conference preview

AISC 341 THEN AND NOW

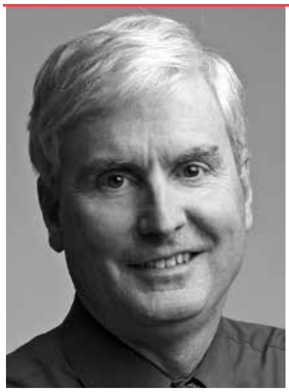
BY JAMES O. MALLEY, S.E., P.E.

Steel seismic design and AISC's *Seismic Provisions* have come a long, long way in 20 years.

FROM THE TIME of its incorporation into building codes in the 1950s until the mid-1980s, seismic design of steel structures had very few requirements.

As with all other loading demands, seismic design was rooted in the concepts of allowable stress design of members and their connections. Only special steel moment frames had specific requirements for the system design, with the most prevalent being the provisions that called for the use of "plastic design sections" and for the beam-column connections to be stronger than the full plastic capacity of the beam. The only requirement specific to braced frame design was that the connections needed to be designed for 25% higher forces than the members. Basic requirements for material properties, quality control procedures were also included.

The 1988 Uniform Building Code (UBC) was a major milestone that began the incorporation of system specific requirements for multiple structural steel systems, adding ordinary moment frames and concentrically braced frames. This edition also began the incorporation of system-level capacity design concepts in the development of a new system to be known as eccentrically braced frames (EBFs). About the time of the publication of the 1988 UBC, AISC began to work on developing a parallel set of seismic design provisions for steel structures based on LRFD requirements, that could be incorporated into the government-funded National Earthquake Hazard Reduction Program (NEHRP) Recommended Provisions that were intended for use throughout the United States. The first edition of these provisions was published by AISC in 1990, with a few minor changes incorporated into the 1992 edition.



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Major Changes Since Northridge

Damage to the connections in many moment frame buildings in the January 17, 1994 Northridge earthquake led to an unprecedented level of research and investigations on the seismic performance of steel frame structures, most notably the six-year FEMA/SAC project. As findings from these investigations were generated, AISC began to make major changes to the Seismic Provisions document.

The AISC *Seismic Provisions* were almost completely rewritten in 1997, with additional major modifications in 1999 and late 2000. The 2002 AISC *Seismic Provisions* became the basis for the steel seismic design provisions in the 2003 *IBC*, incorporating information from the final FEMA/SAC recommendations presented in FEMA 350 through 355. The 2005 *Seismic Provisions* (ANSI/AISC 341-05) were developed so that the new main AISC *Specification* (ANSI/AISC 360-05) could be used us a primary reference and were referenced in the 2006 and 2009 editions of the *IBC*. The 2010 edition of AISC 341 includes a new format that is more consistent with the main AISC *Specification* (AISC 360-10). AISC 341-10 was developed in conjunction with ASCE 7-10 and was incorporated into the 2012 *IBC*. Work is well underway on the next edition of AISC 341, which is planned for publication in 2016. Below is a very brief listing of the intent of the major additions and modifications the AISC 341 that have occurred since the Northridge earthquake.

Scope. The scope of the document has been much better defined, and includes building-like non-building structures.

Materials. Prior to the Northridge earthquake, the majority of steel wide-flange shapes were either A36 or A572 Grade 50. This has changed to A992 steel, partially in response to the Northridge earthquake, since this material provides a specified maximum yield strength and yield to tensile strength ratio.

Consumables for welding. No special requirements for weld filler metals were implemented for seismic design prior to Northridge. Now, all welds in the SLRS must be made with filler metals that have a designated minimum Charpy V-notch toughness for the requirements of AWS D1.8. In addition, more stringent toughness requirements are prescribed for "Demand Critical" welds that are designated for each structural system as being especially important to the overall performance of the SLRS.

Project documentation. Structural design drawings and specifications, fabricator shop drawings and erection drawings now have a very detailed list of information that is required to be provided to help ensure that the intent of the structural design is completely conveyed and understood by all parties.

Width-to-thickness limitations. For each system designation, all members of the SLRS have width-to-thickness limitations specified, based on the expected level of inelastic behavior of the member.

Stability bracing. All systems now have consistently applied requirements for stability bracing of beams in the SLRS, also based on the level of inelastic behavior in the members.

Protected zones. All SLRS must now identify the areas of the members that are designed to undergo significant inelastic deformation, termed the "protected zones." In order for this level of deformation to occur, these areas must be protected from discontinuities and other disturbances to the steel materials that could be caused by various types of construction operations.

