(9) Fillet Welds in Holes and Slots. Fillet welds in holes or slots may be used to transmit shear in lap joints or to prevent the buckling or separation of lapped parts and to join elements of built-up members. Such fillet welds may overlap, subject to the provisions of (6). Fillet welds in holes or slots are not to be considered plug or slot welds.

(e) Plug and Slot Welds

(1) Use of Plug and Slot Welds. Plug and slot welds may be used to transmit shear in a lap joint or to prevent buckling of lapped parts and to join component parts of built-up members.

(2) Diameter of Holes for Plug Welds. The diameter of the holes for a plug weld shall be not less than the thickness of the part containing it plus 7/16 in. (8 mm), rounded to the next greater odd 7/16 in. (1.5 mm), nor greater than the minimum diameter plus 7/8 in. (3 mm) or 27/16 times the thickness of the weld metal.

(3) Spacing of Plug Welds. The minimum center-to-center spacing of plug welds shall be four times the diameter of the hole.

(4) Length of Slot Welds. The length of slot for a slot weld shall not exceed 10 times the thickness of the weld. The width of the slot shall be not less than the thickness of the part containing it plus 7/16 in. (8 mm), rounded to the next greater odd 7/16 in. (1.5 mm), nor greater than the minimum diameter plus 7/8 in. (3 mm) or 27/16 times the thickness of the weld. The ends of the slot shall be semicircular or shall have the corners rounded to a radius not less than the thickness of the part containing it, except for those ends which extend to the edge of the part.

(5) Spacing of Slot Welds. The minimum spacing of lines of slot welds in a direction transverse to their length shall be four times the width of the slot. The minimum center-to-center spacing in a longitudinal direction on any line shall be two times the length of the slot.

(6) Thickness of Plug and Slot Welds. The thickness of plug and slot welds in material 7/8 in. (16 mm) or less in thickness shall be equal to the thickness of the material. In material over 7/8 in. (16 mm) in thickness, it shall be at least one-half the thickness of the material but not less than 7/16 in. (16 mm).

(7) Effective Shearing Area of Plug and Slot Welds. The effective shearing area of plug and slot welds shall be considered as the nominal cross-sectional area of the hole or slot in the plane of the facing surface.

(f) Full Penetration and Partial Penetration Joints. The effective area shall be the effective weld length multiplied by the effective throat thickness.

(1) The effective weld length for any groove weld, square or skewed, shall be the length of weld throughout which the correct proportioned cross section exists. In a curved weld it shall be its true length measured along its curvature.

(2) The effective throat thickness of a full penetration groove weld which shall conform to the requirements of Article NF-4000 shall be the thickness of the thinner part joined. No increase is permitted for weld reinforcement.

(3) The effective throat of partial penetration groove welds is dependent upon the type of groove.

(a) For square, U, and J groove welds, the effective throat is equal to the depth of preparations.

(b) For V and bevel groove welds with an included angle at the root equal to or greater than 60 deg, the effective throat shall be the minimum distance from the root to the face of the weld.

(c) For V and bevel groove welds with an included angle at the root less than 60 deg but equal to or greater than 45 deg, the effective throat shall be the minimum distance from the root to the face of the weld less 1/8 in. (3 mm).

(d) For V and bevel groove welds, with an included angle at the root less than 45 deg but equal to or greater than 30 deg, the effective throat shall be the minimum distance from the root to the face of the weld less 1/8 in. (3 mm) and multiplied by 0.75. The required effective throat must be specified on the drawing.

(e) For V and bevel groove welds, angles less than 30 deg at the root are not allowed.

(f) For flare bevel groove welds, when filled flush to the surface, the effective throat shall be 0.31 times the outside radius of the curved section forming the groove. For formed rectangular tubing, the outside radius may be considered as two times the wall thickness.

(g) For flare V groove welds, when filled flush to the surface, the effective throat shall be 0.5 [except use 0.375 for GMAW when R ≥ 7/16 in. (13 mm)] times the outside radius.

(g) Consideration of Lamellar Tearing. Welded joint configurations causing significant through-thickness tensile stress [as defined in NF-1215(b)] during fabrication and/or service on rolled product forms should be avoided. However, if this type of construction is used, the designer should consider one or several of the following factors that may reduce the susceptibility of the joint to experience lamellar tearing and provide documentation, including fabrication requirements, in the Design Output Documents:

(1) Reduce volume of weld metal to the extent practical.

