Prequalified Seismic Moment Connections

Here's a visual summary of the seismic requirements for two prequalified moment connections.

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The new standard, *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* (ANSI/AISC 358-05), has arrived.

Special Moment Frame (SMF) and Intermediate Moment Frame (IMF) structural steel systems designed in accordance with the AISC *Seismic Provisions for Structural Steel Buildings* (ANSI/AISC 341-05) are required to have beam-to-column connections that satisfy the requirements of Section 9.2 for SMF or 10.2 for IMF. These requirements include a minimum interstory drift angle each connection must be capable of sustaining, a minimum flexural resistance at that drift angle, and a minimum shear strength based on full yielding of the moment connection at each end of the beam. There are two ways to demonstrate that these criteria have been met:

- Provision of qualifying test results in accordance with Appendix S of the *Seismic Provisions*.
- Use of a connection prequalified in accordance with Appendix P of the *Seismic Provisions*, such as those in the prequalified connections standard.

The first option requires that the engineer of record substantiate the ability of the connection to meet the requirements of section 9.2 or 10.2 and prove that the tests were performed according to Appendix S. Tests involve additional expense and the engineer must convince the authority having jurisdiction that all the requirements are met, but this may still be a viable option. Tests reported in literature performed in accordance with Appendix S can also be used, but demonstrating the applicability of those tests still rests on the engineer of record.

The second option requires that a prequalification panel is set up and approved by the authority having jurisdiction. This panel must then create guidelines and approve connections based on test data to be prequalified.

AISC's Connection Prequalification Review Panel (CPRP) reviews connection test data and prequalifies connections in accordance with Appendix P. The result is the prequalified connections standard. This document is specifically permitted to be used in the *Seismic Provisions*. The CPRP continues to review connections and will release a new chapter for each new prequalified connection. Using this document is currently the easiest and most direct method of satisfying the conformance demonstration requirements for SMF and IMF connections in the *Seismic Provisions*.

The prequalified connections standard offers the following connections to choose from when designing IMF and SMF systems:

Reduced Beam Section (RBS) Moment Connection (Chapter 5): Portions of the beam flange are selectively trimmed in the region adjacent to the column-beam connection to ensure yielding and hinge formation within the reduced area. This connection type can be used for SMF and IMF systems.

Bolted Unstiffened and Stiffened Extended End-Plate (EEP) Moment Connections (Chapter 6): By welding the beam to an end-plate and bolting one of three end-plate configurations to the column the connection ensures that inelastic deformation of the connection is achieved by beam yielding when designed in accordance with these provisions. This connection type can be used for SMF and IMF systems; however it is not currently permitted to be used for SMF when a structural concrete slab is in contact with the beam, unless the slab is isolated from the beam.

The following details are a visual representation of the major requirements of the *Seismic Provisions* and the prequalified connections standard. These two documents contain the detailed design requirements and should be consulted on each design. The often-overlooked commentary on the *Seismic Provisions* and the prequalified connections standard can prove extremely helpful and offers guidance concerning the intent and application of the requirements. Make sure to visit **www.aisc.org/freePubs** for free pdf files of the *Seismic Provisions* and the prequalified connections standard.

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Notes

1. Details shown are for hot-rolled wide-flange members. For built-up members see Sections 2.3.2, 2.4.4, 5.3.1(2), and 5.3.1(3) of the prequalified connections standard.
2. Although details are presented in LRFD format, corresponding to the format of ANSI/AISC 358-05, the connections can be designed with ASD provisions as well.

