Introduction to the AISC *Seismic Provisions*

The 2005 *Seismic Provisions* coordinate with the 2005 *Specification for Structural Steel Buildings*, the 13th Edition *Steel Construction Manual*, and the upcoming *Seismic Manual*.

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A MAJOR CHANGE TO AISC'S 2005 *SEISMIC PROVISIONS FOR STRUCTURAL STEEL BUILDINGS*, INCLUDING SUPPLEMENT NUMBER 1 IS IN ITS FORMAT. The 2005 *Seismic Provisions* are written as a supplement to the 2005 AISC *Specification for Structural Steel Buildings*, combining allowable strength design (ASD) and load and resistance factor design (LRFD) into a single, unified approach.

The section that accommodated ASD in previous editions was absorbed into Parts I and II of the new provisions: "Structural Steel Buildings" and "Composite Structural Steel and Reinforced Concrete Systems." Other revisions have been incorporated throughout the 2005 provisions, in addition to new quality criteria and two new seismic systems: buckling-restrained braced frames and special plate shear walls. (Throughout the provisions, exceptions to the 2005 specification and additional criteria are specified.)

Part I: Structural Steel Buildings

The first four sections of Part I establish the provisions' relationship with the 2005 specification, as well as with the applicable building code and other applicable national standards such as ASCE and ASTM, among others.

Section Overviews

Section 1—Scope: Section 1 defines the scope of the 2005 provisions: they apply to buildings classified by the applicable building code as seismic design category D or more severe. In seismic design categories A, B, and C, which are less severe, the system must satisfy one of two conditions: a seismic response modification coefficient, *R* of 3, must be used and elements must be designed to satisfy the 2005 specification only; or a higher *R* value must be used and the system must be designed to meet all of the requirements of the 2005 provisions. The second requirement is to ensure that large *R*-values are not being used for a structure without meeting the ductile detailing requirements of the 2005 provisions.

Sections 2-4—Applicable Codes and Standards: Section 2 lists referenced standards beyond those given in the 2005 specification. Sections 3 and 4 direct the user to the applicable building code for determining the required strength, where the applicable building code is defined as the "building code under which the structure is designed."

Section 5—Construction Documents: The newly developed Section 5 outlines information required in the construction documents prepared by the engineers, fabricators, and erectors. Design drawings and specifications must identify all elements of the seismic load resisting system (SLRS), demand critical welds, protected zones, connection configuration, welding requirements, etc. Shop drawings and erection drawings must include similar information to verify that the fabricator and erector understand the design intent.

Section 6—Material Properties and Characteristics: Section 6 considers acceptable material properties and characteristics for structural steel systems in seismic regions. One of this section's most important points is that the expected yield strength and the expected tensile strength must be considered in determining the required strength. For each structural material, F_yR_y results in the expected yield strength of the material. A second term, R_t, has been introduced. When R_t is multiplied by the nominal tensile strength, F_u, the result is the expected tensile strength of the material. The remainder of the provisions identifies when the R_y and R_t terms are to be used in determining the required strength of the members.

Section 7—Design of Connections, Joints, and Fasteners: The design of connections, joints, and fasteners in the SLRS is addressed in Section 7. All connections should be detailed so that a ductile limit state controls the strength of the components. It also defines the "protected zone," or the critical regions of elements in the SLRS where discontinuities must be avoided to minimize the chance of premature brittle fracture of the members.

All bolted connections must use pretensioned high-strength bolts, with the faying surface prepared for Class A or better slip-critical joints. However, bolted connections may be designed for the strength in bearing. This requirement is meant to avoid joint slip during small earthquakes, while recognizing that bolts will eventu-

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ally develop bearing during a design-level seismic event. Standard holes are required at bolted joints; short-slotted holes are acceptable when the axis is perpendicular to the direction of load. Oversized holes also may be used if they are in only one ply of the slip-critical joint. Bolts and welds are not allowed to share load at the same joint.

Welded connections must be made with filler metals that have a minimum CVN toughness of 20 ft-lbs at 0 °F. This is a relaxation from the previously adopted temperature of -20 °F. Demand critical welds still require filler metal with a minimum CVN toughness of 20 ft-lbs at -20 °F. An additional requirement of 40 ft-lbs at 70 °F CVN toughness is placed on demand critical complete-joint-penetration groove welds in various systems (for example: welds of beam flanges to columns, column splice joints, and welds of beam webs to column flanges). Specific detailing requirements for continuity plates are also provided in this section.