(2) Select materials that are resistant to lamellar tearing.

(3) Invoke any of the special fabrication requirements of NF-4441.
(a) Allowable Stresses. Allowable tensile, shearing, and bearing stresses in bolts and threaded parts shall be as given in the paragraphs below. All allowables are expressed in ksi (MPa) acting on the actual bolt area available in the shear planes of the connected parts. All are expressed in terms of the ultimate tensile strength at temperature (Section II, Part D, Subpart 1, Table U). The shear capacity of bolts is directly proportional to the shear area available in the shear planes. Shear strength is unaffected by shear plane location.

(1) Tensile Stress Only. Bolts loaded in direct tension shall be so proportioned that their average tensile stress \( F_{tb} \), computed on the basis of the actual tensile stress area available (independent of any initial tightening force), shall not exceed

For ferritic steels

\[
F_{tb} = \frac{S_u}{2}
\]

For austenitic steels

\[
F_{tb} = \frac{S_u}{3.33}
\]

The applied load shall be the sum of the external load and any tension resulting from prying action produced by deformation of the connected parts.

(2) Shearing Stress Only

(-a) Bearing-Type Joints

(1) Threads Excluded From Shear Planes. The allowable shear \( F_{vb} \) in bolts and threaded parts loaded in direct shear expressed in ksi (MPa) of actual shear area available in the shear planes shall be

For ferritic steels

\[
F_{vb} = \frac{0.62S_u}{3}
\]

For austenitic steels

\[
F_{vb} = \frac{0.62S_u}{5}
\]

(3) Combined Tensile and Shear Stresses

(-a) Bearing-Type Joints. Bolts subjected to combined shear and tension shall be so proportioned that either the shear or the tensile stress, ksi (MPa) of actual cross-sectional area, shall not exceed the value derived from the ellipse equation below when the corresponding computed tensile or shearing stress is substituted

\[
\frac{F_{tb}^2}{F_{tb}^2} + \frac{F_{vb}^2}{F_{vb}^2} = 1
\]

The allowable tensile and shear stress values shall be those derived from the equations given in (1) and (2).

(-b) Friction-Type Joints. A bolt in a connection designed as a friction-type joint is not subjected to shear (provided the joint does not slip into bearing); it experiences tension only. Friction-type joints shall be designed as given in (4).

(4) Slip Resistance — Friction-Type Joints. The maximum slip resistance to which a friction-type joint may be designed shall not exceed the value of \( P_s \), calculated in the following equation [see Table NF-3324.6(a)(4)-1]:

\[
P_s = mnT_i k_s
\]

If the joint clamping force will be reduced by any direct tension load on the joint, the \( T_i \) value shall be reduced by an equivalent amount before substituting in the above equation. SA-307 and austenitic steel bolting shall not be used for friction-type joints.

(5) Bearing Stress. Allowable bearing stress on the projected area of bolts in bearing type connections shall be

\[
F_p = \frac{LS_u}{2d} \leq 1.5S_u
\]

(b) Minimum Edge Distance

(1) Minimum Edge Distance in Line of Load. In both bearing- and friction-type joints the minimum distance from the center of the end bolt in a connection to that

For Level C and Level D Loadings, the allowable bearing stress on the projected area of bolts in bearing type connections may be increased to:

\[
F_p = \frac{LS_u}{2d} \leq 2.1S_u
\]

(2) Threads Not Excluded From Shear Planes. The allowable shear stress \( F_{vb} \) in bolts and threaded parts loaded in direct shear, expressed in ksi (MPa) of actual shear stress area available (applicable to the total bolt root area in the shear planes in this case), shall not exceed

For ferritic steels

\[
F_{vb} = \frac{0.62S_u}{3}
\]

For austenitic steels

\[
F_{vb} = \frac{0.62S_u}{5}
\]

