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BRACED FOR BETTER SEISMIC DESIGN

An introduction to the newest edition of AISC's *Seismic Design Manual.*

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DO YOU DESIGN PROJECTS with seismic systems? If so, good news: AISC has just released the 3rd Edition *Seismic Design Manual*.

This edition has been expanded with new discussion and design examples to help engineers navigate the design of steel and composite Seismic Force Resisting Systems (SFRS). It includes discussion and practical guidance on applying the latest versions of AISC's core standards—the 2016 *Specification for Structural Steel Buildings* (ANSI/AISC 360), 2016 *Seismic Provisions for Structural Steel Buildings* (ANSI/AISC 341), 2016 *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* (ANSI/AISC 358) and the 15th Edition *Steel Construction Manual*.

The new edition contains more than 60 examples that demonstrate how to design the key members and connections for the most commonly used SFRS. The examples go beyond just seismic-specific checks to also demonstrate the full design, limit state by limit state. The manual is a valuable resource not only for those who design in the seismic world, but for anyone interested in learning the procedures used for designing members, connections and systems.

The overall organization of the *Seismic Manual* has not changed from the 2nd Edition, and the chapters are still organized as follows:

Part 1: General Design Considerations
Part 2: Analysis
Part 3: Systems Not Specifically Designed for Seismic Resistance
Part 4: Moment Frames
Part 5: Braced Frames
Part 6: Composite Moment Frames
Part 7: Composite Braced Frames and Shear Walls
Part 8: Diaphragms, Collectors and Chords
Part 9: Provisions and Standards

Scope and Part 1

Let's take a brief look at these various parts. The manual starts off strong in the Scope section, which outlines cases where the *Seismic Provisions* need to be followed based on the criteria provided in ASCE/SEI 7: *Minimum Design Loads for Buildings and Other Structures*. It also gives a general overview of how the manual is organized.

Following the Scope is Part 1, General Design Considerations, an overview of seismic design concepts. Discussion is provide on topics such as the performance goals for seismic design, anticipated behavior of different systems, drift, quality control, quality assurance, design drawing requirements and referenced standards. The section comparing the notable differences between wind and seismic design offers guidance on how to properly account for the governing loading conditions, particularly in regions or building types where there is no obvious controlling design methodology.

Part 1 also covers the symbols and terminology found in ASCE/SEI 7 that are pertinent to steel seismic design. Seismic performance factors such as the seismic modification coefficient, R, deflection amplification factor, C_d, overstrength factor, Ω_o, and redundancy factor, ρ, are introduced and discussed in detail.

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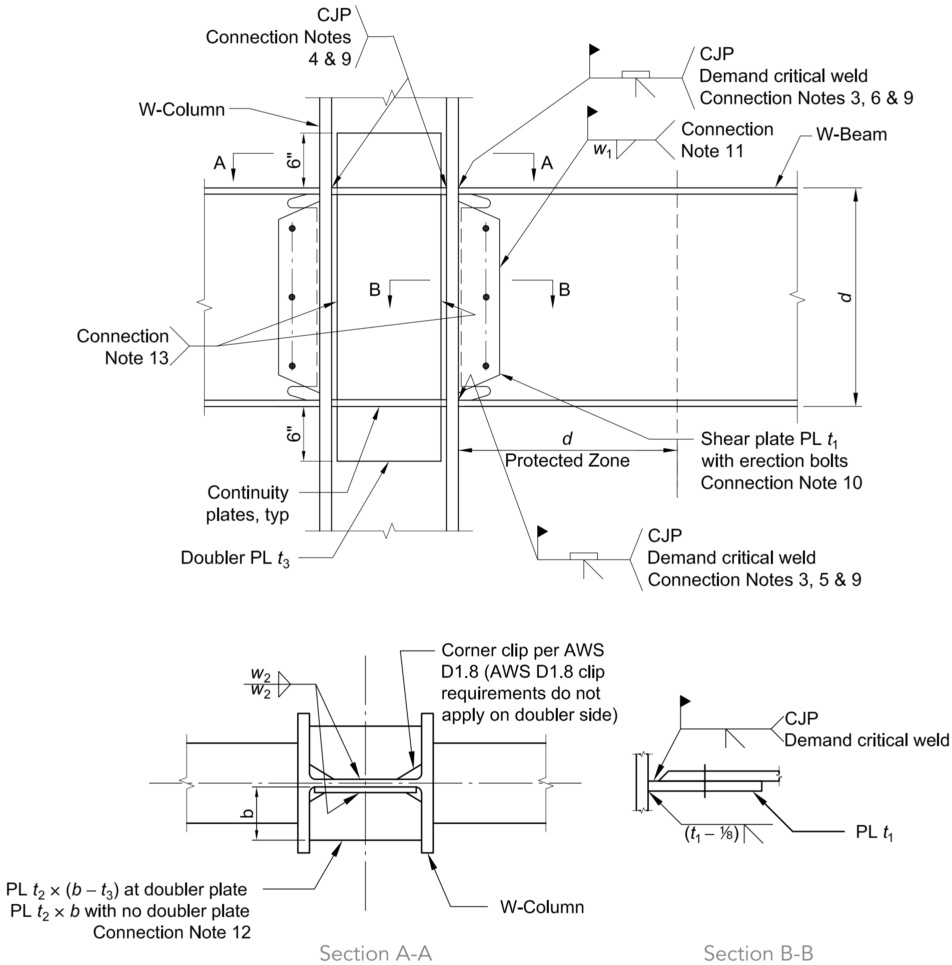
Order your copy of the new 3rd Edition *Seismic Design Manual* at **www.aisc.org/publications**. The new manual is priced at $100 for members/$200 for non-members.

