The AISC Seismic Provisions For Structural Steel Buildings

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Process of Developing the Provisions

**AISC/NEHRP**

- 1992 AISC Seismic (E. Popov, Chair)
  - Cooperation of AISC and BSSC established
  - Roles defined to minimize duplication of effort
AISC Review/Approval Process

- ANSI Consensus Process Procedures Being Followed
  - AISC now ANSI Accredited Organization
- AISC Seismic Provisions Updates
    - Supplement No. 1, February 15, 1999
    - Supplement No. 2, November 10, 2000

Building Code Adoption Process

- 1997 Seismic Provisions, through Supplement No. 1 included with Main LRFD Specifications into 2000 IBC
- 2002 NFPA also includes 2002 AISC Seismic
- 2006 IBC adopted 2005 AISC Seismic (ANSI/AISC 341-05) and AISC Main Spec (ANSI/AISC 360-05)
- Single Set of Unified National Seismic Provisions for Steel Buildings
Major Elements of 2005 Seismic Provisions

- Part I covers all Major Seismic Systems
  - Focus on SDC D, E and F
- Coordinated with ASCE 7-05
- Incorporate Post-Northridge Findings
  - FEMA/SAC Project Results (FEMA 350 Series) as Well as Other Efforts
- Composite Provisions from NEHRP Included (Part II)
- Note that Both Parts are in the “Unified” Format similar to the Main AISC Specification
  - Both LRFD and ASD included in one set of provisions

AISC Seismic Provisions

Scope Statement

- Intended Primarily for Building Structures
  - Also incorporated for “building like” non-building structures
  - Glossary clarifies that SLRS includes diaphragm chords and collectors, and all elements that resist seismic loads
- Required for SDC D, E and F
  - For SDC A, B and C, designer has choice
    - Use the Seismic Provisions with appropriate R factor
    - Use AISC LRFD/ASD Provisions with R=3
- Design Directly Linked to ASCE 7-05

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Project Documentation Requirements

- New Section to Define Expectations of:
  - Design drawings and specifications
  - Shop Drawings
  - Erection Drawings
- Includes lists of information to be provided such as SLRS designation, connection detailing, welding requirements, protected zones, etc.
- Consistent with FEMA 353 and AWS D1.8

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Material Specifications

- ASTM Specifications for Materials Employed
  - All major structural products incorporated
- Limited to 50 ksi, except for “elastic” columns
  - Relaxed to 55 ksi limit for OMF and OCBF
- Material Properties for Determination of Required Strength for Connections or Related Members Based on Expected Yield Strength
  - $R_y = R_y F_y$
  - $R_y = 1.5$ for A36 $1.5 \times 36 = 54$ ksi
  - $R_y = 1.1$ for A992 $1.1 \times 50 = 55$ ksi
  - $R_y = 1.1$ to 1.6 for other steels grades

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Material Specifications

- Available Strength to consider both expected yield and tensile strengths
- $R_t$ term added for tensile strength, with range of 1.1 to 1.3
  > Intent is to ensure expected inelastic response and ductile failure modes

Notch Tough Steel

- For Seismic Force Resisting System, Charpy V-Notch Toughness of 20 ft.-lbs. @ 70° F is required for:
  > ASTM A6 GROUPS 4 and 5, and for
  > ASTM A6 GROUP 3 with flanges > 1 1/2 inches thick
  > Plate material thicker than 2 inches
Connections - Bolted Joints

- Fully Tensioned HSB, Class A Slip-Critical, design for bearing strength.
- No sharing of load with welds in a joint or the same force component in a connection.
- Standard holes, or short slots perpendicular to line of force.
  - Oversized holes in one ply of brace diagonals allowed
  - Other conditions allowed if verified by testing
- Ductile limit - state controls design.
  - Yielding rather than fracture

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Connections - Welded Joints

- New Appendix W with welded joint requirements beyond standard AWS D1.1
  - Consistent with FEMA 353
  - Being incorporated into new AWS D1.8
    - To be published later this year. Future editions of AISC Seismic will reference as appropriate
- WPS required / Approved by EOR
- Continuity plate welding and detailing specified

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Connections - Welded Joints

- Filler metal CVN 20 ft.-lbs. @ -0°F for all welds in the seismic load resisting system (SLRS)
  - Reduction from -20°F in 2002
- Two level toughness required for designated Demand Critical Welds in SMF, IMF, OMF and EBF
  - based on FEMA recommendations
  - Consistent with previous testing
  - Appendix provides requirements for qualification

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Welded Joints (cont.)

