# 2012 IBC®

## SEAOC STRUCTURAL/SEISMIC DESIGN MANUAL

## VOLUME 4

## EXAMPLES FOR STEEL-FRAMED BUILDINGS


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## Publisher

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The Structural Engineers Association of California (SEAOC) is a professional association of four regional member organizations (Southern California, Northern California, San Diego, and Central California). SEAOC represents the structural engineering community in California. This document is published in keeping with SEAOC's stated mission:

> To advance the structural engineering profession; to provide the public with structures of dependable performance through the application of state-of-the-art structural engineering principles; to assist the public in obtaining professional structural engineering services; to promote natural hazard mitigation; to provide continuing education and encourage research; to provide structural engineers with the most current information and tools to improve their practice; and to maintain the honor and dignity of the profession.

SEAOC Board oversight of this publication was provided by 2012 SEAOC Board President James Amundson, S.E. and Immediate Past President Doug Hohbach, S.E.

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International Code Council

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First Printing: August 2013

## Suggestions for Improvement

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## Errata Notification

SEAOC has made a substantial effort to ensure that the information in this document is accurate. In the event that corrections or clarifications are needed, these will be posted on the SEAOC web site at *www.seaoc.org* and on the ICC web site at *www.iccsafe.org*.

SEAOC, at its sole discretion, may issue written errata.

# Table of Contents

# Preface to the 2012 *IBC SEAOC Structural/Seismic Design Manual*

The *IBC SEAOC Structural/Seismic Design Manual*, throughout its many editions, has served the purpose of illustrating good seismic design and the correct application of building-code provisions. The manual has bridged the gap between the discursive treatment of topics in the SEAOC Blue Book (*Recommended Lateral Force Requirements and Commentary*) and real-world decisions that designers face in their practice.

The examples illustrate code-compliant designs engineered to achieve good performance under severe seismic loading. In some cases simply complying with building-code requirements does not ensure good seismic response. This manual takes the approach of exceeding the minimum code requirements in such cases, with discussion of the reasons for doing so.

Recent editions of the *IBC SEAOC Structural/Seismic Design Manual* have consisted of updates of previous editions, modified to address changes in the building code and referenced standards. Many of the adopted standards did not change between the 2006 edition of the *International Building Code* and the 2009 edition. The 2012 edition, which is the one used in this set of manuals, represents an extensive change of adopted standards, with many substantial changes in methodology.

Additionally, this edition has been substantially revised. New examples have been included to address new code provisions and new systems, as well as to address areas in which the codes and standards provide insufficient guidance. Important examples such as the design of base-plate anchorages for steel systems and the design of diaphragms have been added.

This expanded edition comprises five volumes:

- Volume 1: Code Application Examples
- Volume 2: Examples for Light-Frame, Tilt-Up, and Masonry Buildings
- Volume 3: Examples for Reinforced Concrete Buildings
- Volume 4: Examples for Steel-Framed Buildings
- Volume 5: Examples for Seismically Isolated Buildings and Buildings with Supplemental Damping

Previous editions have been three volumes. This expanded edition contains more types of systems for concrete buildings and steel buildings. These are no longer contained in the same volume. Volumes 3 and 4 of the 2012 edition replace Volume 3 of the 2009 edition. Additionally, we have fulfilled the long-standing goal of including examples addressing seismic isolation and supplemental damping. These examples are presented in the new Volume 5.

In general, the provisions for developing the design base shear, distributing the base-shear-forces vertically and horizontally, checking for irregularities, etc., are illustrated in Volume 1. The other volumes contain more extensive design examples that address the requirements of the material standards (for example, ACI 318 and AISC 341) that are adopted by the IBC. Building design examples do not illustrate many of the items addressed in Volume 1 in order to permit the inclusion of less-redundant content.

Each volume has been produced by a small group of authors under the direction of a manager. The managers have assembled reviewers to ensure coordination with other SEAOC work and publications, most notably the Blue Book, as well as numerical accuracy.

This manual can serve as valuable tool for engineers seeking to design buildings for good seismic response.

Rafael Sabelli
Project Manager

# Preface to Volume 4

Volume 4 of the 2012 *IBC SEAOC Structural/Seismic Design Manual* addresses the design of steel building systems for seismic loading. Examples include the illustration of the design requirements for braced frames and moment frames, as were illustrated in previous editions, and also important interfaces with the rest of the structure.

