

Copyright

Copyright © 2023 Structural Engineers Association of California. All rights reserved. This publication or any part thereof must not be reproduced in any form without the written permission of the Structural Engineers Association of California.

“The International Building Code” and the “IBC” are registered trademarks of the International Code Council.

Publisher

Structural Engineers Association of California (SEAOC)
1215 K Street, Suite 1100
Sacramento, California 95814
Telephone: (916) 447-1198; Fax: (916) 444-1501
E-mail: seaoc@seaoc.org; Web address: www.seaoc.org

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:

Empower our members and Member Organizations to advance the people, practice, and position of structural engineering.

Editor

International Code Council. The International Code Council is the leading global source of model codes and standards and building safety solutions that include product evaluation, accreditation, technology, codification, training and certification. The Code Council’s codes, standards and solutions are used to ensure safe, affordable and sustainable communities and buildings worldwide.
888-ICC-SAFE (888-422-7233) www.iccsafe.org

Disclaimer

While the information presented in this document is believed to be correct, neither SEAOC, ICC, ICC/SKGA, NCSEA nor their member organizations, committees, writers, editors, or individuals who have contributed to this publication make any warranty, expressed or implied, or assume any legal liability or responsibility for the use, application of, and/or reference to opinions, findings, conclusions, or recommendations included in this publication. The information provided in this manual does not necessarily reflect the opinions of ICC/SKGA in all aspects. The material presented in this publication should not be used for any specific application without competent examination and verification of its accuracy, suitability, and applicability. Users of information from this publication assume all liability arising from such use.

First Printing: February 2023

ISBN: 978-1-959851-00-4 (soft cover)
978-1-959851-01-1 (PDF download)

T028684

Suggestions for Improvement

Comments and suggestions for improvements are welcome and should be sent to the following:

Structural Engineers Association of California (SEAOC)
Don Schinske, Executive Director
1215 K Street, Suite 1100
Sacramento, California 95814
Telephone: (916) 447-1198; Fax: (916) 444-1501
E-mail: dschinske@seaoc.org

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 2021 <i>IBC SEAOC Structural/Seismic Design Manual</i>	xi
Preface to Volume 1	xiii
Acknowledgments	xv
References	xvii
How to Use This Document.	xix
Design Example 1	
Design Spectral Response Acceleration Parameters §11.4	1
Design Example 2	
Design Response Spectrum §11.4.6	3
Design Example 3	
Site-Specific Ground Motion Procedures §11.4.8	6
Design Example 4	
Importance Factor and Risk Category §11.5	
Seismic Design Category §11.6	11
Design Example 5	
Continuous Load Path and Interconnection §12.1.3	
Connection to Supports §12.1.4	13
Design Example 6	
Combination of Framing Systems in Different Directions §12.2.2	15
Design Example 7	
Combination of Framing Systems in the Same Direction: Vertical. §12.2.3.1	17
Design Example 8	
Combination of Framing Systems in the Same Direction: Horizontal §12.2.3.3	23
Design Example 9	
Combination Framing Detailing Requirements. §12.2.4	25

Design Example 10	
Dual Systems	§12.2.5.1 28
Design Example 11	
Introduction to Horizontal Irregularities	§12.3.2.1 31
Design Example 12	
Horizontal Irregularity Type 1a and Type 1b.	§12.3.2.1 32
Design Example 13	
Horizontal Irregularity Type 2.	§12.3.2.1 36
Design Example 14	
Horizontal Irregularity Type 3.	§12.3.2.1 38
Design Example 15	
Horizontal Irregularity Type 4.	§12.3.2.1 40
Design Example 16	
Horizontal Irregularity Type 5.	§12.3.2.1 42
Design Example 17	
Introduction to Vertical Irregularities	§12.3.2.2 43
Design Example 18	
Vertical Irregularity Type 1a and Type 1b.	§12.3.2.2 44
Design Example 19	
Vertical Irregularity Type 2	§12.3.2.2 48
Design Example 20	
Vertical Irregularity Type 3	§12.3.2.2 50
Design Example 21	
Vertical Irregularity Type 4	§12.3.2.2 52
Design Example 22	
Vertical Irregularity Type 5a/5b—Concrete Wall	§12.3.2.2 54