- Defines term “Protected Zone” where special care is required
  - Eliminates welding and other attachments in plastic hinge zones (shear studs, e.g.). Spot welds acceptable
    - OK outside hinge zones, but need to verify net section strength
  - Discontinuities caused by welding or other construction operations must be repaired.
  - Locations of Protected Zones defined for each system

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Members

- Width-thickness ratios often stricter than main specification requirements
- Columns with high axial load to be checked for amplified seismic loading
- Column Splices
  - Strength requirement for partial penetration and fillet welded splices of 200% of required strength.
  - Beveled transitions not required where partial penetration welds are permitted.
  - Requirements for shear strength check of non-frame columns in all systems.
    - Only location in the provisions that refers to elements not part of the SLRS

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Members (cont.)

• Column base design
  ➤ General intent to design column base for same forces that the elements connecting to the base are designed for.
    • Axial, shear and flexural strength requirements presented
  ➤ Interaction with concrete elements referred to ACI 318 Appendix D.
• H-pile requirements included

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Special Moment Frames (SMF)

• Designs based on cyclic test results to 0.04 radians
  ➤ Appendix S provides test requirements
    • For either project specific or “public” tests
  ➤ Appendix P provides basis for "pre-qualification" of connections
  ➤ Connections designed in accordance with AISC 358 standard
• Shear connection capacity sufficient to develop force generated by fully plastic beam

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(N) AISC Moment Connection Prequalification Standard

• Official title: “Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications”
  ➢ Developed by separate ANSI standards development committee (Ron Hamburger, Chair)

• Allows engineers to submit moment frame designs without producing connection test results
  ➢ First edition focuses on RBS and End Plate connections
  ➢ More connections to be included in future editions

• Adopted by 2005 AISC Seismic

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SMF (Cont.)

• Panel Zone Design
  ➢ Intended to share yielding with beam
  ➢ Equation differs from FEMA 350

• Doubler plate configurations may be adjusted to avoid “k” area

• Continuity plates to match tested configurations

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• SCWB Check required for SMF frames
  ➢ Attempting to avoid weak stories
  ➢ Exceptions provided
• Column splices pushed towards CJP

\[
\frac{\sum M_{pc}}{\sum M_{pb}} \geq 1.0
\]

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• Lateral Bracing of Beams
  ➢ Nominal bracing required along length for both strength and stiffness based on main spec. equations
  ➢ Bracing at hinges (6%) required as well
    • But, not IN hinge zones!

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**IMF/OMF Requirements**

- **Intermediate (IMF) provisions similar to SMF**
  - Tested capacity to 0.02 radians, beam shear, etc.
  - Other requirements (SCWB, panel zone, etc.) not as restrictive as SMF
- **Ordinary (OMF) provisions**
  - Allows calculation only, but for strength above $1.1 R_y M_p$
  - Specific welding and detailing requirements (access holes, e.g.)

**STMF**

- Concept Similar to EBF’s
- Ductile Special Segment (SS)
- Other Parts of the Truss Remain Elastic
- Both Cross-braced and Vierendeel configurations
- Span limited to 65 feet
- Depth limited to 6 feet
Special CBF Provisions

- \( KL/r < 4/\sqrt{E/F_y} \)
- Stricter b/t Ratios and Built-up Member Requirements
- Connection Requirements
  - Strength to Develop Tensile Strength
  - Ductility to Allow Buckling in Member or Gusset Plate
- Restrictions on Chevron and K-Bracing
- Stronger Column Splices Required

OCBF Provisions

- Limited use in high SDC’s
- For V or inverted V, \( KL/r < 4.23/\sqrt{E/F_y} \)
- Connection strength to develop brace tension capacity or amplified force
- Chevron bracing restrictions
- Tension Only Bracing Systems Allowed for Low Buildings (Less than Two Stories) and Penthouses
Elastic Beam Frame (EBF) Provisions

- Inelastic behavior limited to link beams
- Remainder of the system to remain elastic
- Best results for shear link elements, but local demands are higher than SMF’s
  - Extensive stiffening requirements

Elastic Beam Frame (EBF) Provisions (Cont.)

