
Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications

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and issued by the AISC Board of Directors



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SYMBOLS

The Standard uses the following symbols in addition to the terms defined in the 2005 AISC *Specification for Structural Steel Buildings* and the 2005 AISC *Seismic Provisions for Structural Steel Buildings*.

A_c	Contact areas between the continuity plate and the column flanges that have attached beam flanges, in. ² (mm ²)
C_{pr}	Factor to account for peak connection strength, including strain hardening, local restraint, additional reinforcement, and other connection conditions, as given in Equation 2.4.3-2
C_t	Factor used in Equation 6.9-23
F_{fu}	Ultimate flange force, kips (N)
F_{su}	Ultimate stiffener force, kips (N)
F_{up}	Specified minimum tensile strength of end-plate, ksi (MPa)
F_y	Nominal shear strength of bolts, ksi (MPa)
L'	Distance between plastic hinges, in. (mm)
L_{st}	Length of end plate stiffener, in. (mm)
M_{cf}	Column flange flexural strength, kip-in. (N-mm)
M_f	Maximum moment expected at face of column, kip-in. (N-mm)
M_{np}	Moment without prying action in the bolts, kip-in. (N-mm)
M_{pe}	Plastic moment of beam based on expected yield stress, kip-in. (N-mm)
M_{pr}	Probable maximum moment at plastic hinge, kip-in. (N-mm)
N	Thickness of beam flange plus 2 times the <i>reinforcing fillet</i> weld size, in. (mm)
P_t	Minimum specified tensile strength of the bolt, kips (N)
R_n	Required force for stiffener design, kips (N)
R_y	Ratio of expected yield stress to specified minimum yield stress F_y , as specified in the AISC <i>Seismic Provisions</i> .
R_{yb}	Ratio of expected yield stress to specified minimum yield stress F_y , for a beam
R_{yc}	Ratio of expected yield stress to specified minimum yield stress F_y , for a column
S_h	Distance from the face of a column to a plastic hinge, in. (mm)
$V_{gravity}$	Beam shear force resulting from $1.2D + f_1L + 0.2S$, kips (N)
V_{RBS}	Larger of the two values of shear force at the center of the reduced beam section at each end of a beam, kips (N)
V'_{RBS}	Smaller of the two values of shear force at the center of the reduced beam section at each end of a beam, kips (N)
Y_c	Column flange yield line mechanism parameter, in. (mm)
Y_p	End-plate yield line mechanism parameter, in. (mm)
Z_x	Plastic section modulus of a member, in. ³ (mm ³)
Z_e	Effective plastic modulus of a section (or connection) at the location of a plastic hinge, in. ³ (mm ³) Z_{RBS}
	Plastic section modulus at the center of the reduced beam section, in. ³ (mm ³)
a	Horizontal distance between a column flange and the start of an RBS cut, in. (mm)
b	Width of compression element as defined in the AISC <i>Specification</i> , in. (mm)

b	Length of an RBS cut, in. (mm)
b_{bf}	Width of beam flange, in. (mm)
b_p	Width of plate, in. (mm)
c	Depth of cut at the center of the reduced beam section, in. (mm)
$d_{b\text{ Req'd}}$	Required bolt diameter, in. (mm)
f_1	Load factor determined by the applicable building code for live loads but not less than 0.5
g	Horizontal gage between bolts, in. (mm)
h_1	Distance from the centerline of a compression flange to the tension side inner bolt rows in 4E and 4ES end-plate moment connections, in. (mm)
h_i	Distance from centerline of a compression flange to the centerline of the i^{th} tension bolt row, in. (mm)
h_o	Distance from the centerline of a compression flange to the tension side outer bolt row in 4E and 4ES connections, in. (mm)
h_{st}	Height of stiffener, in. (mm)
k_c	Distance from outer face of a column flange to web toe of fillet (design value) or fillet weld, in. (mm)
n_b	Number of bolts at a compression flange
n_i	Number of inner bolts
n_o	Number of outer bolts
p_b	Pitch between the inner and outer row of bolts in an 8ES end-plate moment connection, in. (mm)
p_f	Vertical distance between beam flange and the nearest row of bolts, in. (mm)
p_{fi}	Distance from the inside of a beam tension flange to the nearest inside bolt row, in. (mm)
p_{fo}	Distance from the outside of a beam tension flange to the nearest outside bolt row, in. (mm)
p_{si}	Distance from the inside face of a column stiffener to the nearest inside bolt row, in. (mm)
p_{so}	Distance from the outside face of column stiffener to the nearest outside bolt row, in. (mm)
s	Distance from the centerline of the most inside or most outside tension bolt row to the edge of a yield line pattern, in. (mm)
t_{bw}	Thickness of beam web, in. (mm)
t_{cw}	Thickness of column web, in. (mm)
t_p	Thickness of plate or panel zone including doubler plates, in. (mm)
w	Uniform beam gravity load, kips per linear ft (N per linear mm)
ϕ_d	Resistance factor for ductile limit states
ϕ_n	Resistance factor for non-ductile limit states

