① Relation between $F_U \rightarrow F_{nt}$

F_{nv}

② Bearing and tear out

Relation between F_u & F_{nv} C_a & C_b Factors

The nominal shear strength, F_{nv}, is based on the ultimate tensile stress of the bolt with several modification factors. First, the ultimate shear stress is taken as 0.625 times the ultimate tensile stress (Fisher et al., 1978). Next, there is a length factor of 0.90 for connections no longer than 38 inches (for longer connections, this factor is reduced to 0.75). If the threads are in the plane of shear, the reduction of the bolt area is accounted for by using 80% of the nominal bolt area. Instead of applying this reduction directly to the bolt area, a factor of 0.80 is applied to F_{nv}. In this way, the nominal bolt area can be used whether the threads are in or out of the plane of shear. For example, the ultimate tensile strength of a Group A bolt is 120 ksi, so the nominal shear strength with the threads not in the shear plane is

$$F_{nv} = 120(0.625)(0.90) = 67.5 \text{ ksi}$$

If the threads are in the shear plane,

$$F_{nv} = 0.8(67.5) = 54 \text{ ksi}$$

$$F_{nv} = 0.625(F_u)(C_a)(C_b)$$

C_a : Length Factor

C_b : Threaded Factor

F_u: Ultimate strength

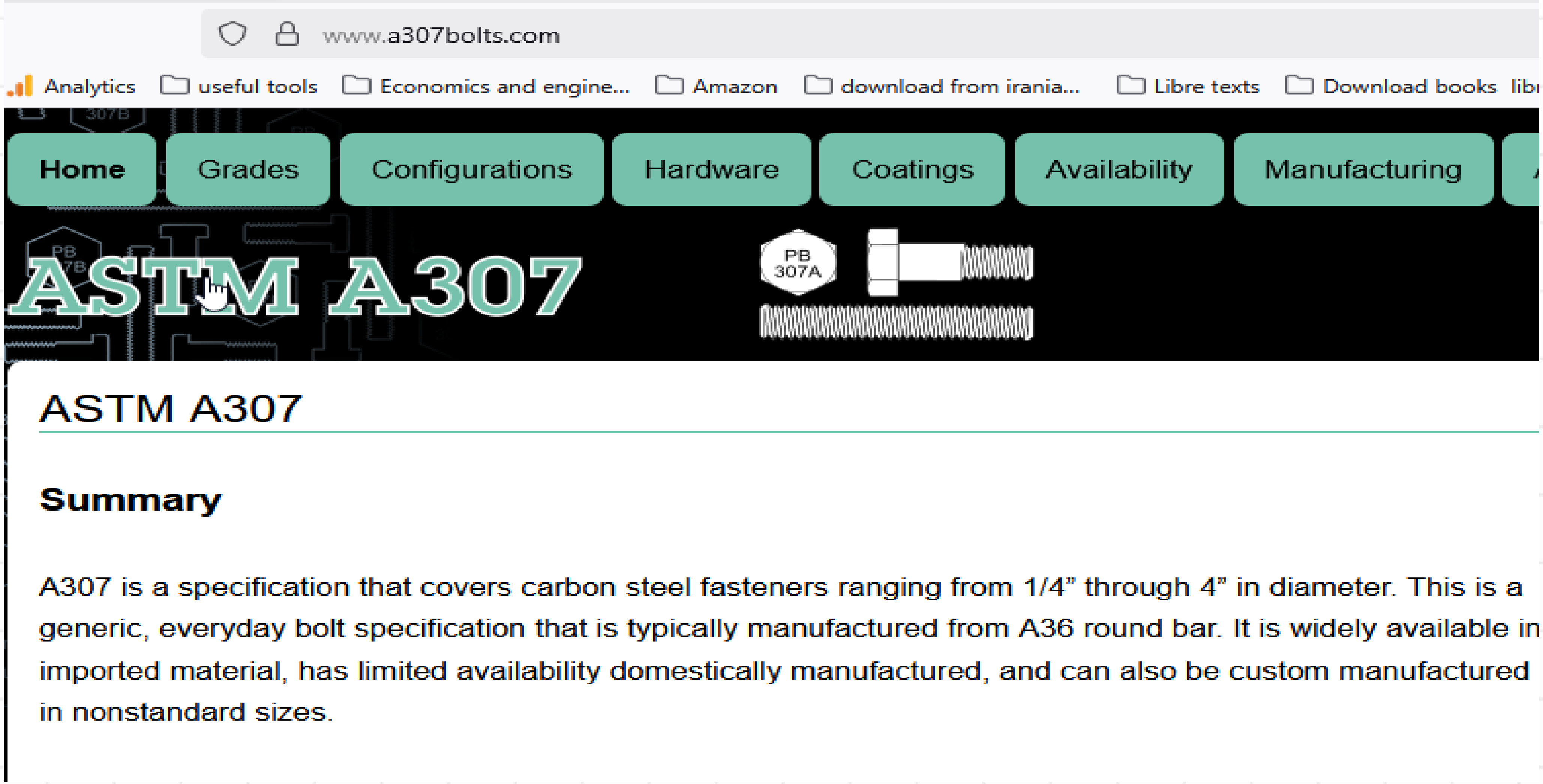
F_{nv}: Nominal shear value

$C_a = 0.90 \leq 38''$ | $C_b = 0.80$ N-Type

$C_a = 0.75 > 38''$ | $C_b = 1$ X-Type

ℓ of connection

Carbon steel Bolts

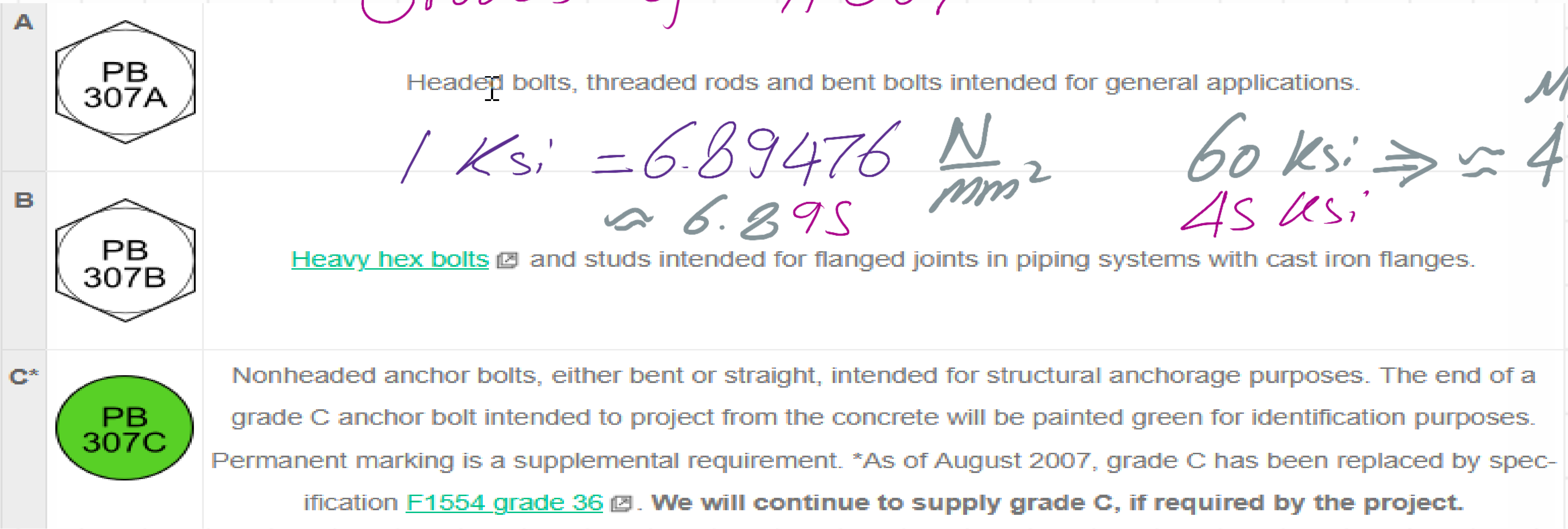


ASTM A307

Summary

A307 is a specification that covers carbon steel fasteners ranging from 1/4" through 4" in diameter. This is a generic, everyday bolt specification that is typically manufactured from A36 round bar. It is widely available in imported material, has limited availability domestically manufactured, and can also be custom manufactured in nonstandard sizes.