The design examples in this volume represent a range of steel structural systems. The *Manual* includes a set of examples that illustrate a more complete design: the design of diaphragms and collectors is illustrated, as are the design of base plates and anchorages for moment-frame and braced-frame columns. With the addition of these items this edition of the *Manual* offers more extensive guidance to engineers, addressing the design of these critical components of the seismic system.

The design of each of these systems is governed by standards developed by the American Institute of Steel Construction (AISC). AISC produces its own *Seismic Design Manual* to illustrate the correct application of the AISC *Seismic Provisions* (AISC 341) and the AISC *Prequalification Standard* (AISC 358). The AISC *Seismic Design Manual* is a valuable resource for designers, and this volume is not intended to duplicate AISC's efforts. This manual, for example, does not include the detailed range of options for gusset-plate design, as the AISC *Seismic Design Manual* addresses this design aspect thoroughly.

Nevertheless, there is a fundamental difference in purpose and approach between this manual and the AISC *Seismic Design Manual*. The AISC *Manual* illustrates the code requirements, while the SEAOC *Structural/ Seismic Design Manual* illustrates SEAOC's recommended practices, which traditionally have gone beyond the code (or in advance of it). The design examples for base plates are important examples of design methodologies not explicitly defined by building codes. Building code provisions for these connections are difficult to apply and do not correspond well to the mechanisms of resistance. The examples herein provide a convenient and valuable alternative methodology, one that is not an illustration of explicit code requirements.

The methods illustrated herein represent approaches consistent with the ductility expectations for each system and with the desired seismic response. In most cases there are several details or mechanisms that can be utilized to achieve the ductility and resistance required, and the author of each example has selected an appropriate option. In many cases alternatives are discussed. This *Manual* is not intended to serve as a building code or to be an exhaustive catalogue of all valid approaches and details.

The *Manual* is presented as a set of examples in which the engineer has considered the building-code requirements in conjunction with the optimal seismic response of the system. The examples follow the recommendations of the SEAOC Blue Book and other SEAOC recommendations. The examples are intended to aid conscientious designers in crafting designs that are likely to achieve good seismic performance consistent with expectations inherent in the requirements for the systems.

Rafael Sabelli
Volume 4 Manager

# Acknowledgements

Volume 4 of the 2012 *IBC SEAOC Structural/Seismic Design Manual* was written by a group of highly qualified structural engineers, chosen for their knowledge and experience with structural engineering practice and seismic design.

**Kevin S. Moore, S.E., SECB, Principal, Simpson Gumpertz & Heger—Examples 1 and 8**
With multiple state licenses, Kevin has more than 18 years of experience in structural engineering design, analysis, and evaluation. He is the Chair of the SEAOC Structural Standards Committee, Past Chair of the SEAOC Seismology Committee, and Chair of the Seismic Subcommittee of the NCSEA Code Advisory Committee. He has written multiple papers and design examples associated with steel design, seismic forces, and structural systems. Kevin is also a member of the AISC Connection Prequalification Review Panel. www.sgh.com

**Rafael Sabelli, S.E., Principal, Director of Seismic Design, Walter P. Moore—Volume 4 Manager and Example 2**
Rafael Sabelli is a member of the AISC Task Committee on the Seismic Provisions for Structural Steel Buildings, Chair of the AISC Seismic Design Manual committee, a member of the ASCE 7 Seismic subcommittee, and a member of the BSSC Provisions Update Committee and Code Resource Support Committee. He is the coauthor (with Michel Bruneau) of AISC *Design Guide 20: Steel Plate Shear Walls* as well as of numerous research papers on conventional and buckling-restrained braced frames. He has served as Chair of the Seismology Committee of the Structural Engineers Association of California and as President of the Structural Engineers Association of Northern California. Rafael was the co-recipient of the 2008 AISC T.R. Higgins Lectureship and was the 2000 NEHRP Professional Fellow in Earthquake Hazard Reduction.