When it comes to conveying the various seismic elements in the design documents, Part 1 now includes a section that will be beneficial to the engineers generating these documents and to any other members of the construction team that use them. Instruction is given for properly indicating SFRS members on plans and elevations, identifying protected zones and calling out demand-critical welds, among other items. To give an idea of what this entails, a sample plan has been generated with SFRS elements such as brace frames, moment frames, collectors and chords identified for both orthogonal directions. A fully developed connection detail and schedule illustrating one method for communicating connection design information, following the requirements of the *Seismic Provisions*, is also provided (Figure 1).

A number of useful design aid tables are also found in Part 1. Table 1-1 gives dimensions for detailing weld access holes using the alternate geometry for seismic applications as found in AWS D1.8. Table 1-2 is a reference for quickly determining member ductility requirements for each of the SRFS covered in the *Seismic Provisions*. Tables 1-3 through 1-7 list the steel member sizes that satisfy width-to-thickness requirements for W-Shapes, angles, rectangular and square HSS and round HSS. The W-shape tables have been expanded to include ASTM A913 Grades 65 and 70 in addition to ASTM A992. The HSS tables are updated from ASTM A500 Grade B to A500 Grade C, corresponding to what is now the preferred material specification, as shown in AISC *Manual* Table 2-4. The HSS tables now also include ASTM A1085 as this material becomes more readily available in the industry. These new high-strength materials are consistent with updates in the new *Specification* and *Seismic Provisions* and are used in several of the design examples. For convenience, the steel and composite system portions of ASCE/SEI 7-16 Table 12.2-1, which defines the R, Ω_o and C_d factors along with system height limitations, are reproduced in Part 1, Tables 1-9a and 1-9b.



Connection Schedule							
Column Size	**Beam Size**	**Shear Plate**		**Continuity Plates**			**Doubler plate thickness t_3, in.**
		Thickness t_1, in.	**Fillet weld w_1, in.**	**Thickness t_2, in.**	**Width b, in.**	**Fillet weld w_2, in.**	
W14×370	W24×76	½	7⁄16	Not required	Not required	Not required	Not required
W14×257	W24×76	½	7⁄16	¾	6	½	½