Grades of A307



A	PB 307A	Headed bolts, threaded rods and bent bolts intended for general applications.
B	PB 307B	Heavy hex bolts and studs intended for flanged joints in piping systems with cast iron flanges.
C*	PB 307C	Nonheaded anchor bolts, either bent or straight, intended for structural anchorage purposes. The end of a grade C anchor bolt intended to project from the concrete will be painted green for identification purposes. Permanent marking is a supplemental requirement. *As of August 2007, grade C has been replaced by specification F1554 grade 36. **We will continue to supply grade C, if required by the project.**

$1 \text{ Ksi} = 6.89476 \frac{N}{mm^2}$

≈ 6.895

$60 \text{ ksi} \Rightarrow \approx 415$ Mpa

45 ksi

A307 bolt }

$F_U = 60 \text{ ksi} \Rightarrow (415 \text{ Mpa})$

$F_{Ut} = 0.75 F_U = 45 \text{ ksi}$ (310 MPa)

$F_{nv} = 0.60 F_{Ut} = 0.6(0.75)(60) = 27 \text{ ksi}$ (155 Mpa)

Group A325

A325 bolt } $F_U = 120$ ksi ⇒ (830 Mpa)

$F_{Ut} = 0.75 F_U = 0.75(120) = 90$ ksi (620 MPA)

$F_{nv} = 0.625 (F_U) C_a C_b$

$\boxed{C_a = 0.90}$

$C_b = 0.80 \rightarrow$ N-Typ

or $C_b = 1 \rightarrow$ X-

A325-N $= 0.625(120)(0.9)(0.80)$

$= 54$ Ksi → (372 Mpa)

A325-X

$F_{nv} = 0.625(120)(0.90)(1) = 67.50$ ksi

$F_{nv} \simeq 68$ ksi → (469 MPA)

Group B - A490

A490 bolt

$F_u = 150$ ksi $\Rightarrow$ (1035 MPA)

$F_{ut} = 0.75 F_u = 0.75(150) = 112.5$ ksi

$F_{ut} \simeq 113$ ksi $\Rightarrow$ (780 MPA)

A490

$F_{nv} = 0.625(F_u)\, C_a C_b$

$\boxed{C_a = 0.90}$

$C_b = 0.80 \rightarrow$ N-Typ

$C_b = 1 \rightarrow$ X-

A490-N $= 0.625(150)(0.9)(0.80)$

$= 67.5$ ksi $\Rightarrow$ (68 ksi) or $\rightarrow \boxed{469 \text{ MPA}}$

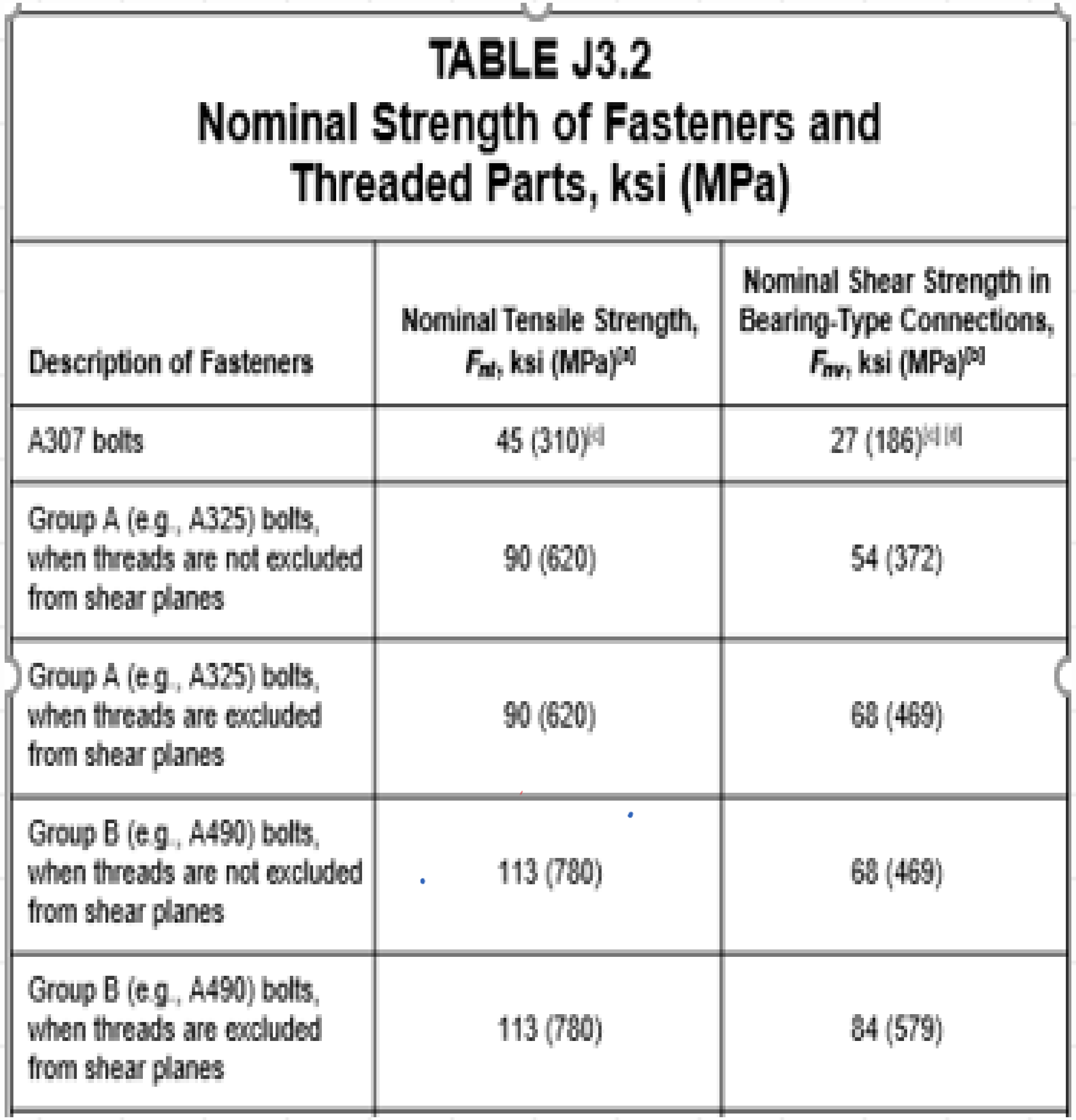
A490-X

$F_{nv} = 0.625(150)(0.90)(1) = 84.4$ ksi

$F_{nv} \simeq 84$ ksi $\Rightarrow$ (579 MPA)

Group C ⇒ $F_U = 200$ ksi

$F_{Ut} \Rightarrow 0.75(200) = 150$ ksi



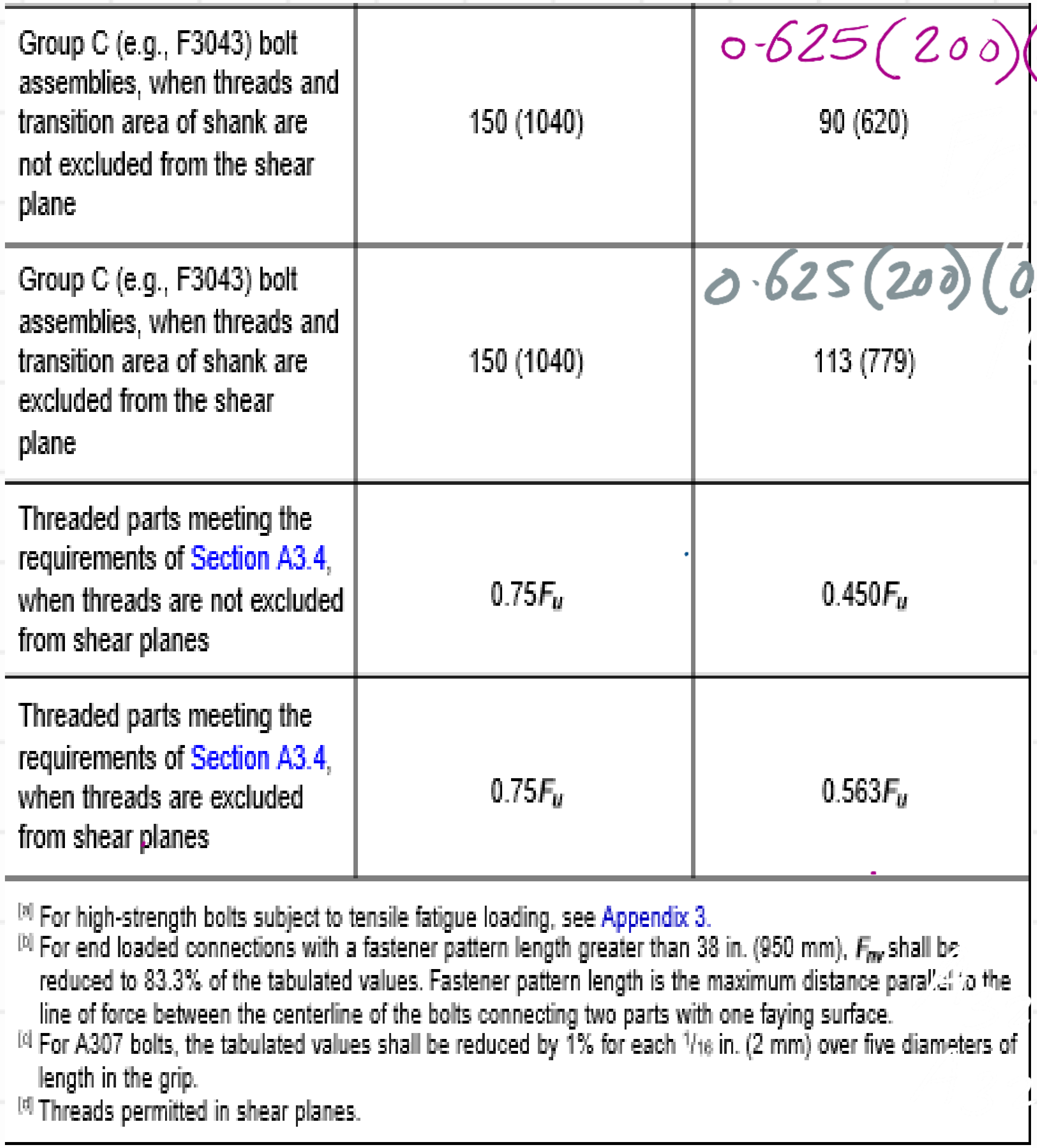


TABLE J3.2
Nominal Strength of Fasteners and Threaded Parts, ksi (MPa)

Description of Fasteners	Nominal Tensile Strength, F_{nt}, ksi (MPa)[a]	Nominal Shear Strength in Bearing-Type Connections, F_{nv}, ksi (MPa)[b]
A307 bolts	45 (310)[c]	27 (186)[c][d]
Group A (e.g., A325) bolts, when threads are not excluded from shear planes	90 (620)	54 (372)
Group A (e.g., A325) bolts, when threads are excluded from shear planes	90 (620)	68 (469)
Group B (e.g., A490) bolts, when threads are not excluded from shear planes	113 (780)	68 (469)
Group B (e.g., A490) bolts, when threads are excluded from shear planes	113 (780)	84 (579)
Group C (e.g., F3043) bolt assemblies, when threads and transition area of shank are not excluded from the shear plane	150 (1040)	$0.625(200)(0.72)$ 90 (620)
Group C (e.g., F3043) bolt assemblies, when threads and transition area of shank are excluded from the shear plane	150 (1040)	$0.625(200)(0.8)$ 113 (779)
Threaded parts meeting the requirements of Section A3.4, when threads are not excluded from shear planes	$0.75F_u$	$0.450F_u$
Threaded parts meeting the requirements of Section A3.4, when threads are excluded from shear planes	$0.75F_u$	$0.563F_u$

[a] For high-strength bolts subject to tensile fatigue loading, see Appendix 3.

