SEISMIC DESIGN



MANUAL

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

THIRD EDITION

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by

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FOREWORD

The American Institute of Steel Construction, founded in 1921, is the nonprofit technical specifying and trade organization for the fabricated structural steel industry in the United States. Executive and engineering headquarters of AISC are maintained in Chicago. The Institute is supported by four classes of membership: Full Members engaged in the fabrication, production and sale of structural steel; Associate Members, who include Erectors, Detailers, Service Consultants, Software Developers, and Steel Product Manufacturers; Professional Members, who are individuals or firms engaged in the practice of architecture or engineering, including architectural and engineering educators; and Affiliate Members, who include Building Inspectors, Code Officials, General Contractors, and Construction Management Professionals. The continuing financial support and active participation of Members in the engineering, research, and development activities of the Institute make possible the publishing of this *Seismic Design Manual*.

The Institute's objective is to make structural steel the material of choice, by being the leader in structural-steel-related technical and market-building activities, including: specification and code development, research, education, technical assistance, quality certification, standardization, and market development.

To accomplish this objective, the Institute publishes manuals, design guides and specifications. Best known and most widely used is the *Steel Construction Manual*, which holds a highly respected position in engineering literature. The Manual is based on the *Specification for Structural Steel Buildings* and the *Code of Standard Practice for Steel Buildings and Bridges*. Both standards are included in the *Steel Construction Manual* for easy reference.

The Institute also publishes technical information and timely articles in its *Engineering Journal*, Design Guide series, *Modern Steel Construction* magazine, and other design aids, research reports and journal articles. Nearly all of the information AISC publishes is available for download from the AISC web site at **www.aisc.org**.

PREFACE

This is the third edition of the AISC *Seismic Design Manual*, intended to assist designers in properly applying AISC standards and provisions in the design of steel frames to resist high-seismic loadings. This Manual is intended for use in conjunction with the AISC *Steel Construction Manual*, 15th Edition.

The following consensus standards are printed in Part 9 of this Manual:

- 2016 Seismic Provisions for Structural Steel Buildings (ANSI/AISC 341-16)
- 2016 Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications (ANSI/AISC 358-16)

The design examples contained in this Manual demonstrate an approach to the design, and are not intended to suggest that the approach presented is the only approach. The committee responsible for the development of these design examples recognizes that designers have alternate approaches that work best for them and their projects. Design approaches that differ from those presented in these examples are considered viable as long as the AISC *Specification* and AISC *Seismic Provisions*, sound engineering, and project specific requirements are satisfied.

The following major changes and improvements have been made in this revision:

- More thorough and comprehensive design examples, updated for the 2016 AISC *Seismic Provisions* and 2016 AISC *Specification*
- Addition of Section 1.4 regarding the identification of elements that are part of the seismic force-resisting system
- Addition of examples illustrating the bracing of beams in special moment-frame systems
- Addition of a bolted flange plate example for a special moment frame system
- Addition of an example addressing the strong-column weak-beam exception in a special moment frame system
- · Addition of special truss moment frame examples
- · Addition of multi-tiered ordinary concentric braced frame examples
- Addition of a buckling-restrained braced frame brace-to-beam/column connection example
- Inclusion of the chevron effect in braced frame examples
- Inclusion of ASTM A913, ASTM A500 Grade C, and ASTM A1085 steel in select tables and examples

By the AISC Committee on Manuals,

Mark V. Holland, Chairman Gary C. Violette, Vice-Chairman Allen Adams Scott Adan Abbas Aminmansour Craig J. Archacki Harry A. Cole, Emeritus **Brad Davis** Bo Dowswell Matthew Eatherton Marshall T. Ferrell, Emeritus Patrick J. Fortney Timothy P. Fraser Louis F. Geschwindner, Emeritus John L. Harris III Christopher M. Hewitt William P. Jacobs V

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The committee gratefully acknowledges the contributions made to this Manual by the AISC Committee on Specifications, the Connection Prequalification Review Panel, and the following individuals: Michael Gannon, Cynthia Duncan, Keith Grubb and Leigh Arber.

SCOPE

The specification requirements and other design recommendations and considerations summarized in this Manual apply in general to the design and construction of seismic force-resisting systems in steel buildings and other structures. The AISC *Seismic Design Manual* is intended to be applied in conjunction with the AISC *Steel Construction Manual*, which provides guidance on the use of the AISC *Specification for Structural Steel Buildings*.

In addition to the requirements of the AISC *Specification*, the design of seismic forceresisting systems must meet the requirements in the AISC *Seismic Provisions for Structural Steel Buildings*, except in the following cases for which use of the AISC *Seismic Provisions* is not required:

- Buildings and other structures in Seismic Design Category (SDC) A
- Buildings and other structures in SDC B or C with R = 3 systems [steel systems not specifically detailed for seismic resistance per ASCE/SEI 7, Table 12.2-1 (ASCE, 2016)]
- Nonbuilding structures similar to buildings with $R = 1\frac{1}{2}$ braced-frame systems or R = 1 moment-frame systems; see ASCE/SEI 7 Table 15.4-1
- Nonbuilding structures not similar to buildings (see ASCE/SEI 7, Table 15.4-2), which are designed to meet the requirements in other standards entirely

Conversely, use of the AISC Seismic Provisions is required in the following cases:

- Buildings and other structures in SDC B or C when one of the exemptions for steel seismic force-resisting systems above does not apply
- Buildings and other structures in SDC B or C that use cantilever column systems
- Buildings and other structures in SDC B or C that use composite seismic forceresisting systems (those containing composite steel-and-concrete members and those composed of steel members in combination with reinforced concrete members)
- Buildings in SDC D, E or F
- Nonbuilding structures in SDC D, E or F when the exemption above does not apply

The *Seismic Design Manual* consists of nine parts addressing various topics related to the design and construction of seismic force-resisting systems of structural steel and structural steel acting compositely with reinforced concrete. Part 1 stipulates the specific editions of the specifications, codes and standards referenced in this Manual, and provides a discussion of general design considerations related to seismic design. Part 2 provides some guidance on structural analysis procedures employed. For the design of systems not detailed for seismic resistance, see Part 3. Parts 4 through 7 apply to the various types of seismic force-resisting systems, including design examples. Part 8 discusses other systems, such as diaphragm chords and collectors, that are important in seismic design. For applicable AISC seismic standards, see Part 9.