HEN I COME to the chronicles of steel construction, the concept of prequali ed connections is recent history.

The rst version of AISC 358 *Prequali ed Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* was released in 2005, with subsequent major releases in 2010 and now in 2016. Supplements have been issued in between these versions as new prequali ed connections were added to the standard.

So how did AISC 358 come to be in the rst place? The impetus for its development goes back to damage observed to welded steel moment connections in the 1994 Northridge Earthquake. A major outcome of post-Northridge research was the view that any new steel moment connection detail intended for use in special moment frames (SMFs) or intermediate moment frames (IMFs) should have their seismic performance veri ed by testing at a realistic scale. AISC 341 *Seismic Provisions for Structural Steel Buildings* adopted performance criteria for SMFs and IMFs connections that required connections be capable of developing a story drift angle of ± 0.04 rad for SMFs and ± 0.02 rad for IMFs without signi cant loss in strength, and required that all moment connections demonstrate conformance with this performance requirement by conducting qualifying cyclic tests.

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To facilitate and simplify conformance demonstration, the concept of "prequali ed" moment connections was developed. Prequali ed connections were rst introduced in the SAC-FEMA program in report FEMA 350: *Recommended Seismic Design Criteria for New Steel-Moment Buildings*, which was released in 2000. Building on the recommendations in FEMA 350, the concept of prequali ed moment connections was subsequently incorporated into AISC 341 in 2002. Paraphrasing the commentary to AISC 341, a prequali ed connection is one that has undergone suf cient testing, analysis, evaluation and review so that a high level of con dence exists that the connection can ful ll the performance requirements for SMFs and IMFs. Recognizing that prequalifying moment connections require evaluation by a panel of knowledgeable individuals, AISC created the Connection Prequali cation Review Panel (CPRP) in the early 2000s. The CPRP was assigned the responsibility to prequalify SMF and IMF connections. In addition to creating the CPRP, AISC also created AISC 358 as a new building standard for prequali ed connections (the CPRP is responsible for development and updating of AISC 358).

Basic requirements that a connection must satisfy to become prequali ed are speci ed in AISC 341, and the CPRP is guided by these requirements in prequalifying connections. In AISC 341, requirements for prequali cation are speci ed in Section K1 "Prequali cation of Beam-to-Column and Link-to-Column Connections." While there are numerous requirements, the most basic requirement for prequali cation is the need for cyclic testing of the connection in accordance with AISC 341, Section K2 "Cyclic Tests for Qualifying of Beam-to-Column and Link-to-Column Connections"; it is not possible for a connection to become prequali ed without large-scale testing. Further, Section K2 provides strict limits for extrapolating test results to larger member sizes, and the CPRP adheres to these size extrapolation limits in AISC 358. The New358.sISC 358.-16 has 13 chapte

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Table 1 provides a listing of prequalified connections in AISC 358 and the corresponding chapter for each connection. Several of the prequalified connections, identified with an (*) in the table, are proprietary connections. These are connections for which a patent is held, and designers must work with the patent-holder in the use of these connections in building construction projects. The rest of the connections are nonproprietary.

While the contents of each prequalified connection chapter varies somewhat, there are a number of common features of each connection:

- a general description of the connection and intended location of inelastic action
- systems for which connection is prequalified (SMFs and/or IMFs)
- prequalification limits (limits on beam and column sizes and types for which the connection is prequalified)
- additional prequalification limits (beam-column relationships, connection components, welding and bolting requirements, etc.)
- detailing and fabrication requirements
- design procedure

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The SidePlate moment connection is a proprietary connection that was rst added in AISC 358-10 Supplement No. 2 in February 2014. (A schematic of the connection, when used with planar moment frames, is shown in Figure 2.) With this connection, the beam is not directly connected to the face of