Column design. All columns in the SLRS must now be checked for maximum forces that can be delivered by the system to avoid column overload that could result in severe damage and even collapse of the structural system.

Column splices. The requirements for column splices have been significantly increased—again, to avoid the possible consequences of splice failure on the response of the SLRS. Column splice requirements for gravity columns have also been included to help provide better overall response of the structural system to seismic demands.

Moment frames. System definitions and requirements for ordinary (OMF), intermediate (IMF) and special (SMF) moment frames have been completely overhauled to target the level of expected inelastic demand on the system. These include requirements for strength and deformation of beam-column connections, relative strength of beams, columns and beam panel zones, incorporation of doubler plates and continuity plates. Demonstration of inelastic rotation capacity of IMF and SMF connections is now required, primarily through the AISC 358-10 document *Prequalified Connections for Special and Intermediate Moment Frames for Seismic Applications*. In addition, a moment frame system called a "special truss moment frame" (STMF) was developed primarily based on research at the University of Michigan. Two cantilever column systems have also been developed for application in one-story structures.

Concentrically braced frames. Two concentrically braced frame systems have been identified. The first, ordinary concentrically braced frames (OCBFs), have limited requirements consistent with the limited ductility demand expectations resulting from the small R factor assigned to the system. The other system, special concentrically braced frame (SCBF), has much stricter design requirements for the members, configurations and connections commensurate with the larger ductility demands expected of the system.

Eccentrically braced frames (EBFs). The overall design of this system is conceptually consistent with that which was in place in the 1992 AISC *Seismic Provisions*. Additional requirements for items like protected zones, demand-critical welds, column splices, etc. have been made to be consistent with other SLRSs.

Buckling restrained braced frames (BRBFs). This is an entirely new braced frame system, first introduced in 2005, relying on the design and detailing of steel braces to restrain overall member buckling, thereby significantly increasing the member ductility and overall frame performance. Many of the design provisions for this system were patterned after those for EBFs.

Special plate shear walls (SPSWs). This is the second system that was also introduced in 2005. Based on extensive research in both Canada and the U.S., it relies on vertical steel plates within the steel frame to resist seismic lateral forces. Detailed design and detailing requirements for the web plates, horizontal boundary elements (HBEs) and vertical boundary elements (VBEs) and their connections, are all provided.

Composite systems. A major expansion of AISC 341 has been in the incorporation of systems constructed with structural steel, reinforced concrete and/or composite steel/reinforced concrete elements. These systems were first introduced in the 1997 edition of the *Seismic Provisions*, taken from work first presented in the NEHRP Provisions developed by the Building Seismic Safety Council. Since composite systems are assemblies of steel and concrete components, ACI 318 forms an important reference document for these systems. Both composite moment frame systems (four total) and braced frame/shear wall systems (six total) are included in the provisions.

Fabrication and erection. Both bolted and welded joint fabrication and erection requirements have been increased to better ensure desired performance of SLRS connections. Many of the requirements related to seismic welding are now found in AWS D1.8, *Structural Welding Code, Seismic Supplement*, which was developed in conjunction with AISC 341-10.

Quality control (QC) and quality assurance (QA). A comprehensive quality assurance plan is now required to demonstrate that the intent of the structural design is met in the construction. All of the requirements related to quality for both the QC and QA are provided in either AISC 341 or AWS D1.8. Requirements for both quality control (to be provided by the contractor) and quality assurance are presented. Inspection requirements for both visual and non-destructive evaluation (NDE) inspections of welds are presented in tabular form, based on the recommendations first presented in FEMA 353.

Ongoing Effort

Spurred on by the damage to steel moment frame buildings caused by the 1994 Northridge earthquake, a rational and efficient system has been instituted to incorporate the latest developments in seismic design of steel structures into building code provisions over the last 20 years. This system relies on the coordinated efforts of AISC, AWS and ASCE-SEI committees, and the process provides a single point of responsibility for the development of these provisions, thus eliminating duplicative effort—and more importantly, the development of competing documents that would result in minor differences that would undoubtedly result in major confusion in application by practicing engineers. These anticipated changes should continue the ongoing process of improving structural steel seismic design standards that should result in improved steel construction throughout the United States and other countries throughout the world that adopt this standard. ■

This article serves as a preview of Session C5, "AISC 341 Then and Now" at NASCC: The Steel Conference, taking place March 26-28 in Toronto. Learn more about the conference at ***www.aisc.org/nascc****.*