[b] For end loaded connections with a fastener pattern length greater than 38 in. (950 mm), F_{nv} shall be reduced to 83.3% of the tabulated values. Fastener pattern length is the maximum distance parallel to the line of force between the centerline of the bolts connecting two parts with one faying surface.

[c] For A307 bolts, the tabulated values shall be reduced by 1% for each 1/16 in. (2 mm) over five diameters of length in the grip.

[d] Threads permitted in shear planes.

Bolt Council

Table 5.1. Nominal Strengths per Unit Area of Bolts → 2014

Applied Load Condition $F_n = 0.75\,F_u$			*Nominal Strength* per Unit Area, F_n, ksi	
			ASTM A325 or F1852	ASTM A490 or F2280
Tension [a]	Static		90	113 $\rightarrow 150(0.75) = 112.5$ ksi
	Fatigue		See Section 5.5	
Shear [a,b]	N Threads included in shear plane	$L_s \le 38$ in.	54 $C_a = 1$	68 $\leftarrow C_b = 0.8$
		$L_s > 38$ in.	45 $C_a = 0.9$	56 $C_b = 1$
	X Threads excluded from shear plane	$L_s \le 38$ in.	68 $C_a = 1$	84 $\leftarrow C_b = 0.80$
		$L_s > 38$ in.	56 $C_a = 0.9$	70 $C_b = 1$

[a] Except as required in Section 5.2.

[b] Reduction for values for $L_s > 38$ in. applies only when the joint is end loaded, such as splice plates on a beam or column flange.

$C_a = 0.90$

C_b X = 1

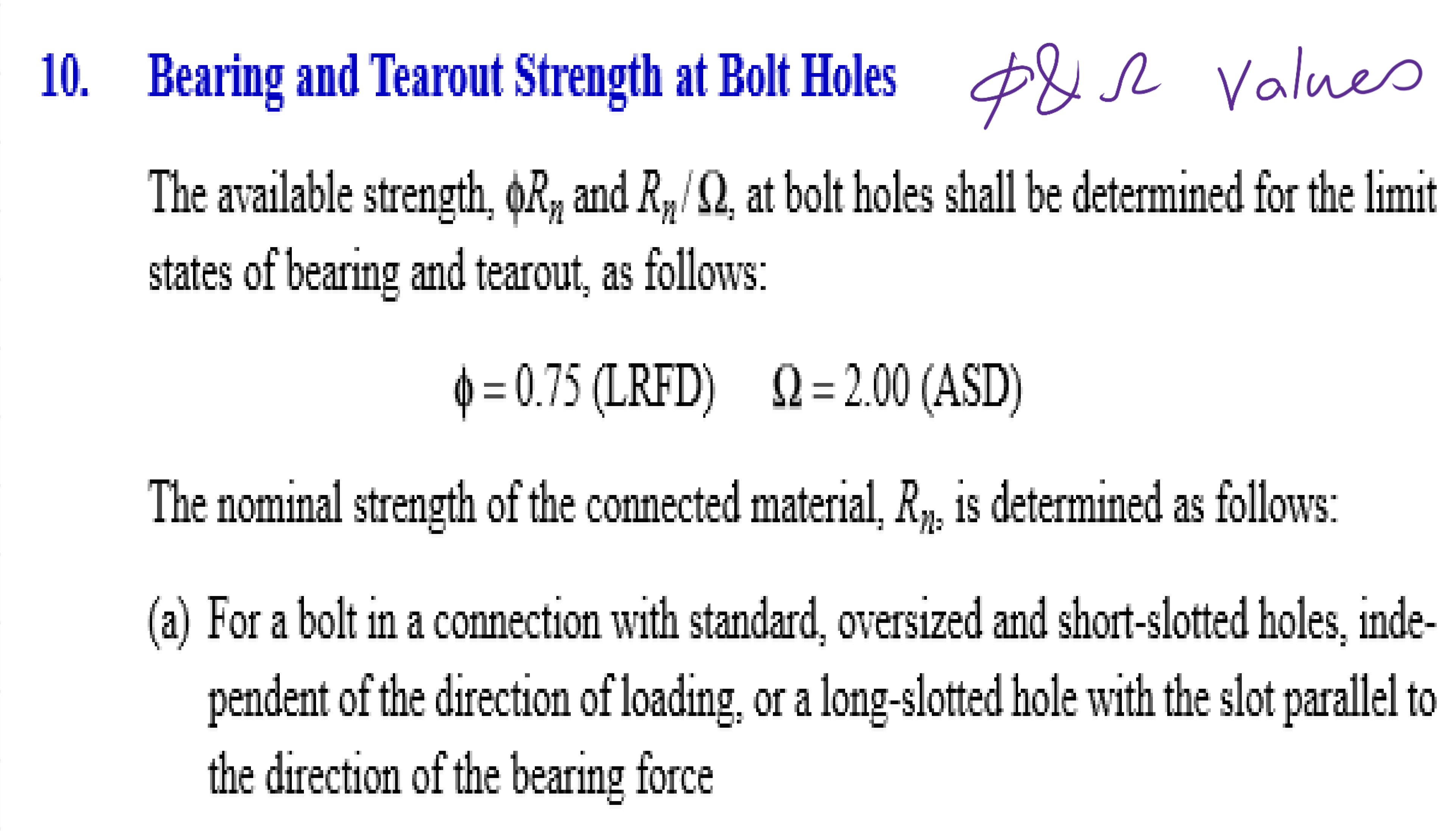
N = 0.8

F_n = nominal strength per unit area from Table 5.1 for the appropriate applied load conditions, ksi, adjusted for the presence of fillers as required below, and,

