# 2012 IBC®

## SEAOC STRUCTURAL/SEISMIC DESIGN MANUAL

## VOLUME 3

EXAMPLES FOR CONCRETE BUILDINGS


## Copyright



## Publisher

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The Structural Engineers Association of California (SEAOC) is a professional association of four regional member organizations (Central California, Northern California, San Diego, and Southern 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

## Disclaimer



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 3

Volume 3 of the 2012 *IBC SEAOC Structural/Seismic Design Manual* illustrates the design requirements for reinforced concrete shear wall and moment-frame seismic systems, and also important interfaces with the rest of the structure.

The design examples in this volume represent a range of structural systems and seismic systems. The design of each of these systems is governed by standards developed by the American Concrete Institute (ACI) in ACI-318. 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, nor 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.

Three examples have been included in past editions of this manual and are updated in this edition: reinforced concrete shear wall, reinforced concrete shear wall with coupling beams, and reinforced concrete special moment frame. Three examples are new and are included in this edition of the manual: reinforced concrete parking garage, reinforced concrete pile foundation, and reinforced concrete diaphragms and collectors.

Jon Kiland
Volume 3 Manager

# Acknowledgements

Volume 3 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. The authors are:

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With 29 years of experience in research and practice, Joe is an expert on the seismic evaluation, design, and retrofitting of structures. He has directed a range of projects, including those using innovative solutions and advanced methods of evaluation. The American Society of Civil Engineers and the American Concrete Institute have appointed Joe to committees writing structural code provisions. www.maffei-structure.com

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Karl joined Rutherford + Chekene Consulting Engineers in San Francisco in 2004, and his experience includes seismic retrofit of concrete buildings as well as design of new structures. Mr. Telleen joined MSE in 2013. He completed a Fulbright Fellowship in Switzerland in 2010, and he performed post-earthquake reconnaissance in Haiti following the January 2010 earthquake. He is currently participating in the ATC-94 project studying the performance of concrete buildings in the 2010 Chile earthquake. www.maffei-structure.com

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Jon has 33 years of experience as a structural design and consulting engineer in Northern California. His practice has included extensive experience in seismic analysis and evaluation of existing buildings, the design of new construction, and the seismic strengthening and rehabilitation of existing building projects. He currently works for the Applied Technology Council in Redwood City, California, as Director of Projects involved with developing advanced engineering applications for natural hazard mitigation. He has been actively involved in the development of codes and standards for over 25 years.

He is a Past President of the Structural Engineers Association of California and the Structural Engineers Association of Northern California, and a Fellow Member of both organizations. His current committee assignments include the ASCE 7-16 Seismic Sub-Committee (SSC) and Chair of the TC-2 General Provisions Task Committee. www.atcouncil.org

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Badri received his BS degree from Bangalore University, India, and MS degree from Mysore University, India. He also obtained his MS degree from the University of Arizona. He is currently a Vice President and Branch Manager—Structural at TTG Engineers, San Francisco, California. He is a registered SE in California and registered PE in Washington State. He has 25 years of experience in the design of various types of structures, such as healthcare facilities, biotechnology facilities, mid- and high-rise structures, schools, and seismic retrofit, among others. He is a member of the SEAONC Seismology Committee's concrete subcommittee and was instrumental in publishing the committee's work titled "Concrete Slab as a Collector Element" in the 2008 SEAOC Blue Book. He is also the project manager for this guide. He has published several papers on buckling restrained braced frames and a research paper on base-isolation system.

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:

Russell Berkowitz

Anindya Dutta

Tim Hart

Mark Jokerst

Jon Kiland

Yixia Liu

Ted Zsutty

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.