GLOSSARY

The Standard uses the following terms in addition to the terms defined in the 2005 AISC *Specification for Structural Steel Buildings* and the 2005 AISC *Seismic Provisions for Structural Steel Buildings*. Glossary terms are italicized where they appear in the text.

Air carbon arc cutting. Process of cutting steel by the heat from an electric arc applied simultaneously with an air jet.

Backing. Piece of metal or other material, placed at the weld root to facilitate placement of the root pass.

Backgouge. Process of removing by grinding or air carbon arc cutting all or a portion of the root pass of a complete joint penetration groove weld, from the reverse side of a joint from which a root was originally placed.

Complete joint penetration (CJP) groove weld. Groove weld in which weld metal extends through the joint thickness.

Concrete structural slab. Reinforced concrete slab or concrete fill on steel deck with a total thickness of 3 in. (75 mm) or greater and a concrete compressive strength in excess of 2000 psi (14 MPa).

Non-fusible backing. Backing material that will not fuse with the base metals during the welding process.

Plastic hinge location. Location in a beam column assembly where inelastic energy dissipation is assumed to occur through the development of plastic flexural straining.

Probable maximum moment at plastic hinge. Expected moment developed at a plastic hinge location along a member, considering the probable (mean) value of the material strength for the specified steel and effects of strain hardening.

Reinforcing fillet. Fillet weld applied to a groove welded “tee-joint” to obtain a contour to reduce stress concentrations associated with joint geometry.

Root. Portion of a multi-pass weld deposited in the first pass of welding.

Thermal cutting. Group of cutting processes that severs or removes metal by localized melting, burning, or vaporizing of the workpiece.

Weld tab. Piece of metal affixed to the end of a welded joint to facilitate the initiation and termination of weld passes outside the structural joint.

CHAPTER 1

GENERAL

1.1 Scope

This Standard specifies design, detailing, fabrication and quality criteria for connections that are prequalified in accordance with the AISC *Seismic Provisions for Structural Steel Buildings* (herein referred to as the AISC *Seismic Provisions*) for use with special moment frames (SMF) and intermediate moment frames (IMF). The connections contained in this Standard are prequalified to meet the requirements in the AISC *Seismic Provisions* only when designed and constructed in accordance with the requirements of this Standard. Nothing in this Standard shall preclude the use of connection types contained herein outside the indicated limitations, or the use of other connection types, when satisfactory evidence of qualification in accordance with Appendix S of the AISC *Seismic Provisions* is presented to the authority having jurisdiction.

1.2 References

The following standards form a part of this Standard to the extent that they are referenced and applicable:

- 2005 AISC *Seismic Provisions for Structural Steel Buildings*
- 2004 AWS *D1.1 Structural Welding Code – Steel* (herein referred to as AWS D1.1)
- 2004 RCSC *Specification for Structural Joints using ASTM A325 or A490 Bolts* (herein referred to as the RCSC Specification)
- 2005 AISC *Specification for Structural Steel Buildings* (herein referred to as the AISC Specification)

1.3 General

All design, materials, and workmanship shall conform to the requirements of the AISC Seismic Provisions, and this Standard. The connections contained in this Standard shall be designed according to the Load and Resistance Factor Design (LRFD) provisions. Connections designed according to this Standard are permitted to be used in structures designed according to the LRFD or Allowable Strength Design (ASD) provisions of the AISC Seismic Provisions.

CHAPTER 2

DESIGN REQUIREMENTS

2.1 Special and Intermediate Moment Frame Connection Types

The connection types listed in Table 2.1 are prequalified for use in connecting beams to column flanges in special moment frames (SMF) and intermediate moment frames (IMF) within the limitations specified in this Standard.

TABLE 2.1.
Prequalified Moment Connections

Connection Type	Reference Section	Systems
Reduced beam section (RBS)	Chapter 5	SMF, IMF
Bolted unstiffened extended end plate (BUEEP)	Chapter 6	SMF*, IMF
Bolted stiffened extended end plate (BSEEP)	Chapter 6	SMF*, IMF
*Not prequalified for special moment frames (SMFs) with concrete structural slabs in direct contact with the steel		

2.2 Connection Stiffness

All connections contained in this Standard shall be considered fully restrained (Type FR) for the purpose of seismic analysis.