Section 8—Local and Global Instabilities: Requirements for local and global instabilities, as well as other general member requirements, are considered in Section 8. The limiting width-to-thickness ratios of flanges and webs for members in the SLRS are provided. These ratios are more restrictive than the compact section ratios given in the 2005 specification because of the expected inelastic demand during seismic behavior. The remaining portion of this section emphasizes column design. Splices for columns that are not part of the SLRS now have special design requirements since research indicates these columns may have significant flexure and shear demand during a severe seismic event.

Sections 9 through 17 provide design requirements for each of the codified structural steel building systems:

Section 9—Special Moment Frames (SMFs): SMFs are considered highly ductile and therefore have the highest *R* factor of the steel buildings systems discussed here. The proposed use of a particular moment-resisting joint must have a demonstrated capability of accommodating an interstory drift of 0.04 radians. This is accomplished by one of the following:

- Using a connection prequalified for use in a SMF in accordance with *Prequalified Connections for Special and Intermediate Moment Frames for Seismic Applications*, (ANSI/AISC 358-05), a new standard developed by the AISC Connection Prequalification Review Panel (CPRP). In the first edition, approved in 2005, ANSI/AISC 358 included prequalification of the reduced beam section and end plate connections. Efforts continue to prequalify all widely used connections.
- Using a connection prequalified for use in a SMF in accordance with Appendix P criteria, where minimum requirements for any moment-resisting joint are established. A CPRP will be established to review all test results and other data to ensure that the connection satisfies all minimum requirements.
- Providing qualifying test results in accordance with Appendix S. This appendix requires the test assembly to be consistent with joints proposed in the prototype building, defines essential test parameters, and identifies the test program implementation and the adequacy of the joint to sustain the required seismic demand. Test results can be taken from tests reported in the literature or from tests performed specifically for the project under consideration.

The panel zone must be consistent with the prequalified test configuration and the expected strength must be approximately "balanced" with the yield strength of the beams. In addition, all column splice strengths in bending and shear must be designed to develop the full flexural capacity of the smaller column spliced.

Section 10—Intermediate Moment Frames (IMFs): Like SMFs, IMFs must have moment-resisting connections qualified in accordance with ANSI/AISC 358 Appendix P or Appendix S. The qualifying interstory drift limit is reduced to 0.02 radians for these connections to reflect the more limited ductility demand expected from these systems. Current building codes limit the use of IMFs in high seismic design categories. Other than the prequalified connection and the more restrictive lateral bracing requirements, the 2005 specification governs the design requirements of these frames.

Section 11—Ordinary Moment Frames (OMFs): OMFs are accepted in light metal buildings and small building applications in the more severe seismic design categories. OMFs may be designed without the prequalified performance testing requirement. In an effort to induce inelastic behavior into the adjoining elements, the connection strength must exceed 1.1 times the expected strength of the connected members. Specific requirements such as continuity plates, removing weld backing and run-off tabs, and weld access holes help ensure minimum ductile performance of OMF connections.

Section 12—Special Truss Moment Frames (STMFs): STMF provisions define a special segment of the truss that is intended to be the primary location of inelastic behavior in the system. All other frame elements are designed with sufficient over-strength to develop yielding in the special segment. Both vierendeel and cross-braced special segment panels are allowed. The requirements also provide lateral bracing requirements similar to those required for SMF systems to prohibit out-of-plane instability.

Section 13—Special Concentrically Braced Frames (SCBFs): The concept for SCBF systems is that diagonal braces buckle and dissipate energy resulting from the design earthquake. The 2005 provisions have been modified to improve the ductility of the system. For example, brace orientation in each line of framing must have approximately the same number of braces in compression and tension. Connections in SCBFs must develop the full tensile capacity of the brace or the maximum force that can be delivered to the brace by the rest of the system. Full flexural strength must also be considered unless the connection includes a yield-line gusset plate that allows ductile post-buckled behavior of the brace. Special limitations are provided for V and inverted-V bracing to reflect the potentially undesirable characteristics of these bracing configurations. Column splices in SCBFs are required to develop a shear capacity of approximately 50% of the member capacity to reflect the substantial demands on these elements during the earthquake.