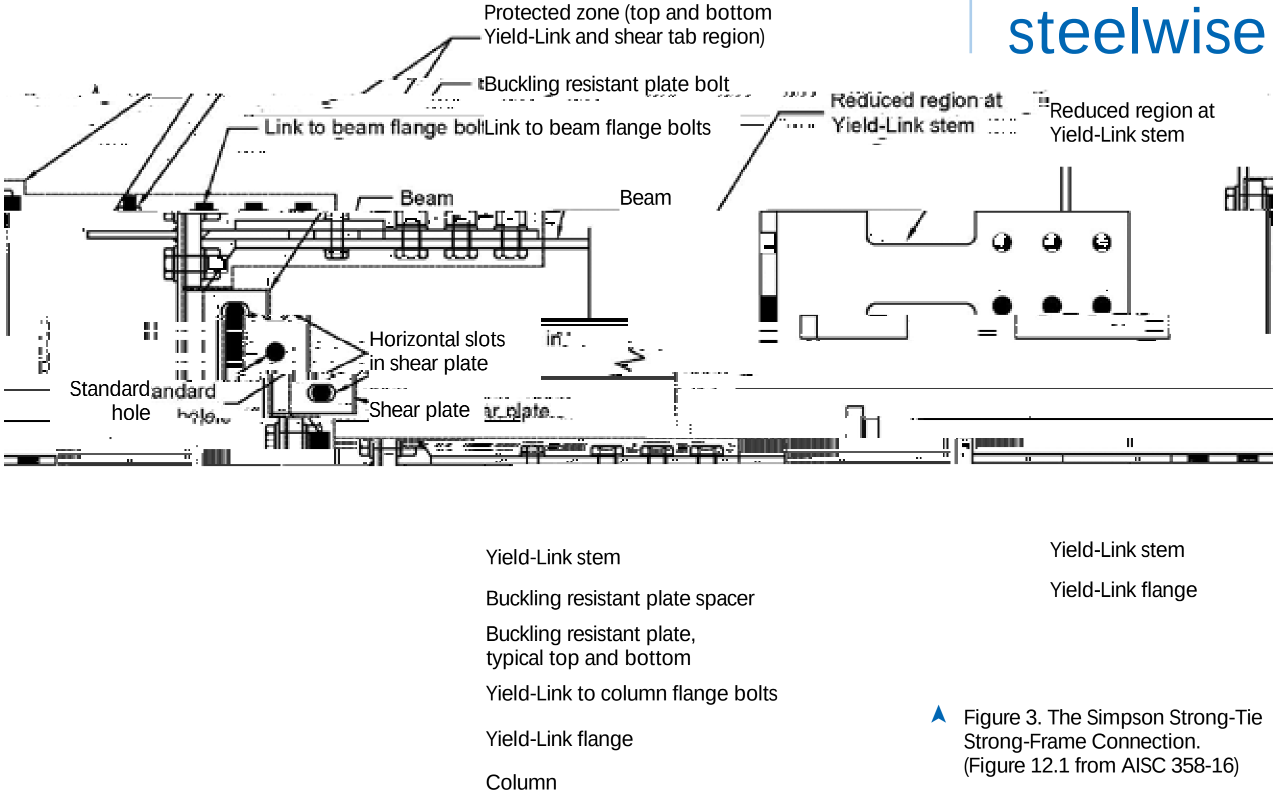

Figure 3. The Simpson Strong-Tie Strong-Frame Connection. (Figure 12.1 from AISC 358-16)

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The Simpson Strong-Tie Strong Frame connection is a newly prequali ed proprietary connection in AISC 358 (a schematic of the connection is shown in Figure 3). The Strong-Frame connection is the rst moment connection classi ed as partially restrained to be prequali ed in AISC 358. The term "partially restrained moment connection" is de ned in AISC 360 as "a connection capable of transferring moment with rotation between connected members that is not negligible." This means that the connection's rotation exibility must be included in the structural analysis model used to predict frame drift and frame member and connection forces. Detailed guidance is provided in Chapter 12 of AISC 358 on how to include connection exibility in the building frame model. In addition to being classi ed as partially restrained, the connection can also be considered a partial-strength connection, as the connection's exural capacity is typically well below M_p of the connected beam.

A key feature of the Strong-Frame Connection is the "Yield-Link" used to connect the beam anges to the column ange. The Yield-Link (shown in the right portion of Figure 3) is a modi ed T-stub that has a reduced section in the stem. The stem of this link is bolted to the beam ange, and the link's ange is bolted to the column ange. The connection is designed so that during a severe earthquake, yielding occurs within the reduced section of the Yield-Link and the beams remain essentially elastic, which differs from all other prequali ed connections, where yielding is intended to occur primarily in the beams. When the stem of the Yield-Link goes into compression, buckling of the Yield-Link is prevented by a separate buckling restraint plate that is bolted over the reduced section of the Yield-Link. Also note that construction of the Strong-Frame connection in the eld requires no welding; all components are eld-bolted.

One of the challenges faced by the CPRP in prequalifying the Strong-Frame connection for SMFs applications is that it did not t the de nition of an SMF connection in AISC 341-10. According to AISC 341-10 Section E3.2, SMFs "are intended to provide signi cant inelastic deformation capacity through exural yielding of the SMF beams and limited yielding of the column panel zone." The Strong-Frame connection did not meet this de nition, as inelastic deformation capacity is provided through yielding of connection elements and not through yielding of the beam or column panel zone. Further, AISC 341-10 requires that beam-to-column connections, when subject to cyclic loading tests, demonstrate a measured exural resistance of at least $0.8M_p$ of the connected beam at a story drift angle of 0.04 rad. Again, the Strong-Frame connection did not satisfy this requirement, as its exural capacity is intentionally signi cantly less than M_p of the connected beam. Finally, AISC 341-10 provided no guidance on the use of partially restrained moment connections in SMF.