A_b = cross-sectional area based upon the nominal diameter of bolt, in.^{2}

A490 - X $F_{nv} = F_u(0.625)(C_a)(C_b) =$

N $= F_u(0.625)(C_a)(C_b) =$



10. Bearing and Tearout Strength at Bolt Holes

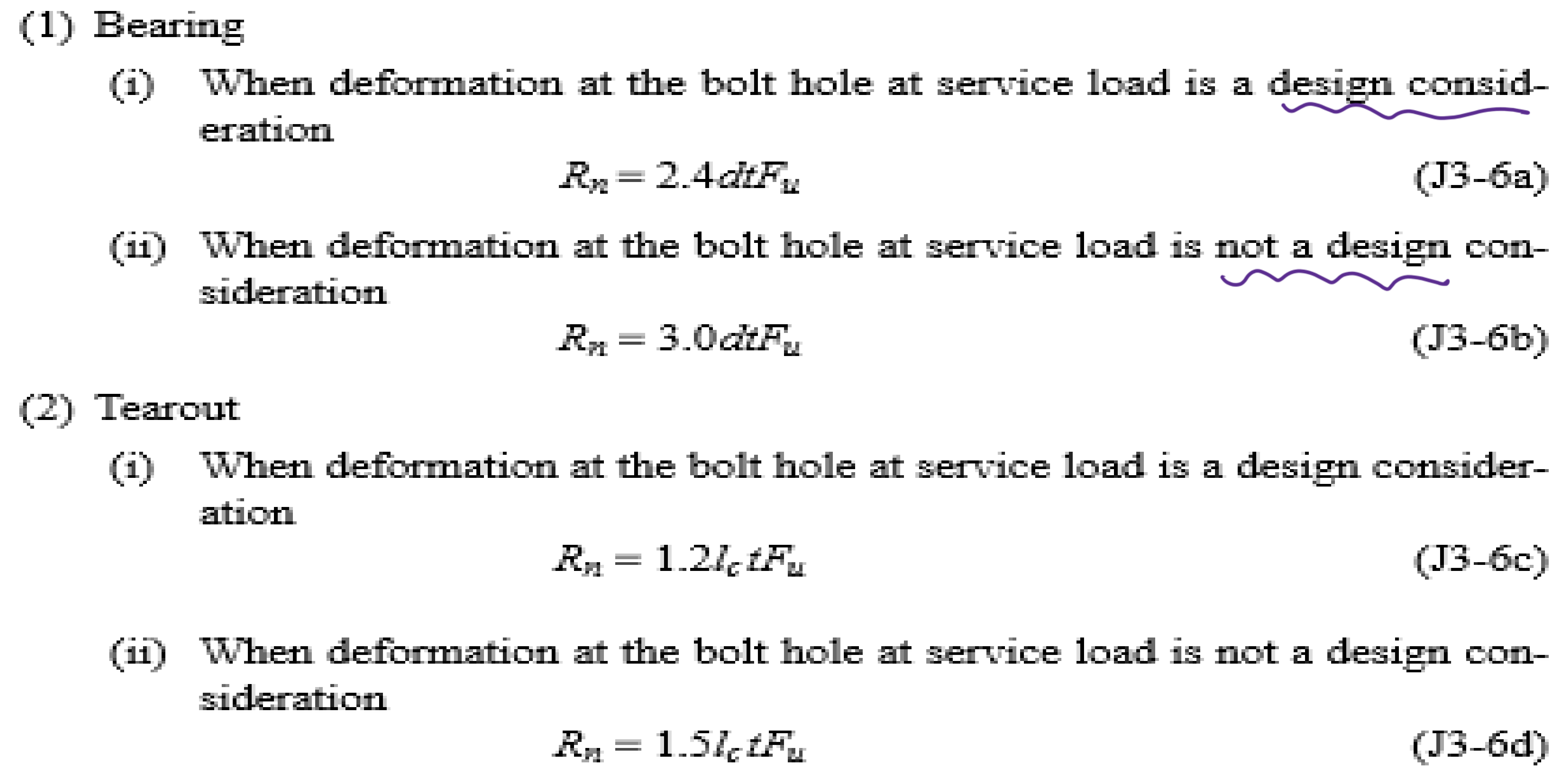
ϕ & Ω values

The available strength, ϕR_n and R_n / Ω, at bolt holes shall be determined for the limit states of bearing and tearout, as follows:

$$\phi = 0.75 \text{ (LRFD)} \qquad \Omega = 2.00 \text{ (ASD)}$$

The nominal strength of the connected material, R_n, is determined as follows:

(a) For a bolt in a connection with standard, oversized and short-slotted holes, independent of the direction of loading, or a long-slotted hole with the slot parallel to the direction of the bearing force



(1) Bearing

(i) When deformation at the bolt hole at service load is a design consideration

$$R_n = 2.4dtF_u \tag{J3-6a}$$

(ii) When deformation at the bolt hole at service load is not a design consideration

$$R_n = 3.0dtF_u \tag{J3-6b}$$

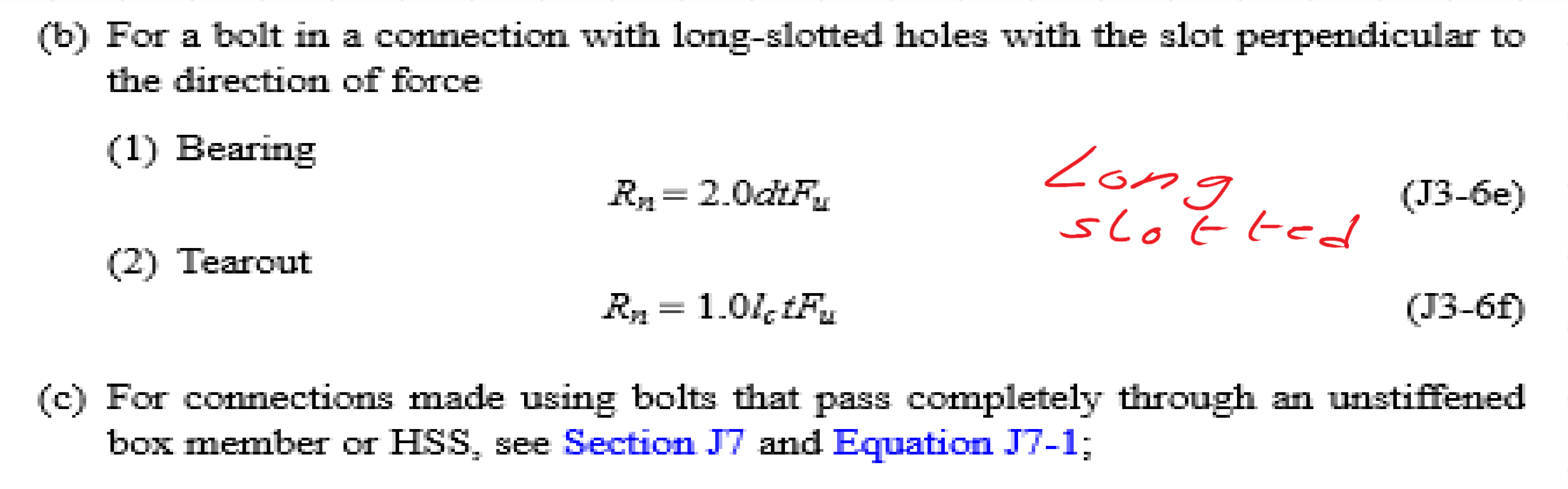
(2) Tearout

(i) When deformation at the bolt hole at service load is a design consideration

$$R_n = 1.2l_c tF_u \tag{J3-6c}$$

(ii) When deformation at the bolt hole at service load is not a design consideration

$$R_n = 1.5l_c tF_u \tag{J3-6d}$$



(b) For a bolt in a connection with long-slotted holes with the slot perpendicular to the direction of force

(1) Bearing

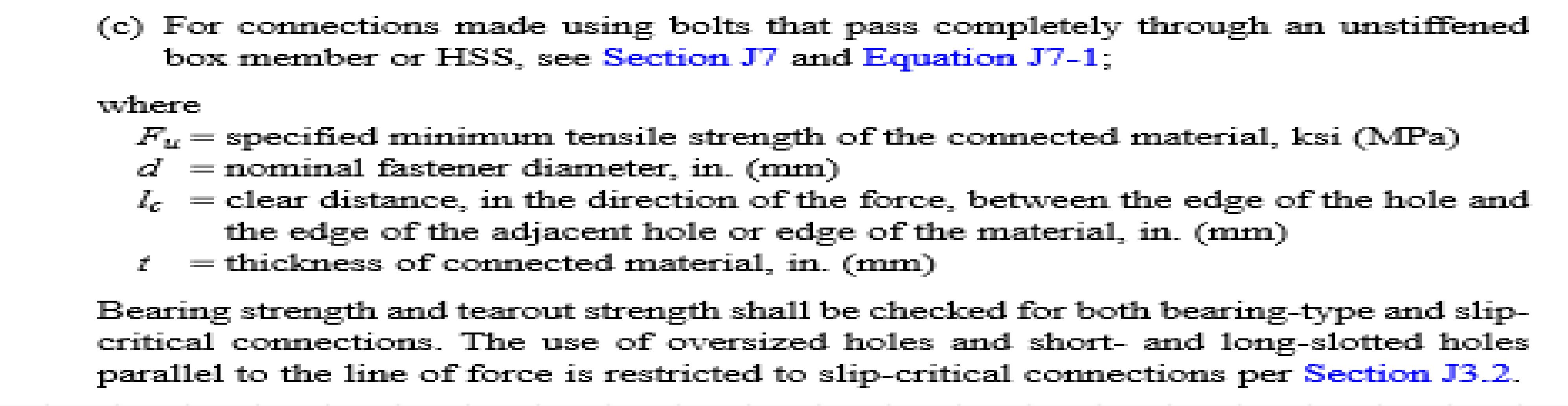
$$R_n = 2.0dtF_u \tag{J3-6e}$$

Long slotted

(2) Tearout

$$R_n = 1.0l_c tF_u \tag{J3-6f}$$

(c) For connections made using bolts that pass completely through an unstiffened box member or HSS, see Section J7 and Equation J7-1;



(c) For connections made using bolts that pass completely through an unstiffened box member or HSS, see Section J7 and Equation J7-1;

where

F_u = specified minimum tensile strength of the connected material, ksi (MPa)
d = nominal fastener diameter, in. (mm)
l_c = clear distance, in the direction of the force, between the edge of the hole and the edge of the adjacent hole or edge of the material, in. (mm)
t = thickness of connected material, in. (mm)

Bearing strength and tearout strength shall be checked for both bearing-type and slip-critical connections. The use of oversized holes and short- and long-slotted holes parallel to the line of force is restricted to slip-critical connections per Section J3.2.