2.3 Members

The connections contained in this Standard are prequalified in accordance with the requirements of the AISC *Seismic Provisions* when used to connect members meeting the limitations of Sections 2.3.1 or 2.3.2, as applicable.

2.3.1 Rolled Wide-Flange Members

Rolled wide-flange members conforming to the cross-section profile limitations applicable to the specific connection in this Standard shall be permitted.

2.3.2 Built-up Members

Built-up members having a doubly symmetric, I-shaped cross-section shall be permitted when:

- (1) Flanges and webs have width, depth, and thickness profiles similar to rolled wide-flange sections meeting the profile limitations for wide-flange sections applicable to the specific connection in this Standard, and

- (2) **Webs are continuously connected to flanges in accordance with the requirements of Sections 2.3.2a or 2.3.2b, as applicable.**

2.3.2a Beams

Within a zone extending from the beam end to a distance not less than one beam depth beyond the *plastic hinge location*, S_h , unless specifically indicated in this Standard the web and flanges shall be connected using *complete joint penetration (CJP) groove welds* with a pair of *reinforcing fillet welds*. The minimum size of these fillet welds shall be the lesser of $5/16$ in. (8 mm) or the thickness of the beam web.

Exception: This provision shall not apply where individual connection pre-qualifications specify other requirements.

2.3.2b Columns

Built-up columns shall conform to the provisions of subsections (1) through (4), as applicable. Built-up columns shall satisfy the requirements of AISC *Specification* Section E6 except as modified in this Section. Transfer of all internal forces and stresses between elements of the built-up column shall be through welds.

1. I-Shaped Welded Columns

The elements of built-up I-shaped columns shall conform to the requirements of the AISC *Seismic Provisions*.

Within a zone extending from 12 in. (300 mm) above the upper beam flange to 12 in. (300 mm) below the lower beam flange, unless specifically indicated in this Standard, the column webs and flanges shall be connected using CJP groove welds with a pair of *reinforcing fillet welds*. The minimum size of fillet welds shall be the lesser of $5/16$ in. (8 mm) or the thickness of the column web.

2. Boxed Wide-Flange Columns

The wide-flange shape of a boxed wide-flange column shall conform to the requirements of the AISC *Seismic Provisions*.

The width-to-thickness ratio (b/t) of plates used as flanges shall not exceed $0.6\sqrt{E_s/F_y}$, where b shall be taken as not less than the clear distance between plates.

The width-to-thickness ratio (h/t_w) of plates used only as webs shall conform to the provisions of Table I-8-1 of the AISC *Seismic Provisions*.

Within a zone extending from 12 in. (300 mm) above the upper beam flange to 12 in. (300 mm) below the lower beam flange, flange and web plates of boxed wide-flange columns shall be joined by CJP groove welds. Outside this zone, plate elements shall be continuously connected by fillet or groove welds.

3. Built-up Box Columns

The width-to-thickness ratio (b/t) of plates used as flanges shall not exceed $0.6\sqrt{E_s/F_y}$, where b shall be taken as not less than the clear distance between web plates.

The width-to-thickness ratio (h/t_w) of plates used only as webs shall conform to the requirements of the AISC *Seismic Provisions*.

Within a zone extending from 12 in. (300 mm) above the upper beam flange to 12 in. (300 mm) below the lower beam flange, flange and web plates of box columns shall be joined by CJP groove welds. Outside this zone, box column web and flange plates shall be continuously connected by fillet welds or groove welds.

4. Flanged Cruciform Columns

The elements of flanged cruciform columns, whether fabricated from rolled shapes or built up from plates, shall meet the requirements of the AISC *Seismic Provisions*.

User Note: For flanged cruciform columns, the provisions of AISC *Specification* Section E6 must be considered.

Within a zone extending from 12 in. (300 mm) above the upper beam flange to 12 in. (300 mm) below the lower beam flange, the web of the tee-shaped sections shall be welded to the web of the continuous I-shaped section with CJP groove welds with a pair of *reinforcing fillet* welds. The minimum size of fillet welds shall be the lesser of $5/16$ in. (300 mm) or the thickness of the column web. Continuity plates shall conform to the requirements for wide-flange columns.