Section 14—Ordinary Concentrically Braced Frames (OCBF): Like OMFs, OCBFs have highly restricted applications in high seismic design categories due to their limited expected ductility. Connections in OCBFs may be designed to consider the amplified seismic load. The previous requirement of member design in OCBFs for the amplified seismic load was removed to address the reduced *R* factor given in ASCE 7-05, *Minimum Design Loads for Buildings and Other Structures*. Like OMFs, OCBF applications are also limited in high seismic design categories by the building codes.

Section 15—Eccentrically Braced Frames (EBFs): The provisions for EBF design state that full yield must be induced and strain hardened within the eccentric link while the diagonal braces, columns, and beams outside the link beams remain essentially elastic. Because of its importance in system performance, proper design of the link beam is the primary focus of this section. Laboratory testing has demonstrated that properly designed shear yielding links can undergo a link rotation angle of 0.08 radians. Moment yielding links are designed to undergo a link rotation angle of 0.02 radians, which is consistent with SMF systems. Interpolation is allowed for links with a length that results in a combination of shear and flexural yielding. Because of the high local deformation demands, link-to-column connections must be demonstrated by testing similar to SMF connections, in accordance with Appendices S and P or ANSI/AISC 358. An exception is provided if there is substantial reinforcement of the connection that would preclude inelastic behavior in the connection welds.

Section 16—Buckling-Restrained Braced Frames (BRBFs): Originally developed in Japan, the BRBF system has been used on a number of recent projects on the West Coast. This system relies on sustained compression due to local buckling of the brace while overall member buckling is restrained. This significantly increases the energy dissipation characteristics compared to the braces in a traditional SCBF system; therefore, BRBFs do not have the in-line brace configuration or other restrictions that are imposed on SCBFs. Similar to other structural system types, braces in a BRBF require prequalification testing as specified by Appendix T. The remaining design provisions are intended to ensure that the connections and other members in the BRBF system remain essentially elastic at full capacity of the brace.

Section 17—Special Plate Shear Walls (SPSWs): Although used on a number of buildings in high seismic regions as early as the 1970s, renewed interest in SPSW systems was generated in the early 1990s as a result of a series of research projects at two Canadian universities. Figure 1 shows typical inelastic behavior that might be expected from a SPSW. From this Canadian research, as well as ongoing research in the United States, design requirements for the system have been developed for this edition of the *Seismic Provisions*. Favorable seismic performance is achieved by controlling stable post-buckled

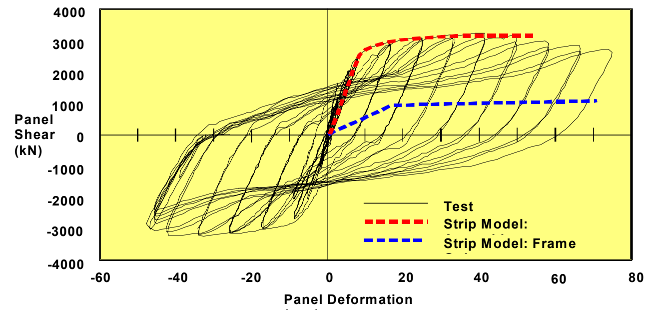

Figure 1. Special Plate Shear Wall test results.

(Driver, R.G., Kulak, G.L., Kennedy, D.J.L., and Elwi, A.E., "Seismic Behavior of Steel Plate Shear Walls," *Structural Engineering Report No. 215*, Department of Civil Engineering, University of Alberta, Edmonton, Alberta, Canada, 1997)