Because of the unique nature of the Strong-Frame connection, being both a partially restrained and partial-strength connection, the CPRP requested two supplemental studies to be completed as part of the prequali cation process. These studies were intended to ensure that moment-resisting frames constructed with the Strong-Frame connection provide seismic-performance similar to more conventional SMF. To this end, comparisons were made between frames constructed with this connection and more conventional SMFs constructed with RBS connections. The rst study examined connection performance equivalency following procedures speci ed in Report FEMA P795: *Quanti cation of Building Seismic Performance Factors – Component Equivalency Methodology*, which examined the equivalency of the Strong-Frame connection with the RBS connection. The second supplemental study requested by the CPRP examined overall system behavior—and again compared systems using Strong-Frame connections with more conventional SMF systems using RBS connections. A series of nonlinear time-history analyses using a suite of strong ground motions were conducted to compare the systems, and both supplemental studies indicated that frames constructed with Strong-Frame connections provided performance that is essentially the same as an SMF with RBS connections. These studies were a key part of the successful prequali cation of the Strong-Frame connection.

The connection is prequali ed for both SMFs and IMFs and is prequali ed for rolled wide- ange of welded built up I-shaped sections; beam depth is limited to W16 or less. Because beams are expected to remain essentially elastic in this system, they are not required to satisfy the compactness limits or lateral bracing requirements for SMFs speci ed in AISC 341. Rather, the beams need only satisfy the compactness and bracing requirements in AISC 360. This reduction in beam lateral bracing requirements is useful when providing such bracing is dif cult, as may be the case with a steel SMF that is integrated in a wood structure. The Strong-Frame connection is further prequali ed for use with rolled or built-up column sections up to W18 in depth, and the beam must be connected to the column ange. Additional prequali cation limits are listed in Chapter 12 of AISC 358.

It should be noted that following the prequali cation of the Strong-Frame connection in AISC 358, changes were made to the SMF requirements in Section E3 of AISC 341-16. This section now permits SMFs where inelastic deformation capacity is provided by yielding within the connection "where equivalent performance of the moment frame system is demonstrated by substantiating analysis and testing."

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The double-tee connection is a new nonproprietary connection in AISC 358 (a schematic of the connection is shown in Figure 4). This is an all- eld-bolted connection wherein the beam anges are connected to the column ange using T-stubs cut from rolled sections, and the beam web is connected to the column using a single plate shear connection. The double-tee connection was the subject of signi cant research and testing in the SAC-FEMA program. This work was subsequently extended with additional research and testing, leading ultimately to prequali cation in AISC 358.

The connection is designed such that in the event of a strong earthquake, yielding occurs in the beam near the ends of the stems of the T-stubs. Like all other prequali ed connections, with the exception of the Strong-Frame connection, the double tee is considered to be a fully restrained moment connection. This means that connection exibility need not be included in the analysis model. As part of the design procedure for the double-tee connection in Chapter 13 of AISC 358, equations are provided to check that the connection has adequate rotational stiffness to ensure that it behaves as fully restrained.

The double-tee moment connection is prequali ed for use in SMFs and IMFs and for rolled wide- ange or welded built-up I-shaped members. Beam depth is limited to a maximum of W24, beam weight is limited to a maximum of 55 lb/ft and beam ange thickness is limited to a maximum of ⅝ in. Columns can be rolled wide- ange shapes, welded built-up I-shapes or anged cruciform columns. Column depth is limited to W36 when a concrete structural oor slab is present and is otherwise limited to W14. Beams must be connected to the column ange. Additional prequali cation limits are listed in Chapter 13 of AISC 358.

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With these four connections that have been prequali ed since the release of AISC 358-10, there are now a total of nine prequali ed connections in AISC 358, providing designers with many choices for beam-to-column moment connections in SMFs and IMFs. As we've provided only a few brief highlights here, we urge you to peruse the new AISC 358 for complete details and requirements for these and other prequali ed connections. And remember that designers are not restricted to only using prequali ed connections in SMFs and IMFs. AISC 341 also permits connections in SMFs and IMFs that have been quali ed by testing but that have not necessarily been prequali ed. Nonetheless, AISC 358 can be a valuable resource for designers by providing prequali ed connections that are deemed to satisfy the connection performance