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Dr. Dutta has over 12 years of experience in structural and earthquake engineering. He has provided analysis and design of a variety structures in high seismic zones. Dr. Dutta's experience also includes seismic evaluation and strengthening of low-rise to high-rise structures. He has taught graduate and undergraduate level courses on concrete design and structural analysis at the State University of New York at Buffalo and is a regular lecturer at the San Francisco State University's graduate program and at the University of California at Berkeley's extension program. He has authored a number of technical reports and journal papers as well as served as a member of the review board for ASCE's *Structural Engineering Journal*.

**Kenneth Tam, Simpson Gumpertz & Heger—Example 3**
Kenneth has more than 17 years of experience in the field of structural and earthquake engineering. His experience includes structural design and evaluation of variety of structures in high seismic zones. He has co-authored various papers on design and analysis of buckling-restrained braced frames and has served on the ASCE41-13 Steel Subcommittee.

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Matt has seven years of experience as a practicing structural engineer conducting high-seismic design in the San Francisco Bay Area. Now he serves on the faculty at Virginia Tech where he teaches classes on steel design, structural dynamics, and earthquake engineering. His research program includes both experimental and computational investigations of steel-plate shear walls, self-centering seismic systems, steel connections, and more. www.eatherton.cee.vt.edu

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With over 21 years of experience, Dr. Adan specializes in the investigation and design of buildings and structures. He is also actively involved in the research and development of steel moment-resisting connections. For the Structural Engineers Association of Northern California, he chairs the Steel Subcommittee. For the American Institute of Steel Construction, he is a member of the Seismic Design Manual Subcommittee, the Connection Prequalification Review Panel, and the Seismic Design Task Committee. www.adanengineering.com

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Anna has eight years of practice in design and analysis of steel and concrete structures. Her focus is on special-use and marine structures including cranes, wharves, and heavy-lift and container-handling equipment. She has specialized experience with ductile tie-down systems for cranes, seismic design and analysis of steel structures, seismic crane-wharf interaction, designing ductile steel frames, and investigating fatigue cracking for various structures. In her spare time, Anna introduces engineering to inquisitive young minds. www.liftech.net

**Katy Briggs, S.E., Project Engineer, Thornton Tomasetti—Example 7**
A licensed S.E. in the State of California, Katy Briggs has seven years of experience in structural analysis and design. She has worked on new buildings and seismic retrofits of existing buildings utilizing wood, steel, concrete, and masonry construction. These projects include education, healthcare, government, correctional, and commercial facilities. She has been involved with writing and editing design examples for steel diaphragms and special concentrically braced frames.

**Amit Kanvinde, Ph.D., Associate Professor of Civil and Environmental Engineering, University of California, Davis—Example 8**
Amit's research heavily focuses on the seismic response of steel structures and connections through experimentation and simulation. Pertinent to the design example, he has conducted 28 large-scale tests on column base connections and is the author of two major technical reports and several journal and conference papers on the topic of base plates. His other recent research has addressed the fracture of seismic column splices in moment frames and braces in SCBF systems. He is the recipient of the 2008 ASCE Norman Medal and the 2003 EERI Graduate Student Paper award addressing the collapse of structures.

**David A. Grilli, M.S., E.I.T., Graduate Student Researcher, University of California, Davis—Example 8**
David is a doctoral student in the Department of Civil and Environmental Engineering at UC Davis. Through large-scale experimentation, his work addresses the seismic response of embedded and exposed column-base plates. Pertinent to this example, he is co-author of a journal article that characterizes the rotational flexibility of exposed column base connections. David was the recipient of the AISC Structural Steel Education Council scholarship in 2009, and the Farrer/Patten Award for outstanding student in Civil Engineering at UC Davis in 2012.

**Lindsey Maclise, Associate, Forell/Elsesser Engineers Inc.—Example 9**
Lindsey is currently an Associate with Forell/Elsesser Engineers specializing in seismic design for both new construction and retrofit. She received her B.S. and M.S. from the University of California, Berkeley and is an active member of SEAONC, SEI, and EERI. She is currently serving as a Housner Fellow for her work in Sustainable Seismic Design. www.forell.com

Additionally, a number of SEAOC members and other structural engineers helped check the examples in this volume. During its development, drafts of the examples were sent to these individuals. Their help was sought in review of code interpretations as well as detailed checking of the numerical computations. The reviewers include:

Geoff Bomba

Mike Cochran

Andrew Cussen

Tom Hale

Walterio López

Sara Jozefiak

Ryan Kersting

Benjamin Mohr

Carrie Leung

Thomas Nunziata

Patxi Uriz

Laura Whitehurst

Close collaboration with the SEAOC Seismology Committee was maintained during the development of the document. The Seismology Committee has reviewed the document and provided many helpful comments and suggestions. Their assistance is gratefully acknowledged.