Connection Notes

1. This connection is part of a seismic force-resisting system.
2. See Connection Schedule for connection parameters.
3. Weld access holes must conform to the requirements of AWS D1.8, Section 6.11.1.2.
4. Steel backing at the continuity plate may be removed (Connection Note 7) or left in place (Connection Note 8).
5. Steel backing at the bottom flange must be removed (Connection Note 7).
6. Steel backing at the top flange may be removed (Connection Note 7) or left in place (Connection Note 8).
7. Where steel backing is removed, the root pass is backgouged to sound weld metal and back welded with a minimum 5⁄16-in. reinforcing fillet. The toe of the reinforcing fillet does not need to be located on the continuity plate base metal.
8. Where steel backing is left in place, it has a 5⁄16-in. fillet to the column flange. No weld should be made from the backing to the beam flange or continuity plate.
9. Weld tabs at beam flanges and continuity plates must be removed in accordance with AWS D1.8, except at the outboard ends of continuity-plate-to-column welds. Weld tabs and weld metal need not be removed closer than ¼-in. from the continuity plate edge.
10. Fabricate single plate per ANSI/AISC 358, Figure 8.3. It is acceptable to use horizontal short-slotted holes in the plate for erection bolts.
11. Weld shear plate to beam web on three sides. See ANSI/AISC 358, Figure 8.3, for additional information.
12. When a doubler plate is required, clip stiffener plate corners to clear doubler plate to W-shape column weld and column fillet. When no doubler plate is required, clip stiffener plate corners per AWS D1.8.
13. Provide weld at the web doubler plate per AWS D1.8, clause 4.3.
14. W-shapes are ASTM A992, connection plates are ASTM A572 Gr. 50, and weld electrodes are E70XX.
15. This example is dependent on AISC *Seismic Provisions*, ANSI/AISC 358 and AWS D1.8 for complete detailing requirements.

Figure 1. Sample seismic connection detail.

Part 2

Part 2, Analysis, provides an overview of the analysis procedures in ASCE/SEI 7, the AISC *Specification* and the *Seismic Provisions*. Three methods for stability design included in the *Specification* are the direct analysis method, effective length method and first-order method. ASCE/SEI 7 then covers three analysis methods, including the equivalent lateral force method, modal response spectrum analysis and nonlinear response history analysis. In Part 2, guidance is provided on implementing the equivalent lateral force method or modal response spectrum analysis using the direct analysis method.

Modeling techniques are recommended regarding steel and composite member stiffness, connection panel zones with rigid offsets, diaphragms, column bases and foundations. The discussion of ductile design mechanism and capacity-based design addresses fundamental topics in seismic design.

Part 3

Part 3, Systems not Specifically Designed for Seismic Resistance, is a standalone chapter that covers designs that do not need to follow the requirements of the *Seismic Provisions*. Oftentimes, there is a misconception that, when designing an R = 3 system not specifically detailed for seismic resistance, there are no additional requirements beyond what is provided in the *Specification*. While the *Seismic Provisions* isn't followed, other seismic considerations included in the applicable building code will still apply. ASCE/SEI 7, for instance, includes requirements for horizontal and vertical irregularities, seismic load combinations, collector design and foundation design. Part 3 contains design examples that walk through the design of members and connections for typical R = 3 moment and braced frame lateral systems. This is a valuable resource for engineers designing in both seismic and nonseismic regions, laying out the basis for two of the most commonly implemented connections in lateral force-resisting systems (LFRS).

Parts 4 through 8

The next four parts of the *Manual* correspond to the chapters in the *Seismic Provisions* that are specific to steel and composite moment frames and braced frames.

Part 4, Moment Frames, addresses system designs for ordinary moment frames, intermediate moment frames and special moment frames (OMF, IMF and SMF, respectively). A number of design examples are then provided for the key members and connections of OMF and SMF systems. Note that in order to avoid repetition, design examples are not provided for IMF systems, considering the extensive overlap of requirements between IMF and SMF systems.

New examples detail two common connection configurations that meet the stability bracing requirements of an SMF beam. Beam-to-beam connections are designed to provide torsional bracing of the moment-connected beam outside of the protected zone as it extends from the column. The first of these two examples covers two beams of equal depth (Figure 2) while the second case is for a support beam that is less than the depth of the moment frame beam (Figure 3).

