



UPCOMING CHANGES TO AISC 341 – SEISMIC PROVISIONS FOR STRUCTURAL STEEL BUILDINGS

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Abstract

American Institute of Steel Construction (AISC) document 360, Specification for Structural Steel Buildings, is the basic reference for the design, fabrication and erection of structural steel buildings and other “building-like” steel structures in the United States. When applied in conjunction with AISC 360, AISC 341, Seismic Provisions for Structural Steel Buildings, is the standard reference document for the seismic design of steel structures throughout the United States. Balloting is complete to update AISC 341-16 (AISC, 2016b) that will be incorporated with ASCE 7-16 (ASCE, 2016) and AISC 360-16 (AISC 2016a) into the 2018 International Building Code. The document will have significant technical modifications including new material specifications, use of steel braced diaphragms, new column splice details, requirements for SCBF gusset plate welds, and application of demands on columns that participate in intersecting frames. In addition, significant new provisions related to the seismic design of multi-tier braced frames will be provided. A new composite shear wall system has also been developed. This paper will summarize the changes proposed for AISC 341-16.

Keywords: Steel; AISC 341; Multi-tier braced frames; composite shear walls; braced diaphragms

1. Introduction

The 2016 AISC Seismic Provisions introduce a number of new and updated provisions while remaining mostly unchanged from the 2010 edition. The overall organization of the standard is the same, with Chapters A-D containing analysis and connection requirements that apply to all seismic force-resisting systems, Chapters E-H addressing moment and braced frame and their composite counterparts, and Chapters I, J, and K covering fabrication and erection, quality assurance and quality control, and prequalification and qualification testing. The most significant changes include provisions for multi-tiered braced frames, an option to use partial-joint penetration welds in Special Moment Frame (SMF) column splices, and clearer provisions for continuity plates, doubler plates, and associated welding. Other changes include new and updated R_y values, new provisions for horizontal truss diaphragms, a new application of composite plate shear walls using concrete-filled steel panel walls, a requirement to consider simultaneous inelasticity in shared columns in orthogonal seismic force-resisting systems, updated welding requirements for Special Concentrically Braced Frame (SCBF) gusset-plate edge welds, and a few updates to prequalification of moment frame connections.

2. New Provisions for Multi-Tier Braced Frames

Multi-tiered braced frames are defined as braced frames with two or more levels of bracing between diaphragms or locations of out-of plane support. This type of frame, shown schematically in Figure 1, was considered a K-braced frame in the 2010 Provisions and therefore prohibited. In the 2016 Provisions, this bracing configuration is permitted within the definition of either an Ordinary Concentrically Braced (OCBF), an SCBF, or a Buckling Restrained Braced Frame (BRBF), and carries an extra set of requirements in each case. Generally, these requirements include providing a strut in the plane of the frame at each tier level, torsionally bracing the columns, and designing the strut, column, and connections for amplified forces, which might be forces based on the capacity of the brace or on the ASCE 7 overstrength factor. The commentary explains some of the typical issues with this system, including stability of the column and the tendency for inelastic behavior to concentrate in one tier. The commentary also refers to the ongoing research on these systems.

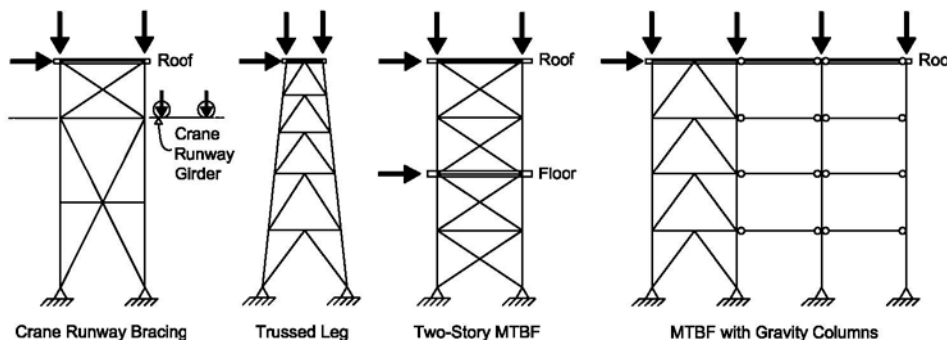


Figure 1 – Multi-Tier Braced Frame Configurations

3. New Provision for Partial Joint Penetration Column Splices

Previous to the 2016 edition of the Seismic Provisions, all Special Moment Frame (SMF) column splices, if welded, were required to be complete-joint-penetration groove welds. In the 2016 edition, partial joint penetration (PJP) welds are now permitted, thereby saving significant costs in welding and erection. Section E3.6g includes provisions for this weld, which require that the flange connection have a tapered transition between column shafts and that the effective throat of the weld be at least 85% of the thickness of the thinner flange. The PJP splice provision allows for several options including single- or double-bevel groove welds, depending on the member thickness, and whether web access holes are provided or not. Companion requirements for nondestructive evaluation of these welds are also included. Industry efforts are underway to validate proper approaches to these evaluations, since ultrasonic testing of PJP welds is not routinely done, due at least partially to the difficulty that can arise in interpreting results of the weld scans.

