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# The AISC Seismic Provisions For Structural Steel Buildings

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AISC Seismic Provisions



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## Process of Developing the Provisions AISC/NEHRP

- 1992 AISC Seismic (E. Popov, Chair)
- 1997 NEHRP Adoption of 1997 AISC Seismic Provisions
  - Cooperation of AISC and BSSC established
  - Similar for 2000 and 2003 NEHRP Provisions
  - Roles defined to minimize duplication of effort

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## AISC Review/Approval Process

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- ANSI Consensus Process Procedures Being Followed
  - ▶ AISC now ANSI Accredited Organization
- AISC Seismic Provisions Updates
  - ▶ 1997 AISC Seismic Provisions
    - Supplement No. 1, February 15, 1999
    - Supplement No. 2, November 10, 2000
  - ▶ 2002 Provisions, May 21, 2002

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## Building Code Adoption Process

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- 1997 Seismic Provisions, through Supplement No. 1 included with Main LRFD Specifications into 2000 IBC
  - ▶ 2002 Seismic Provisions in 2003 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

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## Major Elements of 2005 Seismic Provisions

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- 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

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## Scope Statement

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- 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

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- 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

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## Notch Tough Steel

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- 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

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## Connections - Bolted Joints

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- 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

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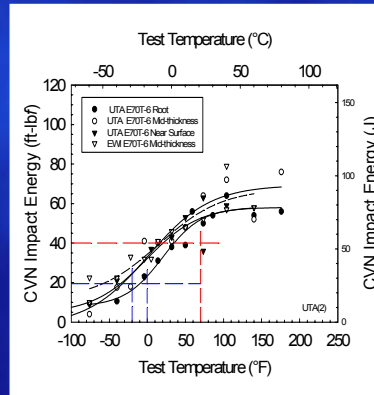
- New Appendix W with welded joint requirements beyond standard AWS D1.1
  - ▶ Consistent with FEMA 353
  - ▶ Being incorporated into new AWS D1.8
    - To be published later this year. Future editions of AISC Seismic will reference as appropriate
- WPS required / Approved by EOR
- Continuity plate welding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

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## Connections - Welded Joints

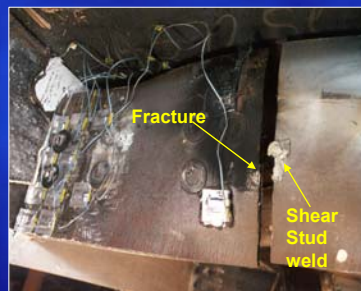
- Filler metal CVN 20 ft.-lbs. @ -0° F for all welds in the seismic load resisting system (SLRS)
  - Reduction from -20° F in 2002
- Two level toughness required for designated Demand Critical Welds in SMF, IMF, OMF and EBF
  - based on FEMA recommendations
  - Consistent with previous testing
  - Appendix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

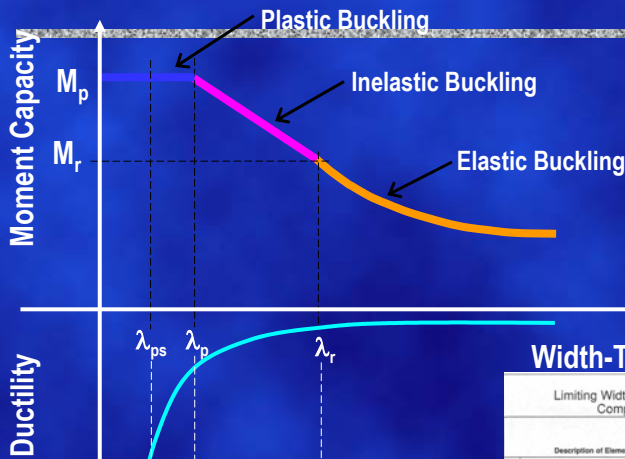


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# Members

- 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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## Width-Thickness Ratio

TABLE I-8-1  
Limiting Width Thickness Ratios  $\lambda_{ps}$  for  
Compression Elements

Description of Element	Width Thickness Ratio	Limiting Width-Thickness Ratio
		$\lambda_{ps}$ (essentially compact)
Flanges of I-shaped rolled, hybrid or welded beams (a), (b), (c), (f)	$b/t$	$0.50 \sqrt{E_c/F_c}$
Flanges of I-shaped rolled, hybrid or welded columns (a), (c)	$b/t$	$0.30 \sqrt{E_c/F_c}$
Flanges of channels, angles and I-shaped rolled, hybrid or welded beams and bracing (a), (b), (f)	$b/t$	$0.30 \sqrt{E_c/F_c}$
Flanges of I-shaped rolled, hybrid or welded columns (a), (b)	$b/t$	$0.38 \sqrt{E_c/F_c}$
Flanges of H-pile sections	$b/t$	$0.45 \sqrt{E_c/F_c}$
Flat bars (a)	$b/t$	2.5
Legs of single angle, legs of double angle members with separations, or flanges or legs (f)	$b/t$	$0.30 \sqrt{E_c/F_c}$
Welds of legs (f)	$d/t$	$0.50 \sqrt{E_c/F_c}$

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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