---

**Table NF-3324.6(a)(4)-1: Effective Slip Coefficient Versus Surface Condition**

<table>
<thead>
<tr>
<th>Surface Condition</th>
<th>Slip Coefficient, ( k_s )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clean mill scale</td>
<td>0.25</td>
</tr>
<tr>
<td>Grit-blasted carbon and low alloy</td>
<td>0.41</td>
</tr>
<tr>
<td>high-strength steel</td>
<td>0.41</td>
</tr>
<tr>
<td>Grit-blasted, heat-treated steel</td>
<td>0.25</td>
</tr>
<tr>
<td>Hot dip galvanized wire, brushed, scored, or blasted</td>
<td>0.31</td>
</tr>
<tr>
<td>Blast cleaned, zinc rich paint</td>
<td>0.31</td>
</tr>
<tr>
<td>Blast cleaned, zinc silicate paint</td>
<td>0.45</td>
</tr>
</tbody>
</table>
edge of the connected part toward which the load is directed shall be determined in accordance with either (a) or (b).

(a) The edge distance shall satisfy all of the following:

\[
\begin{align*}
(-1) \ L/d & \geq 0.5 + 1.43 \left( f_p / S_u \right) \\
(-2) \ L/d & \geq 1.2 \\
(-3) \ f_p / S_u & \leq 1.5
\end{align*}
\]

where

\[ f_p = P / dt \]

(b) The edge distance shall be determined in accordance with either Table NF-3324.6(b)(1)-1.

(2) Minimum Edge Distance in Line of Load for Level C and Level D. For Level C and Level D Loadings, the edge distance shall satisfy all of the following:

\[
\begin{align*}
(-a) \ L/d & \geq 0.5 + \frac{1.43}{f_p} \left( S_u \right) \\
(-b) \ L/d & \geq 1.2 \\
(-c) \ f_p / S_u & \leq 2.1
\end{align*}
\]

(c) Maximum Edge Distance. The maximum distance from the center of any rivet or bolt to the nearest edge of parts in contact shall be 12 times the thickness of the connected part under consideration, but shall not exceed 6 in. (150 mm). Bolted joints in unpainted steel exposed to atmospheric corrosion must meet special limitations on pitch and edge distance.

For unpainted, built-up members made of weathering steel which will be exposed to atmospheric corrosion, the spacing of fasteners connecting a plate and a shape or two-plane components in contact shall not exceed 14 times the thickness of the thinnest part nor 7 in. (175 mm), and the maximum edge distance shall not exceed eight times the thickness of the thinnest part, or 5 in. (125 mm).

(d) Minimum Spacing. The distance between centers of standard, oversized, or slotted fastener holes shall be not less than three times the nominal diameter of the bolt. Along a line of transmitted force, the distance between centers of holes shall be not less than the following:

\[ \text{Standard Holes:} \ 2P / S_u t + d/2 \]

(e) Effective Bearing Area. The effective bearing area of bolts shall be the diameter multiplied by the length in bearing, except that for countersunk bolts one-half the depth of the countersink shall be deducted.

(f) Long Grips. SA-307 bolts, which carry calculated stress and the grip of which exceeds five diameters, shall have their number increased 1% for each additional \( \frac{1}{16} \) in. (1.5 mm) in the grip.

(g) Anchor Bolts. Anchor bolts shall be designed to provide resistance to all conditions of tension and shear at the bases of columns, including the net tensile components of any bending moments which may result from fixation or partial fixation of columns.

### NF-3324.7 Design Requirements for Column Bases

Proper provision shall be made to transfer the column loads and moments, if any, to the footings and foundations.

#### NF-3330 HIGH CYCLE FATIGUE DESIGN FOR CLASS 1

#### NF-3331 Introduction

**NF-3331.1 Scope.** Members and their connections, subject to a number of cycles (>20,000) of fatigue loading resulting in damage as defined in NF-3331.2, shall be proportioned to satisfy the stress range limitations provided therein.

**NF-3331.2 Definitions.** High cycle fatigue, as used in this subarticle, is defined as the damage that may result in fracture after a sufficient number of fluctuations of stress. Stress range is defined as the numerical sum of maximum repeated tensile and compressive stresses or the sum of maximum shearing stresses of opposite direction at a given point, resulting from differing arrangements of live load.

#### NF-3332 Design Requirements

**NF-3332.1 Design Considerations.** In the design of members and connections subject to repeated variation of live load stress, consideration shall be given to the number of stress cycles, the expected range of stress, and the type and location of member or detail.

**NF-3332.2 Classification of Loading Conditions.** Loading conditions shall be classified as shown in Table NF-3332.2-1.