Production and art was provided by the International Code Council.

# References

## Standards


American Concrete Institute. *ACI 318: Building Code Regulations for Reinforced Concrete*, Farmington Hills, Michigan, 2011.

American Institute of Steel Construction. *AISC 341: Seismic Provisions for Structural Steel Buildings,* Chicago, Illinois, 2010.

American Institute of Steel Construction. *AISC 358: Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications,* Chicago, Illinois, 2010.

American Institute of Steel Construction. *AISC 360: Specification for Structural Steel Buildings*, Chicago, Illinois, 2010.

American Society of Civil Engineers. *ASCE 7: Minimum Design Loads for Buildings and Other Structures*. ASCE 2010.

International Code Council. *International Building Code (IBC).* Falls Church, Virginia, 2012.


## Other References


American Institute of Steel Construction. *Manual of Steel Construction*, Chicago, Illinois, 2012.

American Institute of Steel Construction. *Seismic Design Manual*, Chicago, Illinois, 2013.

Anonymous, 1977. "Shear walls and slipforming speed Dallas' Reunion project" *Engineering News Record*, 20–21, July 28.

Anonymous, 1978a. "Patent problems, challenge spawn steel seismic walls" *Engineering News Record*, 17, January 26.

Anonymous, 1978b. "Quake-proof hospital has battleship-like walls" *Engineering News Record*, 62–63, Sept. 21.

Astaneh-Asl, A. 2005. "Design of Shear Tab Connections for Gravity and Seismic Loads," *Steel Technical Information and Product Report*. Structural Steel Educational Council, CA.

Basler, K. 1961. "Strength of Plate Girders in Shear" *Journal of the Structural Division*, ASCE, Vol. 87, No. ST7 October.

Berman, J. W. and Bruneau, M. 2004. "Steel Plate Shear Walls are Not Plate Girders" *AISC Engineering Journal*, Third Quarter.

Berman, J. W. and Bruneau, M. 2008. "Capacity Design of Vertical Boundary Elements in Steel Plate Shear Walls" *AISC Engineering Journal,* First Quarter.

Bozorgnia, Y., Bertero, V., 2004. *Earthquake Engineering: From Engineering Seismology to Performance-Based Engineering.* CRC Press, LLC, Danvers, Massachusetts.

Bruneau, M., Uang, C.M., and Sabelli, R. *Ductile Design of Steel Structures*. McGraw-Hill, 2011.

CAN/CSA S16-09 2009. "Limit States Design of Steel Structures," published by Canadian Standards Association.

Cheng, J.J.R., and Kulak, G.L. 2000. Gusset plate connection to round HSS tension members. *Engineering Journal*, AISC, 4th Quarter, 133–139.

Clifton, C., Bruneau, M., MacRae, G., Leon, R., Russell, A., 2011. "Steel Structures Damage from the Christchurch Earthquake of February 22, 2011," NZST, Bulletin of the New Zealand Society for Earthquake Engineering, Vol. 44, No. 4.

DeWolf, J. T., and Ricker, D. T. 1990. *AISC Design Guide 1—Column Base Plates*, Published by the American Institute of Steel Construction, AISC.

Engelhardt, M., and Popov, E., 1989. "On Design of Eccentrically Braced Frames," *Earthquake Spectra, EERI,* Vol. 5, No. 3, 495–511.

Englehardt, M. Personal correspondence and notes. 2012.

Fisher, J.M. and Kloiber, L.A. 2006. "Base Plate and Anchor Rod Design," 2nd Ed., Steel Design Guide Series No. 1, American Institute of Steel Construction, Inc., Chicago, IL.

Gomez, I.R., Kanvinde A.M., and Deierlein G.G. 2010. "Exposed Column Base Connections Subjected to Axial Compression and Flexure," Report Submitted to the American Institute of Steel Construction (AISC), Chicago, IL.