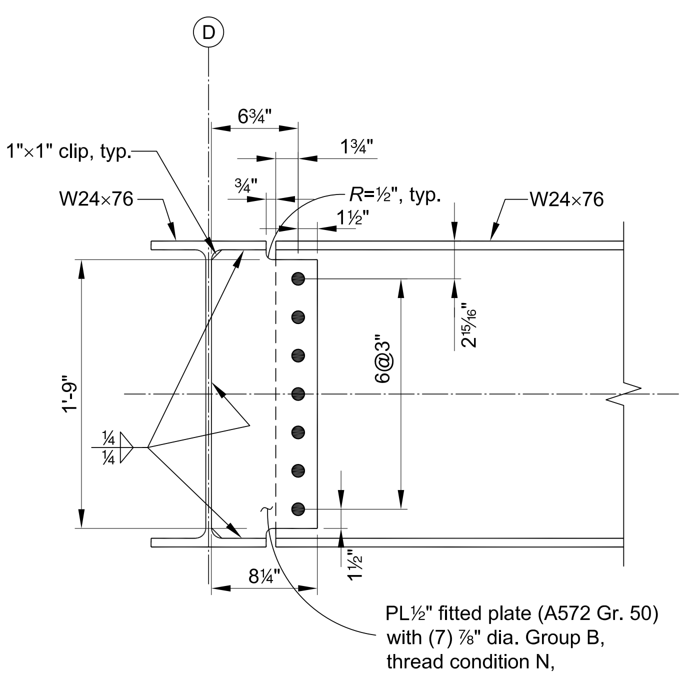


Figure 2. Torsional brace for SMF beam—equal-depth beams.

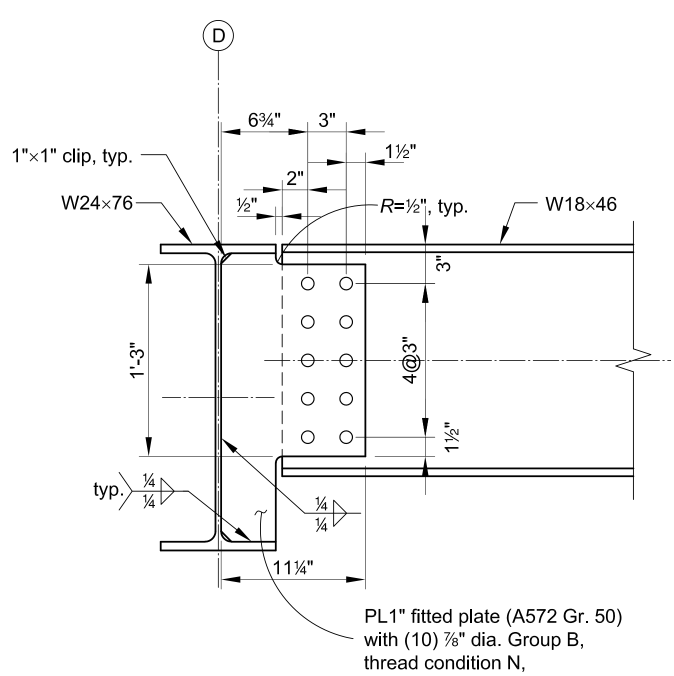


Figure 3. Torsional brace for SMF beam—unequal-depth beams.

Part 4 also has an entirely new section on special truss moment frame (STMF) systems. While this system has been included in previous editions of the *Seismic Provisions*, new design examples have been added illustrating the design of this system type. For designers not familiar with this system, an STMF is similar to a moment frame except that it implements a truss as the spanning element between columns instead of a moment-connected beam. Lateral forces and displacements are resisted though the flexural and shear strength of the truss chords and web members as well as the columns. Seismic energy is dissipated through inelastic behavior of the special segment at the center few panels of the truss (Figure 4).

Also new to Part 4 is an example related to the *Seismic Provisions* strong-column, weak-beam requirement, which encourages the ductility of the system to be concentrated in the beams and not the columns. The *Seismic Provisions* lists exceptions, and the new example satisfies one such exemption, thereby eliminating the need for the designer to meeting this requirement. This particular example in Part 4.

The additional flexibility in detailing of web doublers and continuity plates, as found in the latest *Seismic Provisions*, is employed (Figure 5). The example illustrates the complete design for both a fitted doubler plate and an extended doubler plate option. Furthermore, due to the cost and labor implications of this column reinforcement, the example presents the selection of a heavier column shape that then precludes the need for this reinforcement.

Part 5 covers system designs for ordinary and special concentric braced frames (OCBF and SCFB, respectfully). There are also design examples provided for eccentrically braced frames (EBF) and buckling restrained braced frames (BRBF).