2.4 Connection Design Parameters

2.4.1 Load Combinations and Resistance Factors

Where available strengths are calculated in accordance with the AISC *Specification*, the resistance factors specified therein shall apply. When available strengths are calculated in accordance with this Standard, the resistance factors ϕ_d and ϕ_n shall be used as specified in the applicable section of this Standard. The values of ϕ_d and ϕ_n shall be taken as:

- (a) For ductile limit states:

$$\phi_d = 1.00$$

- (b) For non-ductile limit states:

$$\phi_n = 0.90$$

2.4.2 Plastic Hinge Location

The distance of the plastic hinge from the face of the column, S_h , shall be taken in accordance with the requirements for the individual connection as specified herein.

2.4.3 Probable Maximum Moment at Plastic Hinge

The probable maximum moment at the location of the plastic hinge shall be taken as:

$$M_{pr} = C_{pr} R_y F_y Z_e \quad (2.4.3-1)$$

where

M_{pr} = probable maximum moment at plastic hinge, kip-in. (N-mm)

R_y = ratio of the expected yield stress to the specified minimum yield stress F_y ; see AISC *Seismic Provisions*

Z_e = effective plastic modulus of the section (or connection) at the location of the plastic hinge, in.³ (mm³)

C_{pr} = factor to account for the peak connection strength, including strain hardening, local restraint, additional reinforcement, and other connection conditions. Unless otherwise specifically indicated in this Standard, the value of C_{pr} shall be:

$$C_{pr} = \frac{F_y + F_u}{2F_y} \leq 1.2 \quad (2.4.3-2)$$

where

F_y = specified minimum yield stress of the type of steel to be used in the yielding element, ksi (MPa)

F_u = specified minimum tensile strength of the type of steel to be used in the yielding element, ksi (MPa)

2.4.4 Beam Flange Continuity Plates

Continuity plates shall be provided.

Exceptions:

- (1) For bolted end-plate connections, the provisions of Section 6 shall apply.
- (2) When the beam flange connects to the flange of a wide-flange or built-up I-shaped column having a thickness that satisfies Equations 2.4.4-1 and 2.4.4-2, continuity plates need not be provided:

$$t_{cf} \geq 0.4 \sqrt{1.8 b_{bf} t_{bf} \frac{F_{yb} R_{yb}}{F_{yc} R_{yc}}} \quad (2.4.4-1)$$

$$t_{cf} \geq \frac{b_{bf}}{6} \quad (2.4.4-2)$$

where

t_{cf} = minimum required thickness of column flange when no continuity plates are provided, in. (mm)

b_{bf} = beam flange width, in. (mm)

t_{bf} = beam flange thickness, in. (mm)

F_{yb} = specified minimum yield stress of the beam flange, ksi (MPa)

F_{yc} = specified minimum yield stress of the column flange, ksi (MPa)

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*

- (3) When the beam flange connects to the flange of the I-shape in a boxed wide-flange column having a thickness that satisfies Equations 2.4.4-3 and 2.4.4-4, continuity plates need not be provided.

$$t_{cf} \geq 0.4 \sqrt{\left[1 - \frac{b_{bf}}{b_{cf}2} \left(b_{cf} - \frac{b_{bf}}{4} \right) \right] 1.8 b_{bf} t_{bf} \frac{F_{yb} R_{yb}}{F_{yc} R_{yc}}} \quad (2.4.4-3)$$

$$t_{cf} \geq \frac{b_f}{12} \quad (2.4.4-4)$$

2.4.4a Continuity Plate Thickness

Where continuity plates are required, the thickness of the plates shall be determined as follows:

- (a) For one-sided (exterior) connections, continuity plate thickness shall be at least one-half of the thickness of the beam flange.
- (b) For two-sided (interior) connections, the continuity plate thickness shall be at least equal to the thicker of the two beam flanges on either side of the column.

Continuity plates shall also conform to the requirements of Section J10 of the AISC *Specification*.

2.4.4b Continuity Plate to Column Attachment

Continuity plates, if provided, shall be welded to column flanges using CJP groove welds.

Continuity plates shall be welded to column webs using groove welds or fillet welds. The required strength of the sum of the welded joints of the continuity plates to the column web shall be the smallest of the following:

- (a) The sum of the design strengths in tension of the contact areas of the continuity plates to the column flanges that have attached beam flanges.
- (b) The design strength in shear of the contact area of the plate with the column web.

- (c) The design strength in shear of the column panel zone.
- (d) The sum of the expected yield strengths of the beam flanges transmitting force to the continuity plates.