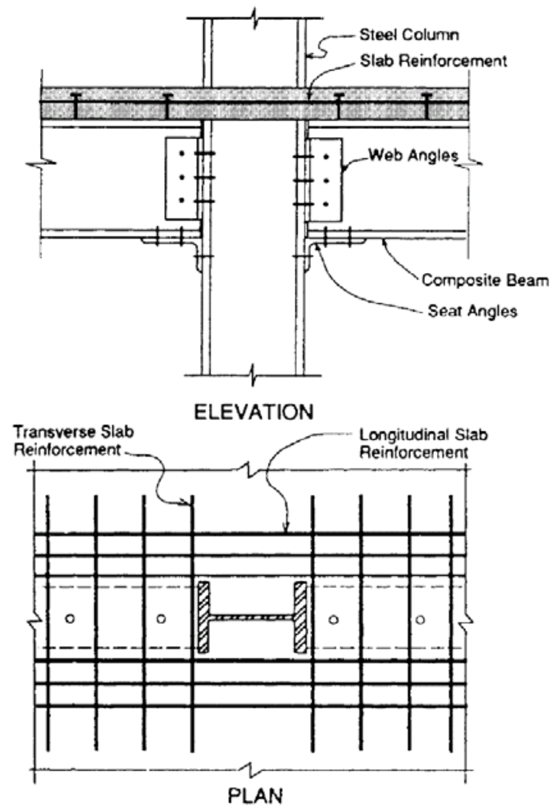

Figure 2. Example of a partially restrained composite connection.

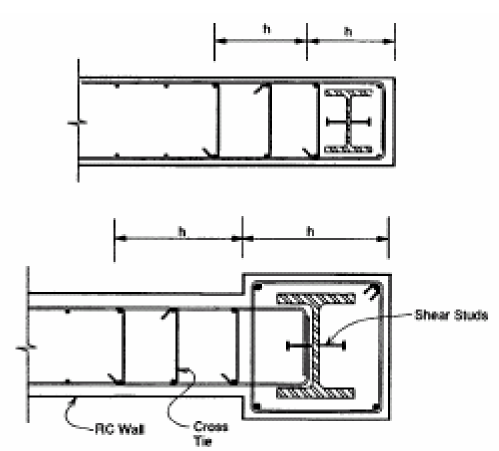

Figure 3. Composite shear wall boundary element.

strength in the web of the steel plate shear wall.

Similar to plate girder behavior, tension field action develops as the relatively thin web buckles during lateral loading. Limitations on configuration, width-thickness ratios, and other design parameters are provided to be consistent with the successful test results.

Section 18—Quality Assurance: Section 18, the final section of Part I, addresses a comprehensive quality assurance plan that is required to demonstrate that the structural design intent is accomplished during construction. Newly developed Appendix Q discusses requirements related to quality assurances and quality control to be provided by the contractor. Inspection requirements, both visual and non-destructive evaluation (NDE) inspections, for welds are presented in tabular form. A similar table for bolted connections is also provided.

Part II: Composite Structural Steel and Reinforced Concrete Buildings

Part II of the *Seismic Provisions* considers the design of composite systems of structural steel and reinforced concrete. This part contains individual sections governing design requirements for beams composite with concrete slabs, composite columns, and the design of connections between concrete and steel elements. (A cross-reference with ACI 318 is an important new feature.)

Composite connections have been designed using the basic principles of mechanics, existing standards for steel and concrete construction, test data, and engineering judgment. The connection section is intended to standardize and improve design practices by establishing basic behavioral assumptions for developing design models that satisfy equilibrium of internal forces in the seismic design connection.

The remaining sections of Part II address the design of various composite structural system types. These sections parallel those found in Part I and generally have *R* factors and system application limitations similar to the comparable structural steel systems. In addition to the composite SMF, IMF, and OMF system requirements, there is a composite partially restrained moment frame (C-PRMF) system having connection details similar to those shown in Figure 2.

Similar to Part I, there are two concentrically braced composite systems and one eccentrically braced composite system addressed in Part II. Part II also identifies three composite systems that use wall elements as the primary component in the SLRS. Two types of composite walls, one special and one ordinary, parallel the reinforced concrete wall specifications of ACI 318; however, structural steel elements are used in the boundary elements (as shown in Figure 3). Finally, a composite steel plate shear wall system is also codified.

More information may be found in the paper "The 2005 AISC *Seismic Provisions for Structural Steel Buildings*," published in the 2005 North American Steel Construction Conference Proceedings, available for AISC members to download free at **www.aisc.org**.

The 2005 *Seismic Provisions for Structural Steel Buildings, Including Supplement Number 1* is available to download free from AISC's web site at **www.aisc.org**. It is also available in print at **www.aisc.org/bookstore**. This document has been adopted by reference in the 2006 *International Building Code*, and, as a result, will soon govern the seismic design of all steel buildings in the United States.