Nominal hole in inches For different Types

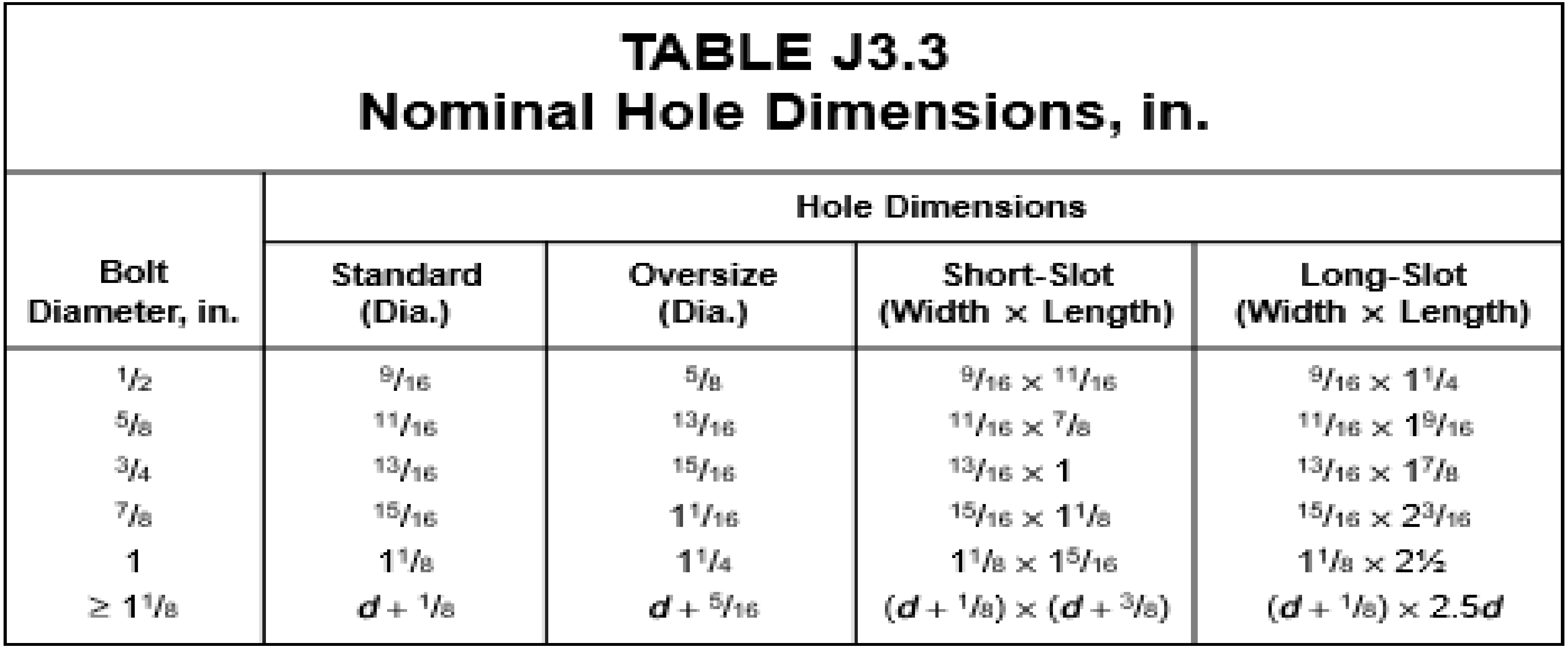


TABLE J3.3
Nominal Hole Dimensions, in.

Bolt Diameter, in.	Hole Dimensions			
	Standard (Dia.)	Oversize (Dia.)	Short-Slot (Width × Length)	Long-Slot (Width × Length)
$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{9}{16} \times \frac{11}{16}$	$\frac{9}{16} \times 1\frac{1}{4}$
$\frac{5}{8}$	$\frac{11}{16}$	$\frac{13}{16}$	$\frac{11}{16} \times \frac{7}{8}$	$\frac{11}{16} \times 1\frac{9}{16}$
$\frac{3}{4}$	$\frac{13}{16}$	$\frac{15}{16}$	$\frac{13}{16} \times 1$	$\frac{13}{16} \times 1\frac{7}{8}$
$\frac{7}{8}$	$\frac{15}{16}$	$1\frac{1}{16}$	$\frac{15}{16} \times 1\frac{1}{8}$	$\frac{15}{16} \times 2\frac{3}{16}$
1	$1\frac{1}{8}$	$1\frac{1}{4}$	$1\frac{1}{8} \times 1\frac{5}{16}$	$1\frac{1}{8} \times 2\frac{1}{2}$
$\geq 1\frac{1}{8}$	$d + \frac{1}{8}$	$d + \frac{5}{16}$	$(d + \frac{1}{8}) \times (d + \frac{3}{8})$	$(d + \frac{1}{8}) \times 2.5d$

RCSC standards → bolt Council

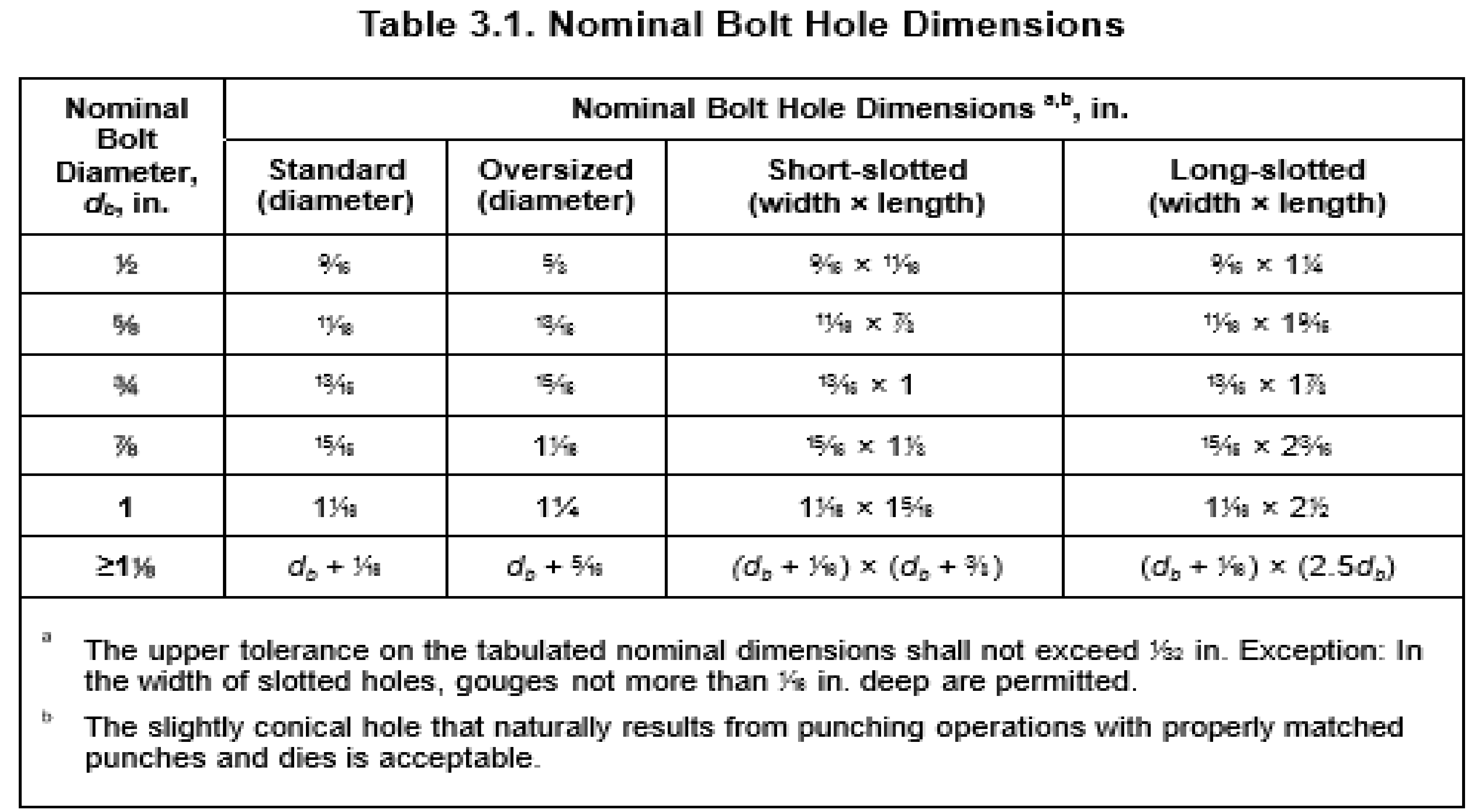


Table 3.1. Nominal Bolt Hole Dimensions

Nominal Bolt Diameter, d_b, in.	Nominal Bolt Hole Dimensions [a,b], in.			
	Standard (diameter)	Oversized (diameter)	Short-slotted (width × length)	Long-slotted (width × length)
½	9/16	5/8	9/16 × 11/16	9/16 × 1¼
5/8	11/16	13/16	11/16 × 7/8	11/16 × 1 9/16
¾	13/16	15/16	13/16 × 1	13/16 × 1 7/8
7/8	15/16	1 1/16	15/16 × 1⅛	15/16 × 2 3/16
1	1 1/16	1¼	1 1/16 × 1 5/16	1 1/16 × 2½
≥1⅛	d_b + 1/16	d_b + 5/16	(d_b + 1/16) × (d_b + 3/8)	(d_b + 1/16) × (2.5d_b)

[a] The upper tolerance on the tabulated nominal dimensions shall not exceed 1/32 in. Exception: In the width of slotted holes, gouges not more than 1/16 in. deep are permitted.

[b] The slightly conical hole that naturally results from punching operations with properly matched punches and dies is acceptable.