2.5 Panel Zones

Panel zones shall conform to the minimum requirements for SMF or IMF, as applicable, in Section 9.3 or Section 10.3 of the AISC *Seismic Provisions*. References to matching of tested connections shall not apply.

2.6 Protected Zone

The protected zone shall be as defined for each prequalified connection. The protected zone shall meet the requirements of Section 7.4 of the AISC *Seismic Provisions*, except as indicated in this Standard. Unless otherwise specifically indicated in this Standard, the protected zone of the beam shall be defined as the area from the face of the column flange to one-half of the beam depth beyond the theoretical hinge point. Bolt holes in beam webs, when detailed in accordance with the individual connection provisions of this Standard, shall be permitted.

CHAPTER 3

WELDING REQUIREMENTS

3.1 Filler Metals

Filler metals shall conform to the requirements of Section 7.3 and Appendix W of the AISC *Seismic Provisions*.

3.2 Welding Procedures

Welding procedures shall be in accordance with Section 7.3 and Appendix W of the AISC *Seismic Provisions*.

3.3 Backing at Beam to Column and Continuity Plate to Column Joints

3.3.1 Steel Backing at Continuity Plates

Steel *backing* used at continuity plate to column welds need not be removed. At column flanges, steel *backing* left in place shall be attached to the column flange using a continuous $\frac{5}{16}$ -in. (8-mm) fillet weld on the edge below the CJP groove weld.

When *backing* is removed, following the removal of *backing*, the *root* pass shall be *backgouged* to sound weld metal and backwelded with a *reinforcing fillet*. The *reinforcing fillet* shall be continuous with a minimum size of $\frac{5}{16}$ in. (8 mm).

3.3.2 Steel Backing at Beam Bottom Flange

Where steel *backing* is used with CJP groove welds between the bottom beam flange and the column, the *backing* shall be removed.

Following the removal of *backing*, the *root* pass shall be *backgouged* to sound weld metal and backwelded with a *reinforcing fillet*. The size of the *reinforcing fillet* leg adjacent to the column shall be a minimum of $\frac{5}{16}$ in. (8 mm), and the *reinforcing fillet* leg adjacent to the beam flange shall be such that the fillet toe is located on the beam flange base metal.

Exception: If the base metal and weld *root* are ground smooth after removal of *backing*, the *reinforcing fillet* adjacent to the beam flange need not extend to base metal.

3.3.3 Steel Backing at Beam Top Flange

Where steel *backing* is used with CJP groove welds between the top beam flange and the column, and the *backing* is not removed, the *backing* shall be attached to the column by a continuous $\frac{5}{16}$ -in. (8-mm) fillet weld on the edge below the CJP groove weld.

3.3.4 Prohibited Welds at Steel Backing

Backing at beam flange-to-column flange joints shall not be welded to the underside of the beam flange, nor shall tack welds be permitted at this location. If fillet welds or tack welds are placed between the *backing* and the beam flange in error, they shall be repaired as follows:

- (1) The weld shall be removed such that the fillet weld or tack weld no longer attaches the *backing* to the beam flange.
- (2) The surface of the beam flange shall be ground flush and shall be free of defects.
- (3) Any gouges or notches shall be repaired. Repair welding shall be done with E7018 SMAW electrodes or other filler metals meeting the requirements of Section 3.1 for demand critical welds. A special welding procedure specification (WPS) is required for this repair. Following welding, the repair weld shall be ground smooth.

3.3.5 Non-Fusible Backing at Beam Flange-to-Column Joints

Where *non-fusible backing* is used with CJP groove welds between the beam flanges and the column, the *backing* shall be removed, the *root backgouged* to sound weld metal and backwelded with a *reinforcing fillet*. The size of the *reinforcing fillet* leg adjacent to the column shall be a minimum of $\frac{5}{16}$ in. (8 mm) and the *reinforcing fillet* leg adjacent to the beam flange shall be such that the fillet toe is located on the beam flange base metal.

Exception: If the base metal and weld *root* is ground smooth after removal of *backing*, the *reinforcing fillet* adjacent to the beam flange need not extend to base metal.

3.4 Details and Treatment of Weld Tabs

Where used, *weld tabs* shall be removed to within $\frac{1}{8}$ in. (3 mm) of the base metal surface and the end of the weld finished, except at continuity plates where removal to within $\frac{1}{4}$ in. (6 mm) of the plate edge shall be permitted. Removal shall be by *air carbon arc cutting* (CAC-A), grinding, chipping, or *thermal cutting*. The process shall be controlled to minimize errant gouging. The edges where *weld tabs* have been removed shall be finished to a surface roughness of 500 microinches (13 micron) or better. The contour of the weld end shall provide a smooth transition to adjacent surfaces, free of notches, gouges and sharp corners. Weld defects greater than $\frac{1}{16}$ -in. (1.6-mm) deep shall be excavated and repaired by welding in accordance with an applicable WPS. Other weld defects shall be removed by grinding, faired to a slope not greater than 1:5.