Variables and Definitions

341 = refers to the AISC *Seismic Provisions for Structural Steel Buildings*, ANSI/AISC 341-05
358 = refers to AISC's *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications*, ANSI/AISC 358-05
360 = refers to the AISC *Specification for Structural Steel Buildings*, ANSI/AISC 360-05
CJP = complete joint penetration groove weld
EEP = extended end-plate connection
IMF = intermediate moment frame
RBS = reduced beam section connection
SMF = special moment frame
TOS = top of steel beam
a = horizontal distance between a column flange and the start of an RBS cut, in.
b = length of an RBS cut, in.
b_{bf} = width of beam flange, in.
b_p = width of the end-plate, in.
c = depth of an RBS cut at the center of the reduced beam section, in.
C_f = distance from the centerline of the column web to the end of the flange clip in a continuity plate, in.
C_{pr} = $(F_{yb} + F_{ub})/2F_{yb} \le 1.2$ [358 Eq. (2.4.3-2)]
C_w = distance from the outside face of column flange to the end of the web clip in a continuity plate, in.
d_b = depth of the connecting beam, in.
d_c = depth of column, in.
F_{ub} = specified minimum tensile strength of a beam, ksi
F_{yb} = specified minimum yield stress of a beam, ksi
F_{yc} = specified minimum yield stress of a column, ksi
g = gage, the horizontal distance between bolts, in.
k_1 = distance from web center line to flange toe of fillet, in.
k_{det} = distance from outside face of flange to the web toe of fillet, based on the largets fillet used in production, in.
L_b = distance between brace points, in.
L_{st} = length of end-plate stiffener, in.
ΣM^*_{pb} for EEP: $\Sigma M^*_{pb} = \Sigma(1.1R_yF_yZ_b + M_v)$ [341-9.6]
for RBS: $\Sigma M^*_{pb} = \Sigma(M_{pr} + M_v)$ [358-5.4]
ΣM^*_{pc} = $\Sigma Z_c(F_{yc} - P_{uc}/A_g)$ [341-9.6]
M_{pe} for EEP: $M_{pe} = C_{pr}R_yF_yZ_x$ [358 Eq (6.9-3)]
for RBS: $M_{pe} = R_yF_yZ_x$ [358 Eq (5.8-7)]
M_{pr} = $C_{pr}R_yF_yZ_e$ [358 Eq (2.4.3-1) also 5.8-5]
M_v = $V_{RBS}(a + b/2 + d_c/2)$ [358-5.4(2a)]
R = radius of an RBS cut, in.
R_{yb} = ratio of the expected yield stress of the beam material to the specified minimum yield stress, per the AISC *Seismic Provisions*
R_{yc} = ratio of the expected yield stress of the column material to the specified minimum yield stress, per the AISC *Seismic Provisions*
t_{bf} = thickness of beam flange, in.
t_{cf} = column flange thickness, in.
t_{sp} = thickness of shear plate, in.
t_{st} = thickness of end-plate stiffener, in.
$V_{gravity}$ = required beam shear force at beam end due to gravity loads
V_{RBS} = shear force at center of RBS [358-5.4(2a)]
V_{web} = required shear force at beam web-to-column connection, kips
Z_e = effective plastic section modulus of the beam cross section at the location of the plastic hinge, in.^{3}
$Z_{e(RBS)}$ = $Z_x - 2ct_{bf}(d_b - t_{bf})$, in.^{3} [358 Eq (5.8-4)]
Z_x = plastic section modulus of the full beam cross section about the x-axis, in.^{3}

User Notes:

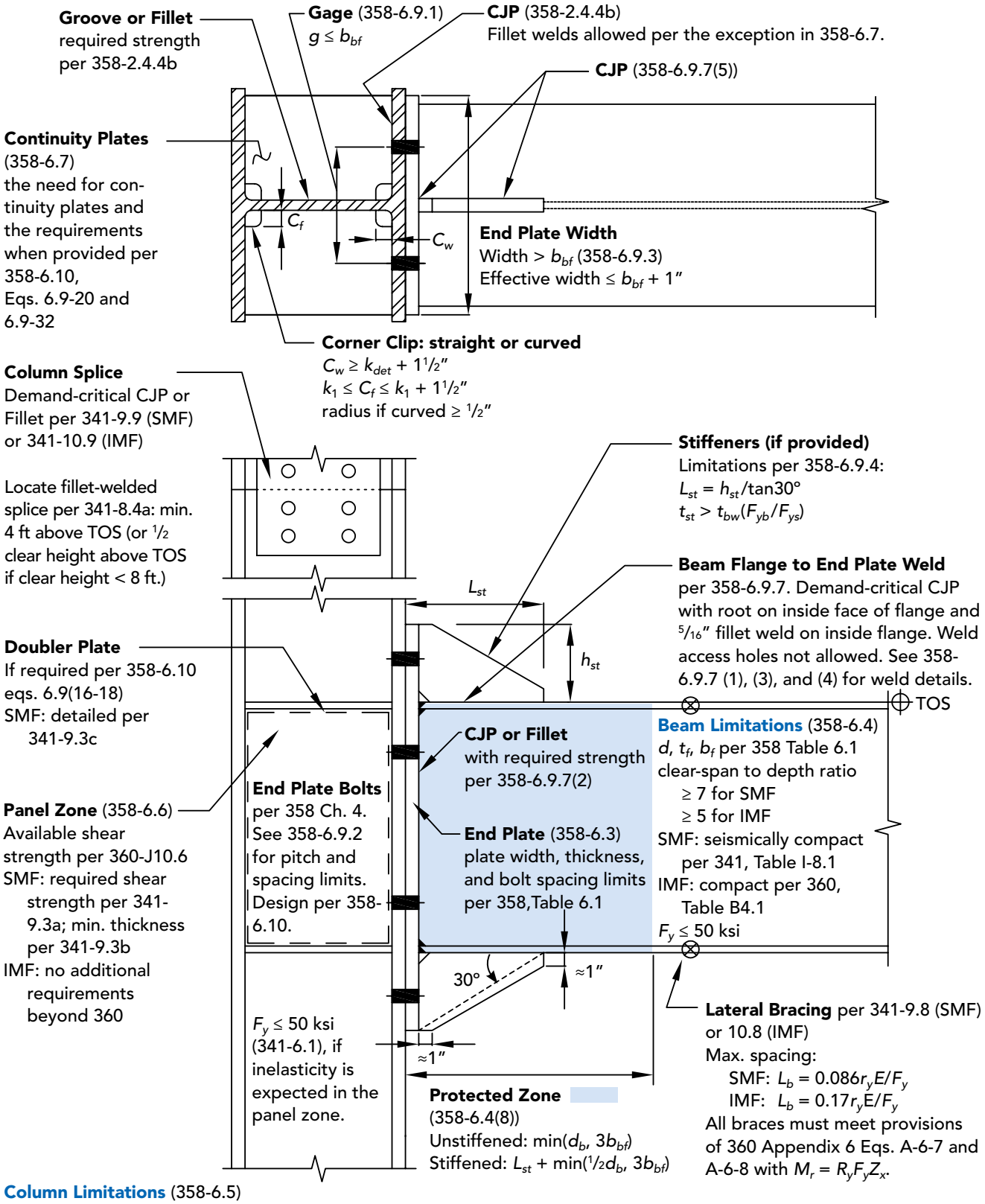
- Demand Critical Welds are welds that require increased ductility requirements. See 341-7.3b for specific requirements.
- all welds per 341 Appendix W, 341-7.3, and 358 Chapter 3.
- all bolts per 358 Chapter 4 (ASTM A325 and A490, or equaivalent twist-off, high-strength bolts allowed).
- The effective beam flange width for compactness can be taken as $b_{bf} - 2[c - R + (R^2 - b^2/9)^{0.5}]$ per 358-5.3.1(6).
- See 341 Commentary Figure C-I-7.2 and Section 9.5 for continuity plate details.
- See 341 Commentary C8.5 for column base plate details.
- See 341 Commentary C9.3 and Figure C-I-9.3 for panel zone doubler plate details.
- See 341-9.7 for lateral bracing requirements for the beam-to-columns connecitons.

Other Important Sections

1. **341-6.3 Heavy Section CVN Requirements:** Special CVN requirements exist for hot-rolled shapes with flanges greater than or equal to 1.5 in. thick and for plates 2 in. thick and thicker.
2. **341-7.2 Bolted Joints:** All bolts shall be pretensioned and have Class A faying surfaces, even though they are designed for bearing shear values. Faying surfaces for end-plate connections are permitted to be painted with coatings without a Class A rating.
3. **341-7.2 Bolted Joints:** Bolts and welds shall not share a force in a joint or a force component in a connection.
4. **341-7.3b** contains the requirements for demand critical welds.
5. **341-7.4** contains the requirements for protected zones.
6. **341-8.4b** contains the requirements for columns splices for columns not part of the seismic load resisting system.
7. **341-8.5** contains the requirements for column bases.

Four-Bolt Unstiffened and Stiffened Extended End-Plate Moment Connections

(Eight-Bolt Stiffened and Unstiffened EEP Connections similar)



Column Limitations (358-6.5)
$d_c \le d_b$
End plate connected to flange
SMF: Seismically compact per 341 Table I-8-1
IMF: Compact per 360 Table B4.1
Column strength per 341-8.3
Lateral bracing per 341-9.7 (SMF) or 10.7 (IMF)

Column-Beam Moment Ratio (358-6.6)
SMF $\sum M^*_{pc}/\sum M^*_{pb} > 1.0$
per 341-9.6 $\sum M^*_{pb} = \sum(1.1 R_y F_{yb} Z_x + M_v)$
IMF: no requirements beyond 360