4. Modified Requirements for Welding of Steel Moment Frame Panel Zones

The 2016 Seismic Provisions clarify reinforcement and welding at SMF panel zones, which is often a difficult location to determine the flow of forces and avoid congestion. First, the decision about whether continuity plates are required more explicitly points to AISC Specification Section J10 local limit states in the column, although a prescriptive minimum is also required. The flange force, which wasn't specifically addressed in the 2010 Provisions, may be determined by the engineer or according to the User Note in Section E3.6f.1. The thickness of the continuity plate is as required for strength but not less than 75% of the beam flange thickness, whereas in the 2010 Provisions it was required to be 100% of the beam flange thickness for two-sided connections. Also at the panel zone, the requirements for doubler plates are more well-defined, with separate sections with and without continuity plates and whether the doublers are extended beyond or fitted between the continuity plates, as shown in Figure 2. This section of the Seismic Provisions makes reference to AWS D1.8 (American Welding Society, 2009), which now includes a useful prequalified groove weld at the doubler-to-column location as shown in Figure 3.

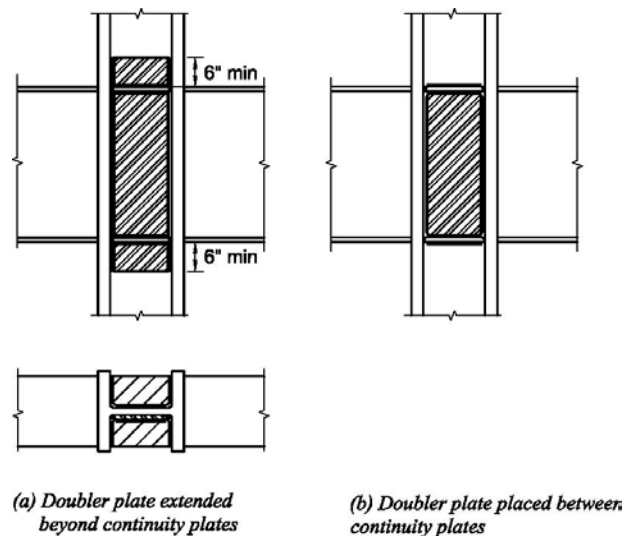


Figure 2 – Doubler Plate Configurations

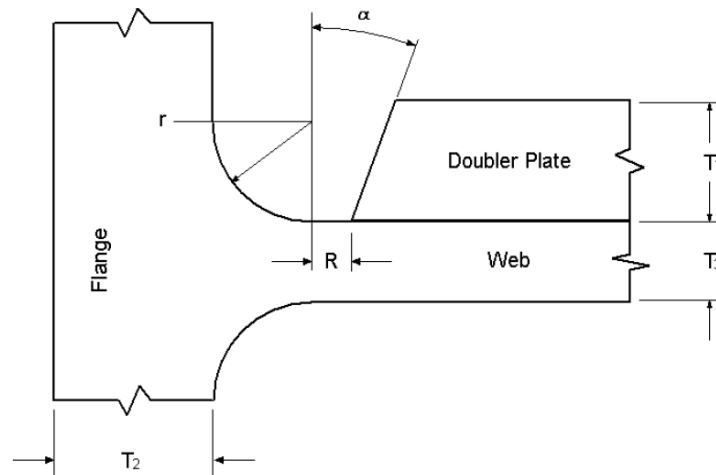


Figure 3 – AWS D1.8 Doubler Plate Weld Definition

5. Use of ASTM 1085 for HSS Shapes

For the 2016 Seismic Provisions, values of R_y , the ratio of the expected yield stress to the specified minimum yield stress, were reviewed and minor updates and additions have been made. A new American Society for Testing and Materials (ASTM) specification for HSS, A1085, was introduced in 2013 and uses $F_y = 50$ ksi and design wall thickness equal to the nominal thickness. In the 2016 Seismic Provisions, the R_y value for A1085 is given as 1.25 and the R_y for A500 Gr. C has been modified from 1.4 to 1.3. These changes will make Hollow Structural Shapes (HSS) more attractive options as the yielding elements in seismic force-resisting systems.

6. New Provisions for Steel Braced Diaphragm Design

A new Section B5 has been added to address diaphragms, chords, and collectors, and particularly horizontal truss diaphragms composed of structural steel members. The requirements for this truss diaphragm include designing the members and connections for overstrength seismic loads (Ω_o), with exceptions for ordinary systems designed as three-dimensional systems, and for cases where the diaphragm truss members are designed to act as yielding elements.