3.5 Tack Welds

In the protected zone, tack welds attaching *backing* and *weld tabs* shall be placed where they will be incorporated into a final weld.

3.6 Continuity Plates

Along the web, the corner clip shall be detailed so that the clip extends a distance of at least $1\frac{1}{2}$ in. (38 mm) beyond the published “ k ” detail dimension for the rolled shape. Along the flange, the plate shall be clipped to avoid interference with the radius of the rolled shape and shall be detailed so that the clip does not exceed a distance of $\frac{1}{2}$ in. (12 mm) beyond the published “ k_1 ” detail dimension. The clip shall be detailed to facilitate suitable weld terminations for both the flange weld and the web weld. When a curved clip is used, it shall have a minimum radius of $\frac{1}{2}$ in. (12 mm).

At the end of the weld adjacent to the column web/flange juncture, *weld tabs* for continuity plates shall not be used, except when permitted by the engineer of record. Unless specified to be removed by the engineer of record, *weld tabs* shall not be removed when used in this location.

Where continuity plate welds are made without *weld tabs* near the column fillet radius, weld layers shall be permitted to be transitioned at an angle of 0° to 45° measured from the vertical plane. The effective length of the weld shall be defined as that portion of the weld having full size. Non-destructive testing (NDT) shall not be required on the tapered or transition portion of the weld not having full size.

3.7 Quality Control and Quality Assurance

Quality control and quality assurance shall be in accordance with Appendix Q of the AISC *Seismic Provisions*.

CHAPTER 4

BOLTING REQUIREMENTS

4.1 Fastener Assemblies

Bolts shall be pretensioned high-strength bolts conforming to ASTM A325 or A490. Twist-off type tension control bolt assemblies of equivalent mechanical properties and chemical composition may be substituted for A325 and A490 fastener assemblies.

4.2 Installation Requirements

Installation requirements shall be in accordance with AISC *Seismic Provisions* and the RCSC Specification, except as otherwise specifically indicated in this Standard.

4.3 Quality Control and Quality Assurance

Quality control and quality assurance shall be in accordance with Appendix Q of the AISC *Seismic Provisions*.

CHAPTER 5

REDUCED BEAM SECTION (RBS) MOMENT CONNECTION

5.1 General

In a reduced beam section (RBS) moment connection (Figure 5.1), portions of the beam flanges are selectively trimmed in the region adjacent to the beam-to-column connection. Yielding and hinge formation are intended to occur primarily within the reduced section of the beam.

5.2 Systems

RBS connections are prequalified for use in special moment frame (SMF) and intermediate moment frame (IMF) systems within the limits of these provisions.

5.3 Prequalification Limits

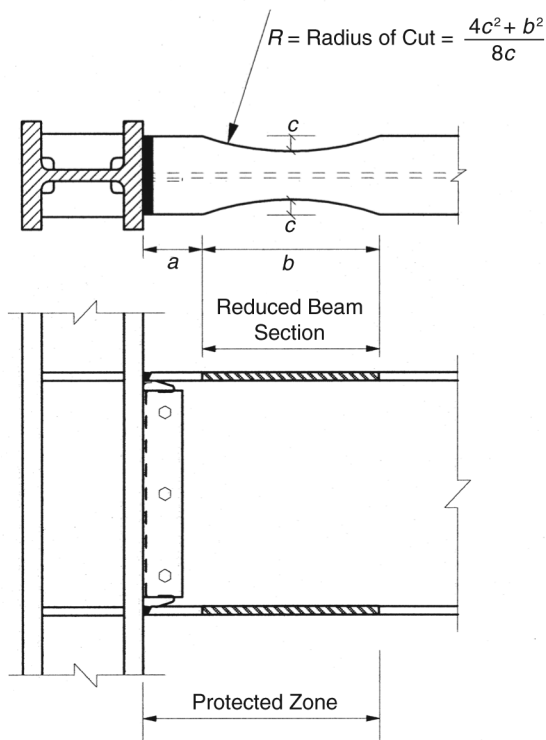


Fig. 5.1. Reduced beam section connection.