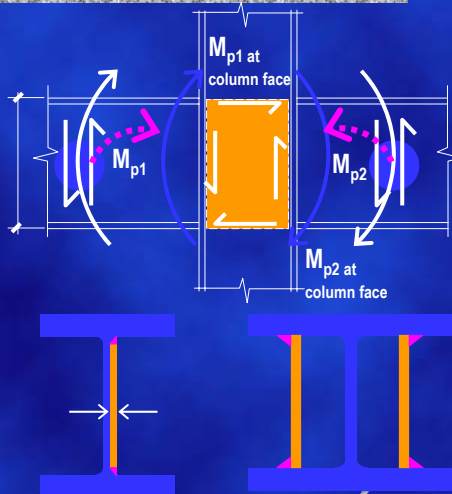
- Official title: “*Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications*”
  - ▶ Developed by separate ANSI standards development committee (Ron Hamburger, Chair)
- Allows engineers to submit moment frame designs without producing connection test results
  - ▶ 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

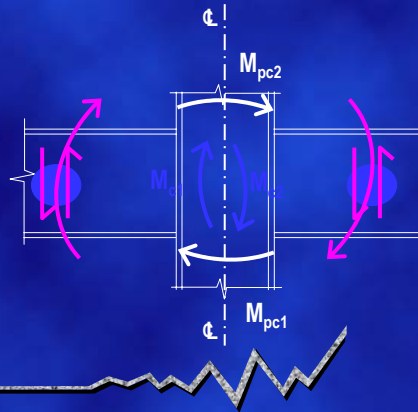


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## SMF (Cont.)

- 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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## SMF (Cont.)

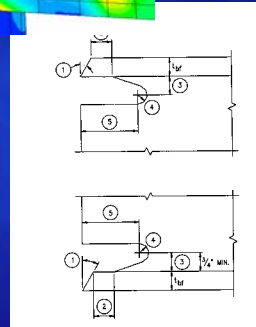
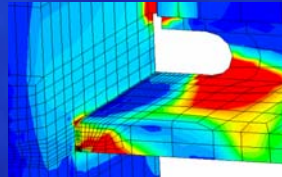
- Lateral Bracing of Beams
  - ▶ Nominal bracing required along length for both strength and stiffness based on main spec. equations
  - ▶ Bracing at hinges (6%) required as well
    - But, not IN hinge zones!



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# IMF/OMF Requirements

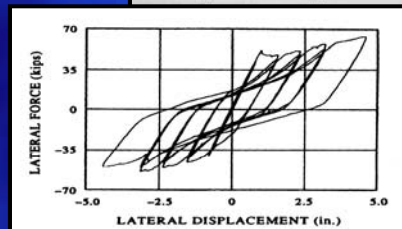
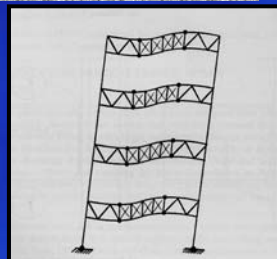
- Intermediate (IMF) provisions similar to SMF
  - ▶ Tested capacity to 0.02 radians, beam shear, etc.
  - ▶ Other requirements (SCWB, panel zone, etc.) not as restrictive as SMF
- Ordinary (OMF) provisions
  - ▶ Allows calculation only, but for strength above  $1.1 R_y M_p$
  - ▶ Specific welding and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



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# STMF

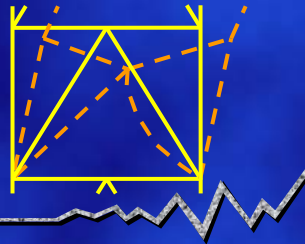
- Concept Similar to EBF's
- Ductile Special Segment (SS)
- Other Parts of the Truss Remain Elastic
- Both Cross-braced and Vierendeel configurations
- Span limited to 65 feet
- Depth limited to 6 feet



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## 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



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## 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



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## 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



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## EBF Provisions (Cont.)

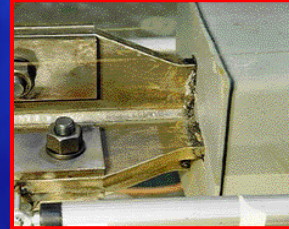
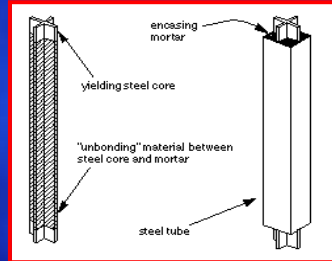
- Link-to-column connections
  - ▶ Require testing like SMF
    - Exception allowed
- Beam outside link, braces and columns designed for link capacity, including strain hardening
- Lateral bracing requirements similar to SMF
  - ▶ 6% at ends of links
  - ▶ Elsewhere, strength and stiffness as required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



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## 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

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## 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.

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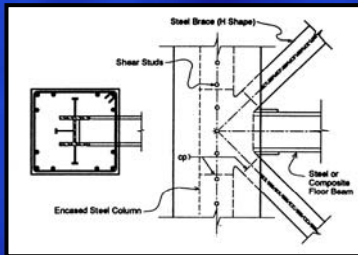


## Part II - Composite Provisions

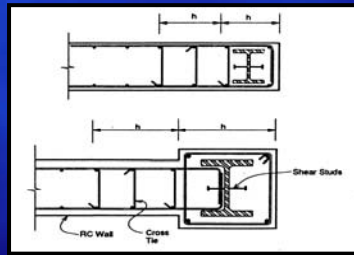
- Part II - Composite Construction Provisions
  - ▶ First Developed for 1994 NEHRP
  - ▶ Identifies Numerous System Options
  - ▶ Provides Detailed Requirements for Member and Connection Design
  - ▶ Modified and Made Consistent with Part 1

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**Composite CBF  
Connection**



**Composite Shear  
Wall Detail**


**AISC Seismic Provisions**

## **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 Seismic Provisions
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## AISC Documents Related to Seismic Design

- 2005 AISC Seismic Provisions (ANSI/AISC 340)
  - ▶ 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

- 1<sup>st</sup> 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!

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