Gomez, I.R., Kanvinde, A.M., and Deierlein, G.G. 2011. "Experimental investigation of shear transfer in exposed column base connections," *Engineering Journal*, American Institute of Steel Construction, 4th Quarter, 246–264.

ICC/SEAOC 2006. "Design Example 4—Steel Plate Shear Walls", *2006 IBC Structural/Seismic Design Manual, Volume 3*, Structural Engineers Association of California, Sacramento, California.

Imanpour, A., Tremblay, R., and Davaran, A. "Seismic Evaluation of Multi-Panel Steel Concentrically Braced Frames," 15th World Conference on Earthquake Engineering, 2012.

Lehman, D., Roeder, C. 2, Johnston, S. 1, Herman D. 1, and Kotulka, B. 1 2008 "Improved Seismic Performance of Gusset Plate Connections", ASCE *Journal of Structural Engineering*, Vol. 134, No. 6, 181–189.

Luttrell, Larry D. 1967. "Strength and behavior of light-gage steel shear diaphragms", Cornell Research Bulletin 67-1, sponsored by the American Iron and Steel Institute, Ithaca, NY.

Moehle, Jack P., Hooper, John D., Kelly, Dominic J., and Meyer, Thomas. 2010. "Seismic design of cast-in-place concrete diaphragms, chords, and collectors: A guide for practicing engineers," *NEHRP Seismic Design Technical Brief Number 3*, produced by the NEHRP Consultants Joint Venture, a partnership of the Applied Technology Council and the Consortium of Universities

for Research in Earthquake Engineering, for the National Institute of Standards and Technology, Gaithersburg, MD, NIST GCR 10-917-4.

Moore, Kevin S., Feng, Joyce Y., June 2007. "Design of RBS Connections for Special Moment Frames," *Steel Tips.* Structural Steel Educational Council, Moraga, California.

Myers, A.T., Kanvinde, A.M., Deierlein, G.G., and Fell B.V. 2009, "Effect of Weld Details on the Ductility of Steel Column Baseplate Connections," *Journal of Constructional Steel Research*, Volume 65, Issue 6, June 2009, 1366–1373.

Porter, D.M., Rockey, K.C. and Evans, H.R. 1975. "The collapse behavior of plate girders loaded in shear", *The Structural Engineer*, London England, Vol. 53, No. 8., Aug.

Prasad, Badri K., Thompson, Douglas S., and Sabelli, Rafael. 2009. *Guide to the design of diaphragms, chords and collectors based on the 2006 IBC and ASCE/SEI 7-05,* International Code Council Publications, Country Club Hills, IL.

Purba, R. and Bruneau, M. 2009. "Finite-Element Investigation and Design Recommendations for Perforated Steel Plate Shear Walls" Journal of Structural Engineering, Vol. 135, No. 11, 1367–1376.

Purba, R., and Bruneau, M. 2007. *Design Recommendations for Perforated Steel Plate Shear Walls* Technical Report MCEER-07-0011.

Qu, B., and Bruneau, M. 2010. "Capacity Design of Intermediate Horizontal Boundary Elements of Steel Plate Shear Walls" Journal of Structural Engineering, Vol. 136, No. 6.

Ricles, J., and Popov, E., 1989, "Composite Action in Eccentrically Braced Frames," *Journal of Structural Engineering*, *ASCE*, Vol. 115, No. 8, 2046–2065.

Roberts, T. M. and Sabouri-Ghomi, S. 1991. "Hysteretic Characteristics of Unstiffened Plate Shear Panels" *Thin-Walled Structures*, Elsevier Science Publishers, Great Britain, 1991.

Rogers, C.A. and Tremblay, R. 2008. "Impact of Diaphragm Behavior on the Seismic Design of Low-Rise Steel Buildings", AISC Engineering Journal, First Quarter.

Sabelli, R. and Bruneau, M. 2006. *AISC Design Guide 20—Steel Plate Shear Walls*, Published by the American Institute of Steel Construction, AISC.