- Link-to-column connections
  - Require testing like SMF
  - Exception allowed
- Beam outside link, braces and columns designed for link capacity, including strain hardening
- Lateral bracing requirements similar to SMF
  - 6% at ends of links
  - Elsewhere, strength and stiffness as required in main spec.

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BRBF Provisions

- BRBF Frames
  - SCBF development improves braced frame performance, but still limited by brace buckling
- Concept developed in Japan, with many applications
  - Hysteretic behavior similar to elastic - perfectly plastic
- Development of provisions in U.S.
  - Joint AISC/SEAOC effort
    - Approach similar to EBF
  - Analytical work indicates good performance
  - U.S. practice will lead to larger drifts
  - Included in 2003 NEHRP

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BRBF Provisions (cont.)

- Steel core restrained from buckling
  - Braces tested for twice Design Story Drift
    - Appendix T specifies testing requirements
  - Brace strength addresses strain hardening and compression strength increase due to confining system
    - Connections designed for adjusted strength
- Chevron requirements less demanding than SCBF
- Column splices similar to SCBF

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SPSW Provisions

- SPSW System
  - SPSW like plate girder design approach (tension field theory)
  - Can generate tremendous strength and stiffness as compared to CBF
- SPSW concept developed in Canada
  - NBCC Code provisions in place
    - UC Berkeley work as well
    - Provisions incorporated into 2003 NEHRP

SPSW Provisions (cont.)

- Panel Capacity Based on Simple Formula
  - Includes panel aspect ratio
    - L/h between 0.8 and 2.5
  - Panels with Openings to have boundary elements (BE)
  - Connection between web and BE’s for capacity
  - BE’s to develop panels. OMF style connections
  - Lateral bracing spacing like SMF.
  - Vertical BE’s also have bending stiffness requirements
Quality Assurance

- Detailed Appendix Q replaces general set of provisions in previous editions
- Consistent with FEMA 353 and AWS D1.8
- QA plan required. Covers both QA and QC.
- Documentation requirements listed
- Visual Inspection Points and Frequency Defined
  - For before, during and after welding or bolting by both QA and QC. Shown in tabular format
  - “Observe, Perform and/or Document”
- NDT locations and requirements specified. Both UT and Magnetic Particle incorporated. All results documented.

Part II - Composite Provisions

- Part II - Composite Construction Provisions
  - First Developed for 1994 NEHRP
  - Identifies Numerous System Options
  - Provides Detailed Requirements for Member and Connection Design
  - Modified and Made Consistent with Part 1
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Composite CBF Connection
Composite Shear Wall Detail

Status and Upcoming Activities

- AISC 341 approved by reference in ASCE 7-05, Supplement No. 1
- Included in 2006 IBC
- AWS D1.8 completed and published
- Work is underway on 2010 Edition
  - Suggestions and comments welcomed and encouraged!

AISC Seismic Provisions
Status of Work on 2010 Edition

- Some re-formatting being done to make document more consistent with AISC 360
- Incorporating Composite Provisions directly into the document (No more Part I and Part II)
- Developing design/analysis provisions that will explicitly follow capacity design approach for ALL systems
- Updates to specific member and system requirements
- First internal ballots this year
- To be included in ASCE 7-10 and 2012 IBC

AISC Documents Related to Seismic Design

  - Available via download
- 2005 AISC Moment Connection Prequalification Standard (ANSI/AISC 358)
  - Available via download
- 2005 AISC Specification for Structural Steel Buildings (ANSI/AISC 360)
  - Available via download
- 2005 AISC Seismic Design Manual
  - Available for purchase

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AISC Seismic Design Manual

• 1st Edition to Assist designers in applying AISC 341
  ➤ Practical guide similar to SEAOC SDC Series
• Common systems addressed with detailed design examples
  ➤ SMF, IMF, OMF
  ➤ CBF, EBF
  ➤ Other systems (BRBF and SPSW) discussed
  ➤ Both R=3 and R>3 designs addressed
• Special elements (chords and collectors) and issues (maximum force that can be delivered) addressed
• ONLY in LRFD format, though ASD is also allowed in AISC 341

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Concluding Comments

• Unified Process for Steel Seismic Provision Development
  ➤ "Single Point of Responsibility" eliminates duplicative effort and minor differences that result in major confusion
  ➤ Allows rapid incorporation of new information
• WE WANT YOUR INPUT AND RECOMMENDATIONS FOR IMPROVEMENTS!