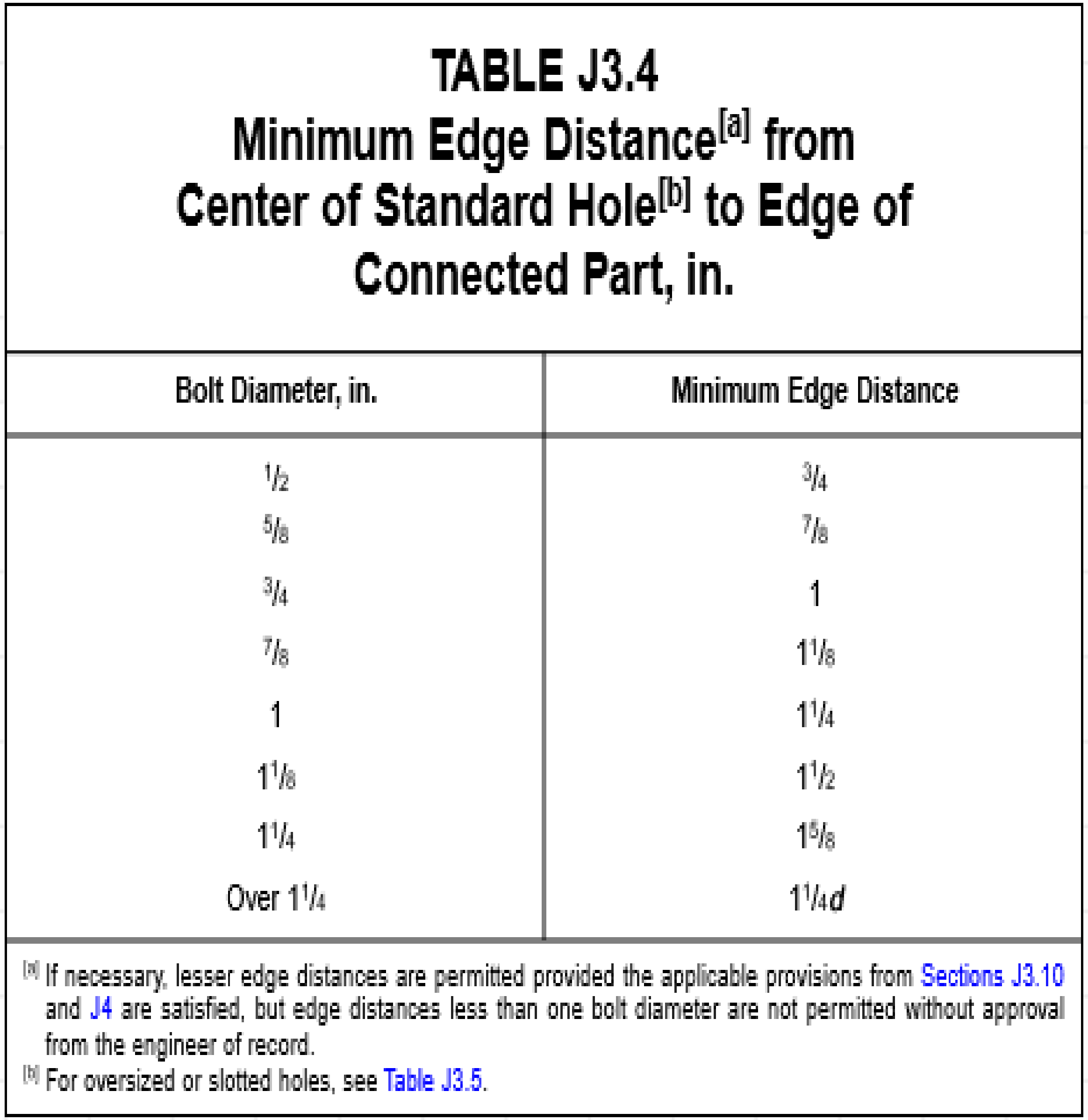
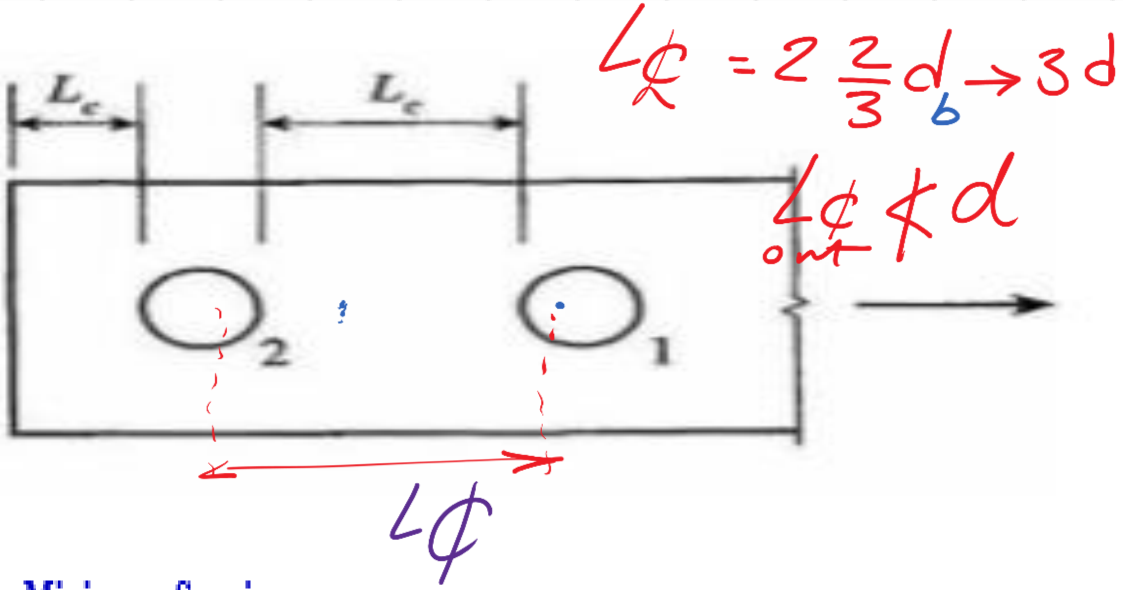


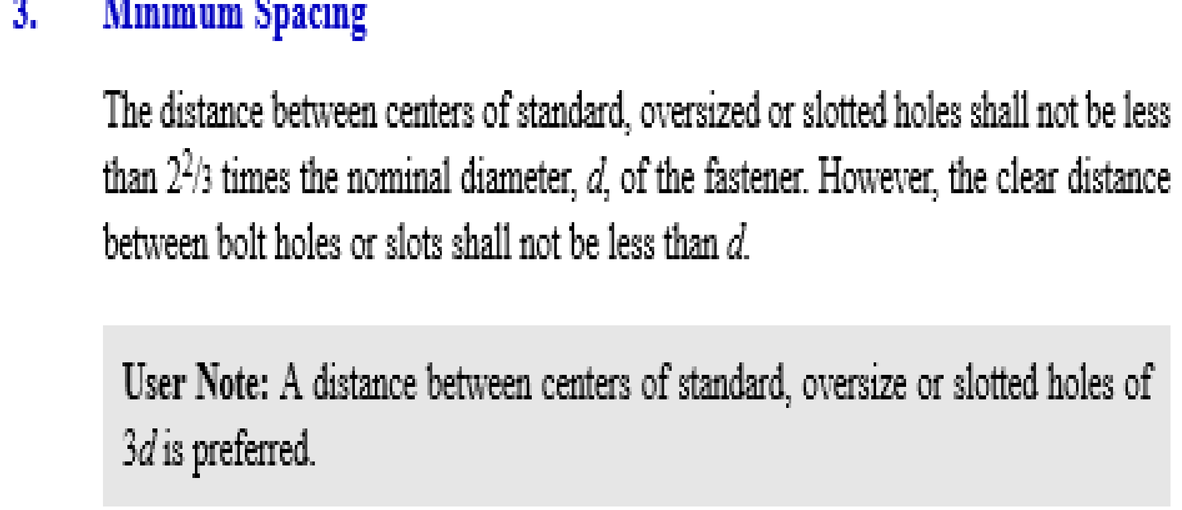
TABLE J3.4
Minimum Edge Distance[a] from Center of Standard Hole[b] to Edge of Connected Part, in.

Bolt Diameter, in.	Minimum Edge Distance
1/2	3/4
5/8	7/8
3/4	1
7/8	1 1/8
1	1 1/4
1 1/8	1 1/2
1 1/4	1 5/8
Over 1 1/4	1 1/4***d***

[a] If necessary, lesser edge distances are permitted provided the applicable provisions from Sections J3.10 and J4 are satisfied, but edge distances less than one bolt diameter are not permitted without approval from the engineer of record.

[b] For oversized or slotted holes, see Table J3.5.

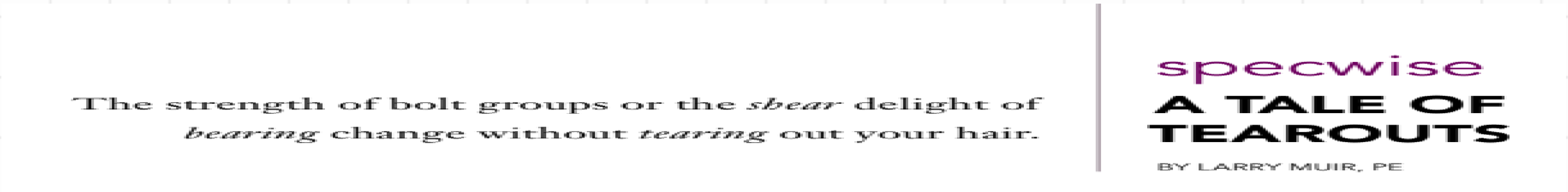




3. Minimum Spacing

The distance between centers of standard, oversized or slotted holes shall not be less than $2^2/_3$ times the nominal diameter, *d*, of the fastener. However, the clear distance between bolt holes or slots shall not be less than *d*.

User Note: A distance between centers of standard, oversize or slotted holes of 3*d* is preferred.