5.3.1 Beam Limitations

Beams shall satisfy the following limitations:

- (1) Beams shall be rolled wide-flange or built-up I-shaped members conforming to the requirements of Section 2.3.
- (2) Beam depth is limited to W36 (W920) for rolled shapes. Depth of built-up sections shall not exceed the depth permitted for rolled wide-flange shapes.
- (3) Beam weight is limited to 300 lbs/ft (447 kg/m).
- (4) Beam flange thickness is limited to $1\frac{3}{4}$ in. (44.5 mm).
- (5) The clear span-to-depth ratio of the beam shall be limited as follows:
 - (a) For SMF systems, 7 or greater.
 - (b) For IMF systems, 5 or greater.
- (6) Width-thickness ratios for the flanges and web of the beam shall conform to the limits of the AISC *Seismic Provisions*.

When determining the width-thickness ratio of the flange, the value of b_f shall not be taken as less than the flange width at the ends of the center two-thirds of the reduced section provided that gravity loads do not shift the location of the plastic hinge a significant distance from the center of the reduced beam section.

- (7) Lateral bracing of beams shall be provided as follows:
 - (a) For SMF systems, in conformance with Section 9.8 of the AISC *Seismic Provisions*. Supplemental lateral bracing shall be provided at the reduced section in conformance with Section 9.8 of the AISC *Seismic Provisions* for lateral bracing provided adjacent to the plastic hinges. References to the tested assembly in Section 9.8 of the AISC *Seismic Provisions* do not apply.

When supplemental lateral bracing is provided, attachment of supplemental lateral bracing to the beam shall be located no greater than $d/2$ beyond the end of the reduced beam section farthest from the face of the column, where d is the depth of the beam. No attachment of lateral bracing shall be made to the beam in the region extending from the face of the column to end of the reduced section farthest from the face of the column.

- (b) For IMF systems, in conformance with Section 10.8 of the AISC *Seismic Provisions*.

Exception: For both systems, where the beam supports a *concrete structural slab* that is connected between the protected zones with welded shear connectors spaced a maximum of 12 in. (300 mm) on

center, supplemental top and bottom flange bracing at the reduced section is not required.

- (8) The protected zone consists of the portion of beam between the face of the column and the end of the reduced beam section cut farthest from the face of the column.

5.3.2 Column Limitations

Columns shall satisfy the following limitations:

- (1) Columns shall be any of the rolled shapes or built-up sections permitted in Section 2.3.
- (2) The beam shall be connected to the flange of the column.
- (3) Rolled shape column depth shall be limited to W36 (W920). The depth of built-up wide-flange columns shall not exceed that for rolled shapes. Flanged cruciform columns shall not have a width or depth greater than the depth allowed for rolled shapes. Built-up box columns shall not have a width or depth exceeding 24 in. (610 mm). Boxed wide-flange columns shall not have a width or depth exceeding 24 in. (610 mm) if participating in orthogonal moment frames.
- (4) There is no limit on the weight per foot of columns.
- (5) There are no additional requirements for flange thickness.
- (6) Width-thickness ratios for the flanges and web of columns shall conform to the limits in Table I–8–1 of the AISC *Seismic Provisions*.
- (7) Lateral bracing of columns shall conform to Section 9.7 or 10.7 for SMF or IMF, as applicable, in the AISC *Seismic Provisions*.

5.4 Beam-Column Relationship Limitations

Beam-column connections shall satisfy the following limitations:

- (1) Panel zones shall conform to the requirements for Sections 9.3 or 10.3 for SMF or IMF, as applicable, in the AISC *Seismic Provisions*.
- (2) Column-beam ratios shall be limited as follows:
 - (a) For SMF systems, the column-beam moment ratio shall conform to the requirements of the AISC *Seismic Provisions*. The value of ΣM_{pb}^* shall be taken equal to $\Sigma (M_{pr} + M_v)$, where M_{pr} is computed according to Equation 5.8–5, and where M_v is the additional moment due to shear amplification from the center of the reduced beam section to the centerline of the column. M_v can be computed as $V_{RBS} (a + b/2 + d_c/2)$, where V_{RBS} is the shear at the center of the reduced beam section computed per Step 4 of Section 5.8, a and b are the dimensions shown in Figure 5.1, and d_c is the depth of the column.

- (b) For IMF systems, the column-beam moment ratio shall conform to the requirements of Section 10.6 of the AISC *Seismic Provisions*.

