When—and when not—
to specify slip-critical connections.

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LE 'S FACE I . Slip-critical connections are speci ed too often.

It is important to understand how slip-critical connections behave and when they are actually required in order to avoid unnecessary fabrication and erection costs.

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What is a slip-critical connection? It's one that transmits shear via friction between the faying surfaces. This is in contrast with bearing-type connections, in which bolt shear and bearing are responsible for transferring shear force (see Figure 1). Slip-critical connections are required to have a minimum amount of tension in the bolt, called "pretension," which creates a normal force between the connected elements. This normal force results in friction between the two surfaces in contact, which is utilized to resist shearing forces. As with any frictional force, the amount of force that can be transmitted is primarily a function of the amount of pretension and the slip surface. This is re ected in the available strength equation for slip-critical connections, from AISC *Speci cation* Section J3.8:

$$R_n = \mu D_u h_f T_b n_s$$

The essence of the equation is a coef cient of friction, μ, multiplied by a normal force equal to the bolt pretension. AISC *Specication* Section J3.8 gives further information on this equation. AISC Design Guide 17: *High Strength Bolts – A Primer for Engineers* by Geoffrey Kulak is a good reference on bolted connections.

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Because slip can occur when designing a slip-critical connection, the strength of the connection in bearing must also be checked. The bearing strength does not typically control but still must be checked to ensure that the connection is adequate if the bolts were to slip into bearing.

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The use of slip-critical connections should be carefully considered. It is estimated that a slip-critical connection costs about three times as much as a snug-tightened, bearing-type connection. The factors that increase cost include lower strength per bolt, surface preparation requirements to achieve the required slip coef cient, and more extensive bolt installation and inspection requirements.

The most common reason slip-critical connections are required is to limit the structural deformations possible when using oversized holes. The adjacent table outlines this case and others when slip-critical connections are required. It includes requirements from Section 4.3 of the RCSC *Speci cation for Structural Joints using High-Strength Bolts* as well as requirements in the AISC *Speci cation*.

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As has already been stated, slip-critical connections resist shear through friction at the faying surfaces. Calculating a strength per bolt can be misleading from a theoretical standpoint, but it is convenient both in practical design and when making comparisons between slip-critical and bearing connections.

Table 7-1 of the AISC *Manual* provides the per bolt strength for bearing joints. The strength for a ⅞-in.-diameter A325 X-type bolt is 30.7 kips (LRFD). Table 7-3 provides the per bolt strength for slip-critical joints. The strength for a ⅞-in.-diam-


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eter A325 with oversize holes and a Class A faying surface is 11.2 kips (LRFD). Depending on which connection limit state governs, these values show that a slip-critical connection may require more than twice as many bolts as a bearing-type connection to resist the same force. This will generally mean that the slip-critical connection will be larger, requiring more material, but the material cost is a secondary concern. The labor costs are the primary concern, and costs become nonlinearly more expensive in cases where more bolts don’t t in the member. As an example, a W21 that works with four bolts in bearing but needs ve for slip resistance and must have an extension welded to the bottom ange and anges coped away to t the extra bolt. The larger joints can also mean more potential for interfering with other elements, such as mechanical and architectural components.

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Applied tension in a slip-critical joint is handled differently than in a bearing-type joint, as discussed in the *Engineering Journal* article “Prying Action for Slip-Critical Connections with Bolt Tension and Shear Interaction” (third quarter 2012, available at **www.aisc.org/ej**). In a bolted joint with no pretension, the entire applied tension is transferred to the bolts immediately. In a bolted joint with pretension, some of the applied tension will overcome the pretension in the bolt. Because the compression between the faying surfaces is reduced, the friction force that resists