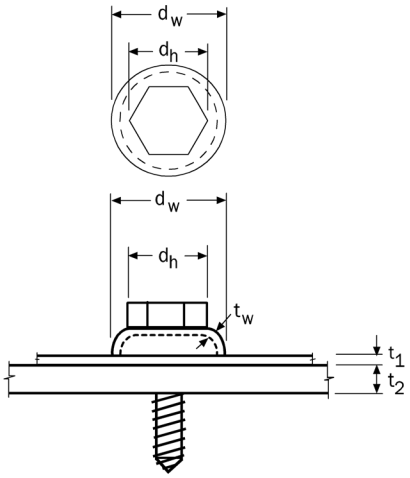
(1) Flat Steel Washer Beneath Hex Head Screw Head



(2) Pancake Screw Washer Head



(3) Flat Steel Washer Beneath Hex Washer Head Screw Head (HWH has Integral Solid Washer)



(4) Domed Washer (Non-Solid) Beneath Screw Head

Figure J4.4.2-1 Screw Pull-Over With Washer

J4.4.3 Tension in Screws

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

The following *safety* and *resistance factors* shall be used to determine the *available strength* [*factored resistance*]:

Ω = 3.00 (*ASD*)

ϕ = 0.50 (*LRFD*)

= 0.40 (*LSD*)

Alternatively, the *safety factor* or the *resistance factor* is permitted to be determined in accordance with Section K2.1 and shall be taken as $1.25\Omega \leq 3.0$ (*ASD*), $\phi/1.25 \geq 0.5$ (*LRFD*),

or $\phi/1.25 \geq 0.4$ (*LSD*).

J4.5 Combined Shear and Tension

J4.5.1 Combined Shear and Pull-Over

For a screw *connection* subjected to combined shear and pull-over, the *required shear strength* [shear due to *factored loads*], $\overline{V}$, and *required tension strength* [tension due to *factored loads*], $\overline{T}$, shall not exceed the corresponding *available strength* [*factored resistance*] determined by Sections J4.3 and J4.4, respectively.

In addition, the following requirements shall be met:

$$\frac{\overline{V}}{P_{nv}} + 0.71\frac{\overline{T}}{P_{nov}} \leq \frac{1.10}{\Omega} \qquad (ASD) \qquad (Eq.\ J4.5.1\text{-}1a)$$

$$\frac{\overline{V}}{P_{nv}} + 0.71\frac{\overline{T}}{P_{nov}} \leq 1.10\phi \qquad (LRFD,\ LSD) \qquad (Eq.\ J4.5.1\text{-}1b)$$

where

$\overline{V}$ = *Required shear strength* [shear force due to *factored loads*] per *connection* screw, determined in accordance with *ASD*, *LRFD*, or *LSD load combinations*

$\overline{T}$ = *Required tension strength* [tensile force due to *factored loads*] per *connection* screw, determined in accordance with *ASD*, *LRFD*, or *LSD load combinations*

P_{nv} = *Nominal shear strength* [*resistance*] of sheet per screw

$$= 2.7t_1dF_{u1} \qquad (Eq.\ J4.5.1\text{-}2)$$

P_{nov} = *Nominal pull-over strength* [*resistance*] of sheet per screw

$$= 1.5t_1d_wF_{u1} \qquad (Eq.\ J4.5.1\text{-}3)$$

where

d_w = Larger of screw head diameter or washer diameter

Ω = 2.35 (*ASD*)

ϕ = 0.65 (*LRFD*)

= 0.55 (*LSD*)

Eq. J4.5.1-1 shall be valid for *connections* that meet the following limits:

(a) 0.0285 in. (0.724 mm) $\leq t_1 \leq$ 0.0445 in. (1.13 mm),
(b) No. 12 and No. 14 self-drilling screws with or without washers,
(c) $d_w \leq$ 0.75 in. (19.1 mm),
(d) Washer dimension limitations of Section J4.4 apply,
(e) $F_{u1} \leq$ 70 ksi (483 MPa or 4920 kg/cm^2), and
(f) $t_2/t_1 \geq 2.5$.

For eccentrically loaded *connections* that produce a nonuniform pull-over force on the screw, the *nominal pull-over strength* [*resistance*] shall be taken as 50 percent of P_{nov}.

J4.5.2 Combined Shear and Pull-Out

For a screw connection subjected to combined shear and pull-over, the *required shear strength* [shear due to *factored loads*], $\overline{V}$, and *required tension strength* [tension due to *factored*

loads], $\overline{T}$, shall not exceed the corresponding *available strength* [*factored resistance*] determined by Sections J4.3 and J4.4, respectively.