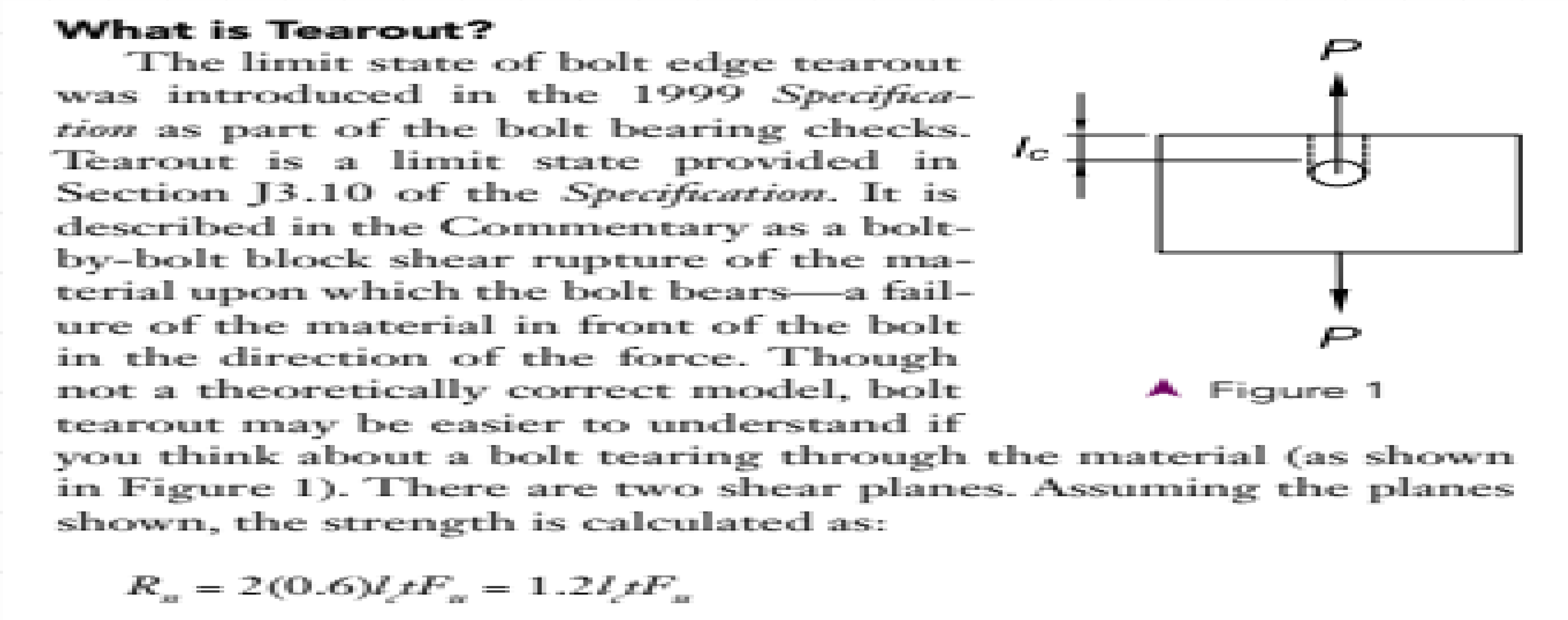


The strength of bolt groups or the *shear* delight of *bearing* change without *tearing* out your hair.

specwise

A TALE OF TEAROUTS

BY LARRY MUIR, PE

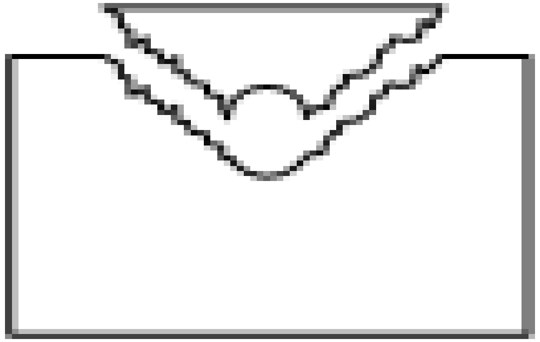


What is Tearout?

The limit state of bolt edge tearout was introduced in the 1999 *Specification* as part of the bolt bearing checks. Tearout is a limit state provided in Section J3.10 of the *Specification*. It is described in the Commentary as a bolt-by-bolt block shear rupture of the material upon which the bolt bears—a failure of the material in front of the bolt in the direction of the force. Though not a theoretically correct model, bolt tearout may be easier to understand if you think about a bolt tearing through the material (as shown in Figure 1). There are two shear planes. Assuming the planes shown, the strength is calculated as:

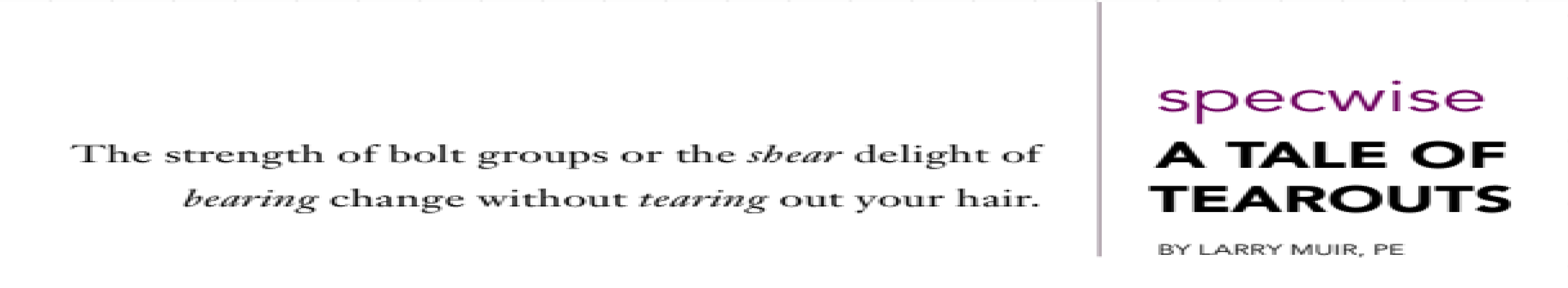
▲ Figure 1

$$R_n = 2(0.6)l_c tF_u = 1.2l_c tF_u$$



▲ Figure 2

Though this is a simple and useful model, it does not reflect the actual behavior. If the bolt tears from the material, the phenomenon looks more similar to Figure 2. The model does, however, produce *Specification* Equation J3-6c, the nominal tearout strength when deformation at the bolt hole is a design consideration. The fact that the model is not precise is reflected by the fact that the *Specification* also presents a limit state for conditions when deformation at the bolt hole is not a design consideration with Equation J3-6d, $R_n = 1.5 l_c t F_u$, which predicts a strength 25% higher than the Figure 1 model.



The strength of bolt groups or the *shear* delight of *bearing* change without *tearing* out your hair.