5.5 Beam Flange to Column Flange Weld Limitations

Beam flange to column flange connections shall satisfy the following limitations:

- (1) Beam flanges shall be connected to column flanges using *complete joint penetration (CJP) groove welds*. Beam flange welds shall conform to the requirements for demand critical welds in Section 7.3 and Appendix W of the AISC *Seismic Provisions*.
- (2) Weld access hole geometry shall conform to the requirements of the AISC *Specification* Section J1.6.

5.6 Beam Web to Column Connection Limitations

Beam web to column web connections shall satisfy the following limitations:

- (1) The required shear strength of the beam web connection shall be determined according to Equation 5.8-9.
- (2) Web connection details shall be limited as follows:
 - (a) For SMF systems, the beam web shall be connected to the column flange using a CJP groove weld extending between weld access holes. The single plate shear connection shall be permitted to be used as *backing* for the CJP groove weld. The thickness of the plate shall be at least $\frac{3}{8}$ in. (10 mm). *Weld tabs* are not required at the ends of the CJP groove weld at the beam web. Bolt holes in the beam web for the purpose of erection are permitted.
 - (b) For IMF systems, the beam web shall be connected to the column flange per as required for SMF systems.

Exception: For IMF, it is permitted to connect the beam web to the column flange using a bolted single plate shear connection. The bolted single plate shear connection shall be designed as a slip-critical connection, with the design slip resistance per bolt determined according to Section J3.8 of the AISC *Specification*. The nominal bearing strength at bolt holes shall not be taken greater than the value given by Equation J3-6a of the AISC *Specification*. The design shear strength of the single plate shear connection shall be determined based on shear yielding of the gross section and on shear fracture of the net section. The plate shall be welded to the column flange with a CJP groove weld, or with fillet welds on both sides of the plate. The minimum size of the fillet weld on each side of the plate shall be 75 percent of the thickness of the plate. Standard-size holes shall be provided in the beam web and in the plate, except that short-slotted holes (with the slot parallel to the beam flanges) may be used in either the beam web or in the plate,

but not in both. Bolts are permitted to be pretensioned either before or after welding.

5.7 Fabrication of Flange Cuts

The reduced beam section shall be made using *thermal cutting* to produce a smooth curve. The maximum surface roughness of the thermally cut surface shall be 500 microinches (13 microns) in accordance with ANSI B46.1, as measured using AWS C4.1–77 Sample 4 or similar visual comparator. All transitions between the reduced beam section and the unmodified beam flange shall be rounded in the direction of the flange length to minimize notch effects due to abrupt transitions. Corners between the reduced section surface and the top and bottom of the flanges shall be ground to remove sharp edges, but a minimum chamfer or radius is not required.

Thermal cutting tolerances shall be plus or minus $\frac{1}{4}$ in. (6 mm) from the theoretical cut line. The beam effective flange width at any section shall have a tolerance of plus or minus $\frac{3}{8}$ in. (10 mm).

Gouges and notches that occur in the thermally cut RBS surface may be repaired by grinding if not more than $\frac{1}{4}$ in. (6 mm) deep. The gouged or notched area shall be faired by grinding so that a smooth transition exists, and the total length of the area ground for the transition shall be no less than five times the depth of the removed gouge on each side of the gouge. If a sharp notch exists, the area shall be inspected by MT after grinding to ensure that the entire depth of notch has been removed. Grinding that increases the depth of the RBS cut more than $\frac{1}{4}$ in. (6 mm) beyond the specified depth of cut is not permitted.

Gouges and notches that exceed $\frac{1}{4}$ in. (6 mm) in depth, but not to exceed $\frac{1}{2}$ in. (12 mm) in depth, and those notches and gouges where repair by grinding would increase the effective depth of the RBS cut beyond tolerance, may be repaired by welding. The notch or gouge shall be removed and ground to provide a smooth radius of not less than $\frac{1}{4}$ in. in preparation for welding. The repair area shall be preheated to a temperature of 150° F or the value specified in AWS D1.1 Table 3.2, whichever is greater, measured at the location of the weld repair.

Notches and gouges exceeding $\frac{1}{2}$ in. (12 mm) in depth shall be repaired only with a method approved by the engineer of record.

5.8 Design Procedure

STEP 1 – Choose trial values for the beam sections, column sections and RBS dimensions a , b , and c (Figure 5.1) subject to the limits:

$$0.5b_{bf} \leq a \leq 0.75b_{bf} \quad (5.8-1)$$

$$0.65d \leq b \leq 0.85d \quad (5.8-2)$$

$$0.1b_{bf} \leq c \leq 0.25b_{bf} \quad (5.8-3)$$