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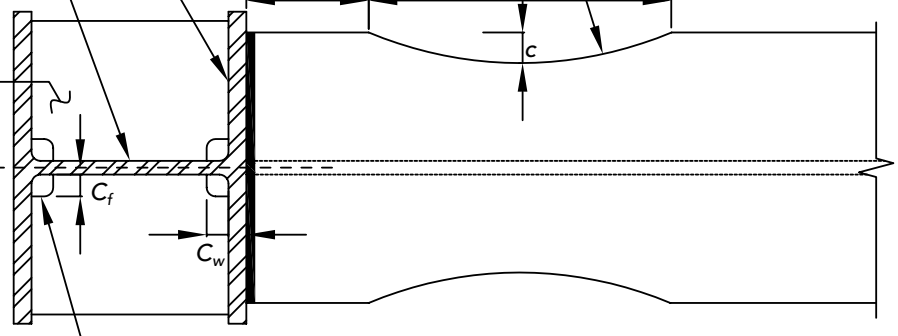
Reduced Beam Section (RBS) Moment Connection



Groove or Fillet
required strength per 358-2.4.4b

CJP (358-2.4.4b)

$R = (4c^2 + b^2)/8c$

Parameter Limits
358-5.8
$0.5b_{bf} \le a \le 0.75b_{bf}$
$0.65d_b \le b \le 0.85d_b$
$0.1b_{bf} \le c \le 0.25b_{bf}$

Continuity Plates
may be required per 358-2.4.4
If provided, design per 360-J10 and 358-2.4.4a

Corner Clip: straight or curved (341-7.5)
$C_w \ge k_{det} + 1\frac{1}{2}$"
$k_1 \le C_f \le k_1 + 1\frac{1}{2}$"
radius if curved $\ge \frac{1}{2}$"

Column Splice
Demand-critical CJP or fillet per 341-9.9 (SMF) or 341-10.9 (IMF)

Locate fillet-welded splice per 341-8.4a: min. 4 ft above TOS (or ½ clear height above TOS if clear height < 8 ft.)

Doubler Plate
If required per 360-J10
SMF: detailed per 341-9.3c
Weld to column flange is CJP or fillet weld to develop full strength of plate.

Panel Zone (358-5.4(1))
Available shear strength per 360-J10.6
SMF: required shear strength per 341-9.3a; min. thickness per 341-9.3b
IMF: no additional requirements beyond 360

Demand-critical CJP
(top and bottom, per 358-5.5) and
Weld Access Hole
(top and bottom per 360-J1.6)

Beam Web Connection Limitations
$V_{web} = 2M_{pr}/L' + V_{gravity}$
CJP between access holes; plate $\ge \frac{3}{8}$" can be used as CJP backing

Shear Plate (if provided)
Allowed for IMF or as CJP backing for SMF when $t_{sp} \ge \frac{3}{8}$" (358-5.6)
(use for temporary erection support bolt holes are allowed in beam web)

TOS

Beam Limitations
$F_y \le 50$ ksi (341-6.1)
$d_b \le$ W36
$t_{bf} \le 1\frac{3}{4}$" (358-5.3.1)
SMF: seismically compact per 341, Table I-8-1
IMF: compact per 360, Table B4.1
weight ≤ 300 lb/ft
clear-span to depth ratio
≥ 7 for SMF
≥ 5 for IMF

Steel Backing (358-3.3.2) when used, backing must be removed and the root pass must be backgouged and back-welded with a reinforcing fillet.

$F_y \le 50$ ksi (341-6.1), if inelasticity is expected in the panel zone.

Protected Zone
$a + b$
358-5.3.1(8)

$d_b/2$

Lateral Bracing per 341-9.8 (SMF) and 10.8 (IMF)
Max. spacing:
SMF: $L_b = 0.086r_yE/F_y$
IMF: $L_b = 0.17r_yE/F_y$
If the exception in 358-5.3.1(7) is not met, first brace must be $\le d_b/2$ from protected zone for SMF (358-5.3.1). All braces must meet provisions of 360 Appendix 6 Eqs. A-6-7 and A-6-8 with $M_r = R_yF_yZ_x$.

Column Beam Moment Ratio (358-5.4)
SMF $\sum M^*_{pc}/\sum M^*_{pb} > 1.0$ per 341-9.6
$\sum M^*_{pb} = \sum(M_{pr} + M_v)$ per 358-5.4
IMF no requirements beyond 360

Column Limitations (358-5.3.2)
$d_c \le$ W36
Beam connected to column flange
SMF: Seismically compact per 341, Table I-8-1
IMF: Compact per 360 Table B4.1
Column strength per 341-8.3
Lateral bracing per 341-9.7 (SMF) or 10.7 (IMF)

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