The multi-tiered braced frame system is new to the 2016 *Seismic Provisions*, and the *Manual* includes a set of examples for using this system as an ordinary braced frame. As suggested by the named of this system, out-of-plane column stability support (such as that provided by floor diaphragm or beams) is not present at intermediate brace end connections. The columns in this system will require higher stiffness and strength to accommodate longer unbraced lengths due to this lack of lateral support at intermediate levels.

The SCBF brace-to-beam connection, or chevron connection, has been expanded to cover the "chevron effect" phenomenon that has been presented in two *Engineering Journal* articles: "The Chevron Effect—Not an Isolated Problem" (second quarter 2015) and "The Chevron Effect and Analysis of Chevron Beams—A Paradigm Shift" (fourth quarter 2017), both available at **www.aisc.org/ej**. The example discusses how the chevron effect at the brace-to-gusset connection can result

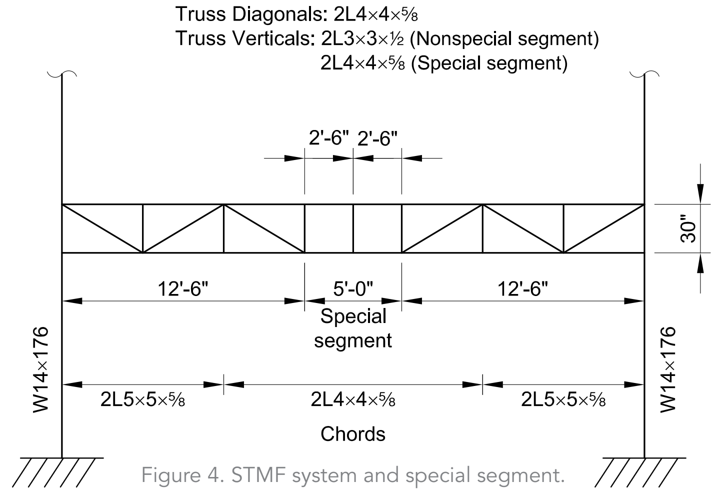
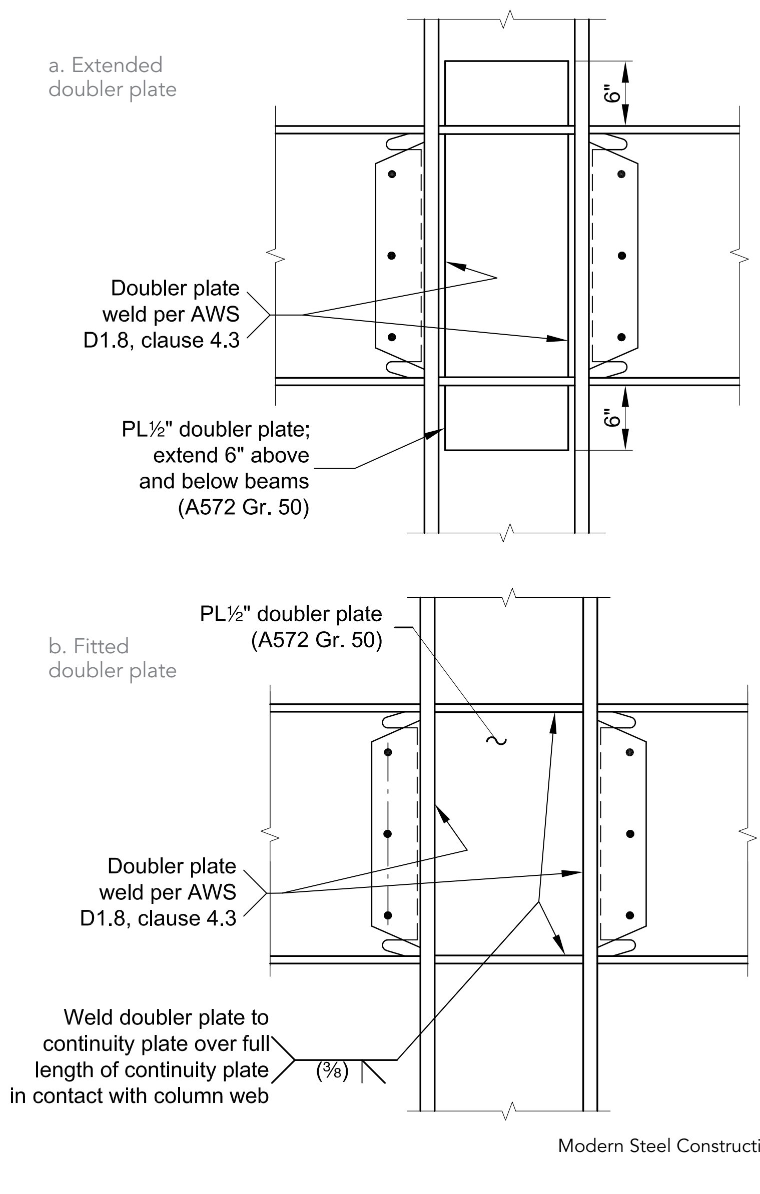