Sabelli, Rafael, Sabol, Thomas A., and Easterling, Samuel W. 2011. "Seismic design of composite steel deck and concrete-filled diaphragms: A guide for practicing engineers," *NEHRP Seismic Design Technical Brief Number 5*, produced by the NEHRP Consultants Joint Venture, a partnership of the Applied Technology Council and the Consortium of Universities for Research in Earthquake Engineering, for the National Institute of Standards and Technology, Gaithersburg, MD, NIST GCR 10-917-10.

Schumacher, A., Grondin, G.Y. and Kulak, G.L. 1999. "Connection of Infill Panels in Steel Plate Shear Walls" *Canadian Journal of Civil Engineering*, Vol. 26.

SDI 2004. *Diaphragm design manual*, Third Edition (SDI DDMO3), Steel Deck Institute, Fox Grove, IL.

SEAOC Blue Book, *Recommended Lateral Force Requirements and Commentary*. Structural Engineers Association of California, Sacramento, California.

SEAOC Seismology Committee 2007. "Development of System Factors," May 2007, *The SEAOC Blue Book: Seismic design Recommendations*, Structural Engineers Association of California, Sacramento, CA.

SEAOC Seismology Committee 2008. "Concentrically Braced Frames," August, 2008, *The SEAOC Blue Book: Seismic Design Recommendations*, Structural Engineers Association of California, Sacramento, CA. Accessible via the world wide web at: http://www.seaoc.org/bluebook/index.html

SEAOC Seismology Committee, FEMA 350 Task Group, 2002. "Commentary and Recommendations on FEMA 350—Appendix D," Structural Engineers Association of California, Sacramento, CA.

Stoakes, C.D., Fahnestock, L.A. "Influence of Weak-axis Flexural Yielding on Strong-axis Buckling Strength of Wide Flange Columns," Proceedings of the Annual Stability Conference, Structural Stability Research Council, April 2012.

Structural Engineers Association of California (SEAOC) Seismology Committee, 2008. *SEAOC blue book: Seismic design recommendations*, Structural Engineers Association of California, Sacramento, CA.

Thornton, W.A., and Fortney, P. 2012, "Satisfying Inelastic Rotation Requirements for In-plane Critical Axis Brace Buckling for High Seismic Design." *Engineering Journal*, AISC, Vol. 49, No. 3, 3rd Quarter.

Tremblay, R. 2001, "Seismic Behavior and Design of Concentrically Braced Steel Frames," *Engineering Journal*, AISC, Vol. 38, No. 3, Chicago, IL.

Tremblay, R., Archambault, M.-H., Filiatrault, A. "Seismic Response of Concentrically Braced Steel Frames Made with Rectangular Hollow Bracing Members," December, 2003, Article 2003. 129:1626–1636, Journal of Structural Engineering, American Society of Civil Engineers.

Tremblay, R., et al. "Seismic Design of Steel Structures in Accordance with CSA-S16-09," July 25–29, 2010, Paper No. 1768, Proceedings of the 9th US National and 10th Canadian Conference on Earthquake Engineering, Toronto, Ontario, Canada.

Vian, D., and Bruneau, M. 2005. "Steel Plate Shear Walls for Seismic Design and Retrofit of Building Structures" Technical Report MCEER 05-0010.

Vian, D., Bruneau, M., Tsai, K.C., and Lin, Y.-C. 2009. "Special Perforated Steel Plate Shear Walls with Reduced Beam Section Anchor Beams 1: Experimental Investigation" Journal of Structural Engineering, Vol. 135, No. 3, 211–220.

Wong, Alfred F. "Multi-tier Bracing Panels within a Storey," Advantage Steel, Canadian Institute of Steel Construction, No. 43, Summer 2012.

Zayas, V., Mahin, S., Popov, E. "Cyclic Inelastic Behavior of Steel Offshore Structures," August 1980, Report No. UCB/EERC-80/27 to the American Petroleum Institute, Earthquake Engineering Research Center & College of Engineering at University of California, Berkeley.

# How to Use This Document

Equation numbers in the right-hand margin refer to the one of the standards (e.g., AISC 341, AISC 358, AISC 360, ASCE 7). The default standard is given in the heading of each section of each example; equation numbers in that section refer to that standard unless another standard is explicitly cited.

Abbreviations used in the "Code Reference" column are

§ – Section T – Table

F – Figure Eq – Equation