In addition, the following requirement shall be met:

$$\frac{\overline{V}}{P_{nv}}+\frac{\overline{T}}{P_{not}}\le\frac{1.15}{\Omega} \qquad (ASD) \qquad (Eq.\ J4.5.2\text{-}1a)$$

$$\frac{\overline{V}}{P_{nv}}+\frac{\overline{T}}{P_{not}}\le 1.15\phi \qquad (LRFD,\ LSD) \qquad (Eq.\ J4.5.2\text{-}1b)$$

where

P_{nv} = *Nominal shear strength* [*resistance*] of sheet per screw

$$= 4.2(t_2^3 d)^{1/2} F_{u2} \qquad (Eq.\ J4.5.2\text{-}2)$$

P_{not} = *Nominal pull-out strength* [*resistance*] of sheet per screw

$$= 0.85 t_c d F_{u2} \qquad (Eq.\ J4.5.2\text{-}3)$$

Ω = 2.55 (*ASD*)

ϕ = 0.60 (*LRFD*)

= 0.50 (*LSD*)

Other variables are as defined in Section J4.5.1.

Eq. J4.5.2-1 shall be valid for *connections* that meet the following limits:

(a) 0.0297 in. (0.754 mm) $\le t_2 \le$ 0.0724 in. (1.84 mm),

(b) No. 8, 10, 12, or 14 self-drilling screws with or without washers,

(c) $F_{u2} \le$ 121 ksi (834MPa or 8510 kg/cm^2), and

(d) $1.0 \le F_u/F_y \le 1.62$.

J4.5.3 Combined Shear and Tension in Screws

For screws subjected to a combination of shear and tension forces, the *required shear strength* [shear due to *factored loads*], $\overline{V}$, and *required tension strength* [tension due to *factored loads*], $\overline{T}$, shall not exceed the corresponding *available strength* [*factored resistance*] determined by Sections J4.3.2 and J4.4.3, respectively.

In addition, the following requirement shall be met:

$$\frac{\overline{V}}{P_{nvs}}+\frac{\overline{T}}{P_{nts}}\le\frac{1.3}{\Omega} \qquad (ASD) \qquad (Eq.\ J4.5.3\text{-}1a)$$

$$\frac{\overline{V}}{P_{nvs}}+\frac{\overline{T}}{P_{nts}}\le 1.3\phi \qquad (LRFD,\ LSD) \qquad (Eq.\ J4.5.3\text{-}1b)$$

where

$\overline{V}$ = *Required shear strength* [shear force due to *factored loads*], determined in accordance with *ASD*, *LRFD,* or *LSD load combinations*

$\overline{T}$ = *Required tension strength* [tensile force due to *factored loads*], determined in accordance with *ASD*, *LRFD,* or *LSD load combinations*

P_{nvs} = *Nominal shear strength* [*resistance*] of screw as reported by manufacturer or determined by independent laboratory testing

P_{nts} = *Nominal tension strength* [*resistance*] of screw as reported by manufacturer or determined by independent laboratory testing

Ω = 3.00 (*ASD*)
ϕ = 0.50 (*LRFD*)
= 0.40 (*LSD*)

References:

Kreiner, J.S., and Ellifritt, D.S. (1998) "Understanding Pullover" (1998), *Proceedings of the 14th International Specialty Conference on Cold-Formed Steel Structures*. University of Missouri-Rolla, Rolla MO (November 1998)

Stevens, T., Sputo, T., and Bridge, J. (2020) "Strength of Steel-to-Steel Screw Connections – Update to Provisions," Proceedings of Cold-Formed Steel Research Consortium Colloquium 2020, https://jscholarship.library.jhu.edu/handle/1774.2/63180

Disclaimer

The material contained herein has been developed by a joint effort of the American Iron and Steel Institute (AISI) Committee on Specifications, CSA Group Technical Committee on Cold Formed Steel Structural Members (S136), and Camara Nacional de la Industria del Hierro y del Acero (CANACERO) in Mexico. The organizations and the Committees have made a diligent effort to present accurate, reliable, and useful information on cold-formed steel design. The Committees acknowledge and are grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject. Specific references are included in the Commentary on the Specification.

With anticipated improvements in understanding of the behavior of cold-formed steel and the continuing development of new technology, this material may eventually become dated. It is anticipated that future editions of this Specification will update this material as new information becomes available, but this cannot be guaranteed.

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