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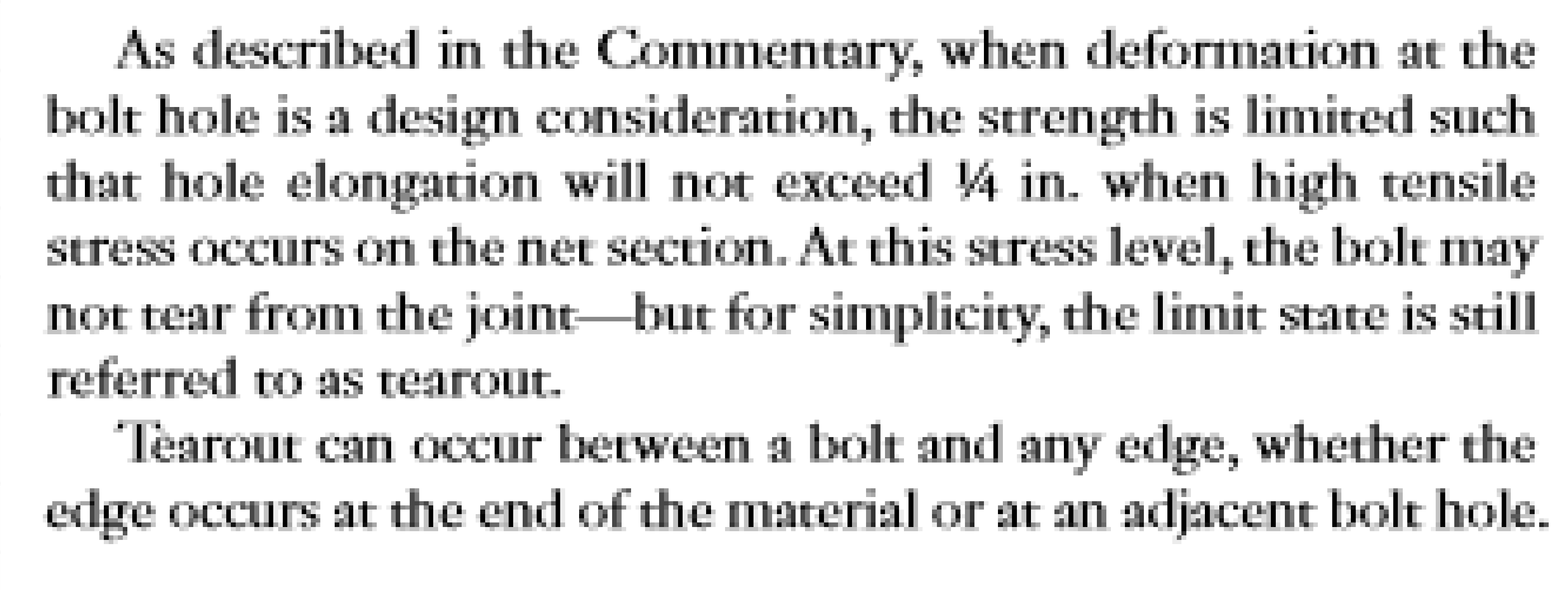
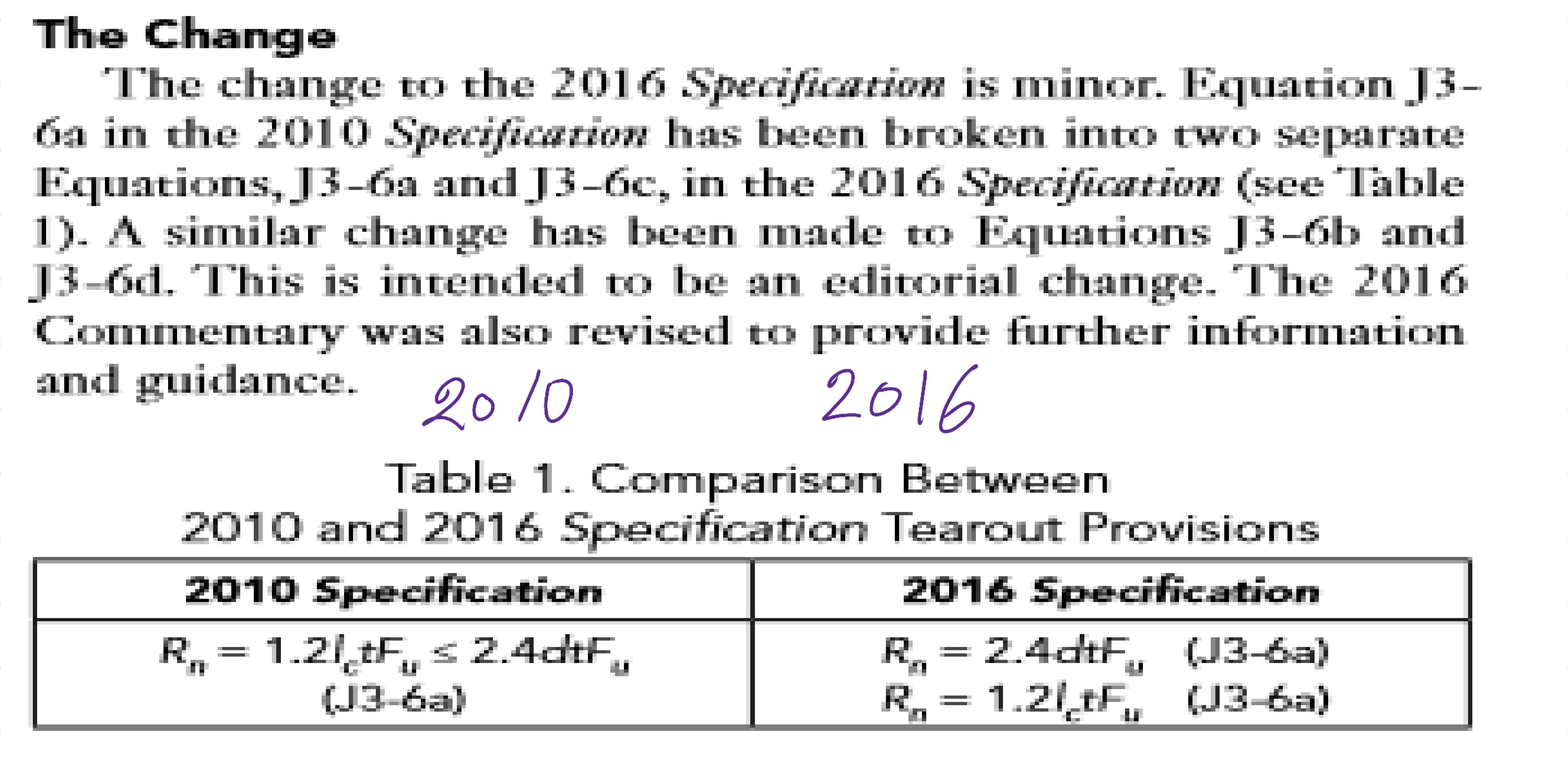
A TALE OF TEAROUTS

BY LARRY MUIR, PE



As described in the Commentary, when deformation at the bolt hole is a design consideration, the strength is limited such that hole elongation will not exceed ¼ in. when high tensile stress occurs on the net section. At this stress level, the bolt may not tear from the joint—but for simplicity, the limit state is still referred to as tearout.

Tearout can occur between a bolt and any edge, whether the edge occurs at the end of the material or at an adjacent bolt hole.



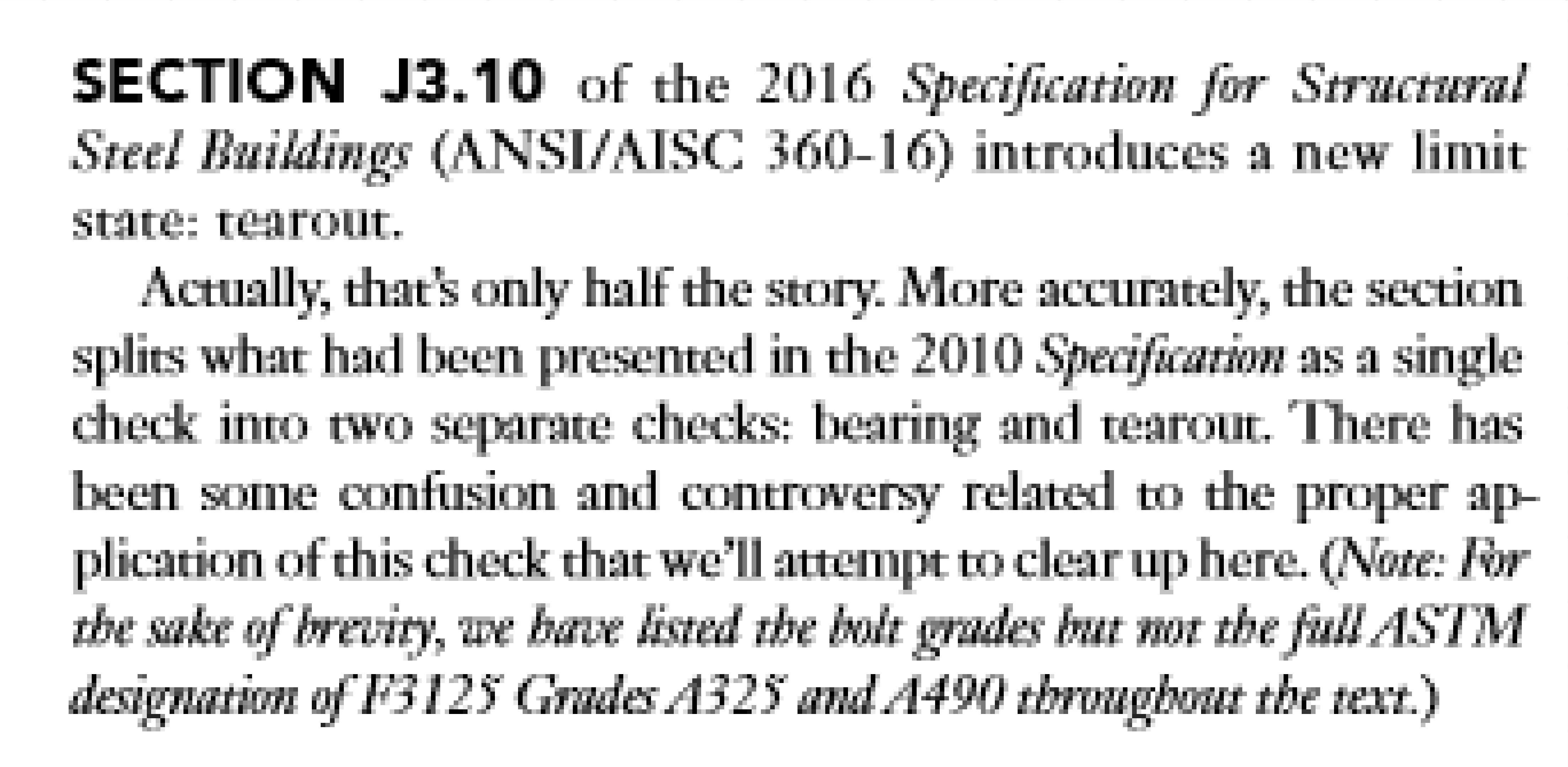
The Change

The change to the 2016 *Specification* is minor. Equation J3-6a in the 2010 *Specification* has been broken into two separate Equations, J3-6a and J3-6c, in the 2016 *Specification* (see Table 1). A similar change has been made to Equations J3-6b and J3-6d. This is intended to be an editorial change. The 2016 Commentary was also revised to provide further information and guidance.

2010 2016

Table 1. Comparison Between 2010 and 2016 *Specification* Tearout Provisions

2010 *Specification*	**2016 *Specification***
$R_n = 1.2 l_c t F_u \leq 2.4 d t F_u$ (J3-6a)	$R_n = 2.4 d t F_u$ (J3-6a) $R_n = 1.2 l_c t F_u$ (J3-6a)



SECTION J3.10 of the 2016 *Specification for Structural Steel Buildings* (ANSI/AISC 360-16) introduces a new limit state: tearout.

Actually, that's only half the story. More accurately, the section splits what had been presented in the 2010 *Specification* as a single check into two separate checks: bearing and tearout. There has been some confusion and controversy related to the proper application of this check that we'll attempt to clear up here. (*Note: For the sake of brevity, we have listed the bolt grades but not the full ASTM designation of F3125 Grades A325 and A490 throughout the text.*)