2018 IBC® SEAOC STRUCTURAL/SEISMIC DESIGN MANUAL

VOLUME 3
EXAMPLES FOR CONCRETE BUILDINGS

STRUCTURAL ENGINEERS ASSOCIATION SOUTHERN CALIFORNIA

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> 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.

Editor

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

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

Table of Contents

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 edition 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 and building components for good seismic response.

Rafael Sabelli and Katy Briggs
Project Managers

Preface to Volume 3

Volume 3 of the 2018 *IBC SEAOC Structural/Seismic Design Manual* illustrates the design requirements for reinforced concrete shear wall and moment-frame seismic systems, parking garages, foundation systems, and diaphragm and collectors.

The design examples in this volume are governed by standards developed by the American Concrete Institute (ACI) in ACI 318, Building Code Requirements for Structural Concrete, and by modifications to that document included in the 2018 IBC. The design examples in this volume approach the solution based on the ductility expectations for the system/component and based on the desired seismic response. In most examples there are several mechanisms that can be utilized to achieve the desired ductility and required resistance, and in each example the author has chosen the appropriate option. The alternatives and the reasons for not choosing them are discussed where applicable.

The examples follow the recommendations provided in the *SEAOC Blue Book* and other SEAOC recommendations. They are intended to assist designers in developing structures and components of structures that achieve good seismic performance. This manual is not intended to be a building code, nor is it intended to provide an exhaustive list of all detailing and design approaches.

Six of the design 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, reinforced concrete special moment frame, reinforced concrete parking garage, pile foundation, and design of concrete diaphragm and collector. A new example for the design of pile foundations at a concrete special moment resisting frame has been added to this volume.

Katy Briggs
Volume 3 Manager

Acknowledgments

Volume 3 of the 2018 *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

Joe Maffei, S.E., Ph.D., Maffei Structural Engineering—Examples 1 and 2
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. Joe has received awards including a Fulbright Fellowship to New Zealand, where he completed his Ph.D. degree, and a post-doctoral scholarship to Japan. He served as Director for EERI and SEAONC, and in 2015 he was elected as a fellow of SEAOC. 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 has 15 years of experience including seismic evaluation and retrofit of concrete buildings, design and peer review of new structures, and wind and seismic and analysis of solar arrays. He completed a Fulbright Fellowship in Switzerland in 2010, and he was selected as an EERI Housner Fellow in 2017. Karl served as Director and Treasurer of SEAONC, and he co-authored papers in the journals Earthquake Spectra, Concrete International, and the ASCE Journal of Structural Engineering. www.maffei-structure.com

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Badri has 30 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 retrofits, 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 2009 *SEAOC Blue Book*. He is the project manager and author of two design guides, related to the design of concrete diaphragm and collectors, published by NCSEA. He has published several papers on buckling restrained braced frames and a research paper on base-isolation system.

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.

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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., ACI 318, ASCE 7 or IBC). 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