2018 IBC® SEAOC STRUCTURAL/SEISMIC DESIGN MANUAL

VOLUME 4
EXAMPLES FOR STEEL-FRAMED BUILDINGS

STRUCTURAL ENGINEERS ASSOCIATION SOUTHERN CALIFORNIA
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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.

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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 website at *www.seaoc.org* and on the ICC website at *www.iccsafe.org*.

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

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Preface to the 2018 *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.

This manual comprises four volumes:

- Volume 1: Code Application Examples
- Volume 2: Examples for Light-Frame, Tilt-Up, and Masonry Buildings
- Volume 3: Examples for Concrete Buildings
- Volume 4: Examples for Steel-Framed Buildings

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 a valuable tool for engineers seeking to design buildings for good seismic response.

Rafael Sabelli and Katy Briggs
Project Managers

Preface to Volume 4

Volume 4 of the 2018 *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

Acknowledgments

Many of the examples in this volume were originally prepared for previous editions and have been updated and revised for this edition based on code changes and evolving practice. The authors of the original problems are 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
Kevin Moore is the Chair of the SEAOC Structural Standards Committee, Past Chair of the SEAOC and SEAONC Seismology Committees and Past Chair of the NCSEA Seismic Subcommittee of the Code Advisory Committee. Mr. Moore serves as an Associate Member on ASCE 7 Main Committee and Seismic Subcommittee, is a voting member of the AISC Connection Prequalification Review Panel and currently Chairs the NCSEA Resilience Committee. He has authored numerous papers on Special Steel Moment Frames and Structural Steel Design topics. Mr. Moore is also past-Chair of Issue Team 3 of the 2015 NEHRP Recommended Seismic Provisions for New Buildings and Other Structures and currently serves on a number of Issue Teams for the 2020 version of these provisions. In his spare time, Kevin races his 1998 BMW M3 in Northern California and other locations throughout the country.

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 15 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*.

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Kenneth has more than 20 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.

Matthew R. Eatherton, Ph.D., S.E., Assistant Professor, Virginia Tech—Example 4
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

Scott M. Adan, Ph.D., P.E., S.E., SECB, Principal, Adan Engineering—Example 5
As a nationally recognized seismic and structural engineer, Dr. Adan has a long-standing career dedicated to the design and investigation of buildings and structures. He has authored a number of engineering-related journal and technical papers and is active in various professional engineering associations. He is also actively involved in the research and development of steel moment-resisting connections. Over the course of his career, he has practiced in nearly all earthquake susceptible regions of the western United States. He has also investigated damage from numerous earthquakes and lectured on their effects. In the past, he has chaired the Structural Steel Subcommittee for SEAONC. For AISC, he has served on both the Manual and Specifications Committee and the Connection Prequalification Review Panel. The Structural Engineers Association of Washington has honored him with a President's Award for Outstanding Service. www.adanengineer.com

Anna Dix, S.E., Associate, Liftech Consultants Inc.—Example 6
Ms. Dix is a registered structural engineer in California and has 14 years of experience in the design and analysis of various steel and concrete structures. Her focus is on ship-to-shore cranes and other structures that reside next to, in, or on top of the water, such as heavy-lift and container-handling equipment, wharves, and floating cranes. She likes earthquake and fatigue engineering topics and working with clients. In her spare time, she enjoys managing difficult people . . . her two young kids.

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Katy is a co-founder of BASE Design and has a wide range of experience working in the AEC industry. She has managed the structural design and analysis of new buildings, retrofits of existing buildings, and the post-disaster evaluation of existing buildings. Katy is the former chair of SEAONC's Seismology Committee and will be a member of the SEAONC Board for the 2019–2020 year, and she has been involved with writing and editing design examples and technical papers related to steel and concrete design in high-seismic regions.

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 33 large-scale tests on column base connections and is the author of four major technical reports and several journal and conference papers on the topic of base connections. 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, Ph.D., Associate, Wiss, Janney, Elstner Associates, Inc.
David is an Associate Engineer with Wiss, Janney, Elstner Associates, Inc. He earned his doctoral degree 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 connections. Pertinent to the design 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.

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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 an EERI Housner Fellow for her work in Sustainable Seismic Design. www.forell.com

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Laura Whitehurst is a structural engineer in the Wellington, New Zealand office of Holmes Consulting with more than a decade of design experience in California and New Zealand. Her work includes design with steel, concrete, wood, and masonry, with an emphasis on seismic design. She is actively involved in many organizations, including the Structural Engineering Society of New Zealand (SESOC), SEAONC, SEAOC, EERI, and the Engineers Alliance for the Arts. She has served as a Director for SEAONC and as Vice President of the Engineers Alliance for the Arts, and now serves as the liaison between SEAOC and SESOC. She is a Structures Specialist with FEMA's Urban Search and Rescue program. She is a licensed civil and structural engineer in California, a Chartered Member of Engineering New Zealand, and holds a B.S. from Cornell University and an M.S. from Stanford University.

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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