7. New Provisions for Concrete Encased Composite Plate Shear Walls

Another completely new section has been added to the 2016 Seismic Provisions: Section H7, on composite plate shear walls – concrete filled (C-PSW/CF). This system is a second application of the C-PSW system, the other being the concrete encased option (C-PSW/CE) as addressed in Section H6. Concrete-filled C-PSW are highly ductile, easily and quickly constructed, and provide redundancy in the building. Two types of wall, with and without boundary elements, are shown in Figure 4.

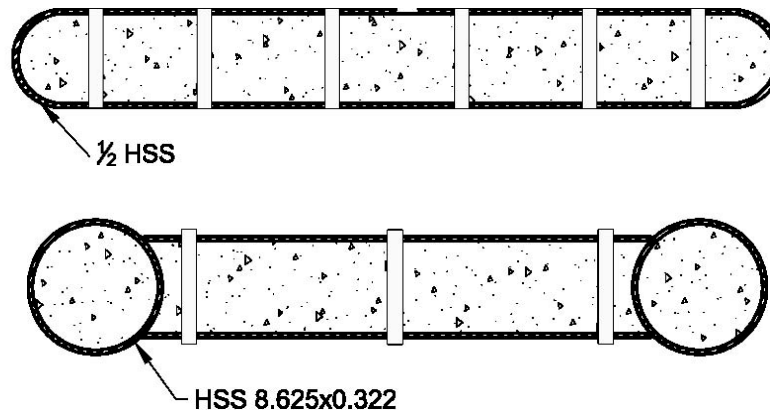


Figure 4- Configurations of Concrete Encased Composite Plate Walls

8. Identification of Additional Considerations for Column Design

Many engineers are familiar with the requirement in ASCE 7 to combine 100% of the seismic forces in one direction with 30% of the forces in the orthogonal direction when a column or other element participates in seismic resistance in both directions. This would be an appropriate approach for elastic response for a “diagonal” event. However, it is recognized that high R factor systems can yield at much lower demands than the elastic response spectrum would imply. The column design could therefore result in a non-conservative size by applying the 100/30 rule. To more properly consider the demands on these columns in steel systems, Section D1.4a of the Seismic Provisions adds that determination of the required axial strength for columns that are common to intersecting frames shall consider the potential for simultaneous inelasticity from all such frames. Columns that are part of ordinary systems are exempt from this consideration. The commentary to this section explains that the possibility of simultaneous yielding of orthogonal frames depends on the configuration and design and the story drift at which yielding is expected. It is likely that low-rise construction may be more susceptible than taller frames, since it is unlikely that all stories of a frame will be simultaneously yielding. A corresponding requirement is included in Section E3.4a for special moment frames when performing the “strong-column/weak-beam” check to ensure that beams are the weakest element.

9. Revised Provisions for SCBF Gusset Plates Connections

In SCBF gusset plates where the brace is designed to buckle out of the plane of the frame, the gusset-to-column-flange and gusset-to-beam-flange welds now have an explicit strength requirement. The welds are required to have an available strength equal to $0.6R_yF_yt_p$, where R_y is the ratio of the expected yield strength of the material, F_y is the nominal yield strength of the gusset plate, and t_p is the thickness of the gusset plate, or the welds may be designed to have available strength to resist gusset-plate edge forces corresponding to compression in the brace combined and gusset plate weak-axis flexure. The commentary explains that accurate prediction of maximum stresses at large drifts is difficult, and therefore it is advisable to proportion the welds to be stronger than the gusset plate allowing local yielding in the plate to protect the weld.



10. Changes to Moment Frame Designations and Pre-Qualifications

Finally, there have been a few changes to moment frames and prequalification. Section E3.2 has been modified to state that SMF and Intermediate Moment Frames (IMF) may provide inelastic deformation capacity not only through the typical behavior of flexural yielding of beams but also by yielding of beam-to-column connections, where substantiated by analysis and testing. This revision opens the door to partially-restrained prequalified connections, including one type which will be included in AISC 358-16 (AISC 2016c). Another change to testing requirements is the inclusion of prequalification and qualification for beam-to-column connections not only for steel systems but composite systems as well. Sections K1 and K2 now cover C-SMF and C-IMF as well as their steel counterparts.

11. Summary

Overall, the 2016 Seismic Provisions has not introduced changes to the way seismic force-resisting systems are analyzed and designed. The familiar concepts of ductility, capacity design, and analyzing the Seismic Force Resisting System as a whole have remained intact. A number of significant changes and additions have been made to specific provisions that reflect new information and responses to user input from the steel industry. These changes include the introduction of new provisions for the design of multi-tier braced frames, a new option for column splices using PJP weld details, improvements to the detailing requirements for SMF panel zones, introduction of ASTM 1085 material for HSS shapes, introduction of new provisions for braced diaphragm design, supplemental provisions for encased composite plate shear walls, identification of additional demands on columns that resist seismic forces in orthogonal directions, revised provisions for SCBF gusset plate connections, and changes to moment frame designations and pre-qualifications. These updates to the 2016 Seismic Provisions should continue to improve the transparency of the requirements and the seismic performance of steel buildings and other structures designed in accordance with the provisions.

12. References

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