Figure 4. STMF system and special segment.

Figure 5. Detailing of web doublers.



in increased bending and shear forces in the supporting beam member within the region of the connection. These increased local forces in the beam may exceed the forces determined from member analysis, and may even exceed the available strength of the beam member. The design example discusses the chevron effect in more detail and provides a method for checking its effect on member design.

Also new in Part 5, Braced Frames, is the connection design of a BRBF brace a beam/column corner gusset plate. This example addresses a case where the brace is provided by a BRB manufacturer along with certain minimum design parameters. It also covers the design of the gusset plate and solving the interface forces in the beam and column members.

Parts 6 and 7, Composite Moment Frames and Composite Braced Frames and Shear Walls, cover composite moment frames and composite braced frames and shear walls. Due to the complexity of these types of systems and the requirement for prequalification, these parts are limited primarily to system discussions. These parts also provide overview "roadmaps" that help direct designers to where applicable requirements can be found in the *Seismic Provisions* and ACI 318. There is much discussion of experimental tests to help provide background on particular composite systems.

Part 8, Diaphragms, Collectors and Chords, discusses diaphragms, collectors and chords—all part of the floor system that is critical in delivering the earthquake loads to the SFRS. There is a comprehensive section about the behavior of diaphragm systems, rigid, semi-rigid and flexible diaphragms and accumulation of loads along a line of collector beams. Member design for axial forces, as is typical for these horizontal members, considers the different restraint conditions based on member and floor type, as well as the associated design checks. The example concluding this part highlights these bracing assumptions in designing a typical collector beam.

Part 9 and Additional Resources

Part 9, Provisions and Standards, contains both the 2016 *Seismic Provisions* and *Prequalified Connections* documents. These, along with all other AISC standards mentioned in this article, are available for free download at **www.aisc.org/specifications**.

Furthermore, designers can visit the technical resources page that is specific to seismic applications at **www.aisc.org/technical-resources/seismic**. A number of other useful resources that supplement the use of the *Seismic Design Manual* and the *Steel Construction Manual* are found at **www.aisc.org/manualresources**. Finally, AISC also posts archival NASCC conference proceedings, many of which are on the topic of seismic design, at **www.aisc.org/educationarchives**.

With these resources and the updated *Seismic Manual*, you shouldn't feel at all shaky about your next seismic design project. ■

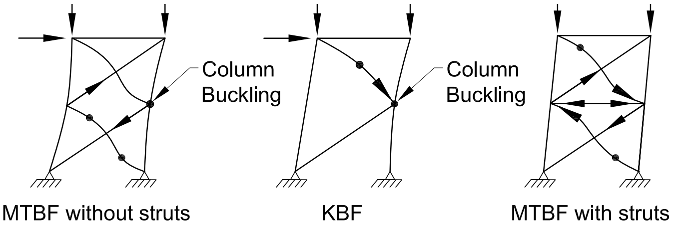


Figure 6. Multi-tiered ordinary concentric braced frame.

Levi's Stadium in Santa Clara, Calif., is the first NFL stadium to use a buckling restrained brace (BRB) system for lateral force resistance. A partial rendering of the structural frame is shown, left. BRBs are visible in the interior spaces (right). Read more about Levi's Stadium in the March 2016 article, "It's Up…It's Good."