Design Example 23	
Vertical Irregularity Type 5a/5b—Steel Moment Frame	§12.3.2.2 56
Design Example 24	
Elements Supporting Discontinuous Walls or Frames	§12.3.3.3 60
Design Example 25	
Elements Supporting Discontinuous Walls or Frames—Light-Frame	§12.3.3.3 64
Design Example 26	
Redundancy Factor ρ	§12.3.4 67
Design Example 27	
Seismic Load Combinations: Strength Design	§2.3.6 72
Design Example 28	
Minimum Upward Force for Horizontal Cantilevers for SDC D through F	§12.4.4 75
Design Example 29	
Interaction Effects	§12.7.4 78
Design Example 30	
Seismic Base Shear	§12.8.1 80
Design Example 31	
Approximate Fundamental Period.	§12.8.2.1 83
Design Example 32	
Vertical Distribution of Seismic Forces.	§12.8.3 87
Design Example 33	
Horizontal Distribution of Forces	§12.8.4 91
Design Example 34	
Amplification of Accidental Torsion	§12.8.4.3 96
Design Example 35	
Story Drift	§12.8.6 100

Design Example 36	
<i>P</i> -delta Effects	§12.8.7 103
Design Example 37	
Scaling Design Values of Combined Response	§12.9.1.4 108
Design Example 38	
Diaphragm Design Forces, F_{px} : One-story Building	§12.10.1.1 112
Design Example 39	
Diaphragm Design Forces, F_{px} : Multistory Building	§12.10.1.1 116
Design Example 40	
Collector Elements—Flexible Diaphragm	§12.10.2 119
Design Example 41	
Out-of-plane Seismic Forces—One-story Structural Wall	§12.11 and §13.3 123
Design Example 42	
Out-of-plane Seismic Forces—Two-story Structural Wall	§12.11.1 and §12.11.2 127
Design Example 43	
Wall Anchorage to Flexible Diaphragms	§12.11.2.1 131
Design Example 44	
Story Drift Limit	§12.12.1 134
Design Example 45	
Structural Separation	§12.12.3 137
Design Example 46	
Deformation Compatibility for Seismic Design Categories D through F	§12.12.5 140
Design Example 47	
Foundation Design	§12.13 143
Design Example 48	
Foundation Ties	§12.13.7.2, §12.13.8.2, and IBC §1810.3.13 150

Design Example 49	
	Simplified Alternative Structural Design Criteria for Simple Bearing Wall or Building Frame Systems. §12.14 154
Design Example 50	
	Seismic Demands on Nonstructural Components on Rigid Supports. . . . §13.3 and §13.4 157
Design Example 51	
	Seismic Demands on Vibration-isolated Nonstructural Components §13.3 and §13.4 161
Design Example 52	
	Seismic Relative Displacements of Component Attachments. §13.3.2 164
Design Example 53	
	Exterior Nonstructural Wall Element §13.5 167
Design Example 54	
	Exterior Nonstructural Wall Element Connections §13.5 170
Design Example 55	
	Lateral Seismic Force on Nonbuilding Structure §15.4 177
Design Example 56	
	Flexible Nonbuilding Structure. §15.4 and §15.5 180
Design Example 57	
	Rigid Nonbuilding Structure §15.4.2 183
Design Example 58	
	Retaining Wall with Seismic Lateral Earth Pressure. §15.6.1 185
Design Example 59	
	Seismic Demands on Nonstructural Components with Building Accelerations §13.3.1.4 189
Design Example 60	
	Redundancy Factor ρ for Concrete Core Shear Wall Building. §12.3.4 194

Design Example 61

Combined Loading for SCBF Column Supporting Mezzanine §12.4.1200

Design Example 62

Shallow Foundation Design on Liquefiable Soil. §12.13.9209

Preface to the 2021 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. Please note that the information presented in this manual is intended to assist structural engineers in their designs; this information should not be treated as design requirements equal to building code requirements.

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 and building components for good seismic response.

Rafael Sabelli and Katy Briggs
Project Managers

Preface to Volume 1

Volume 1 of the 2021 *IBC SEAOC Structural/Seismic Design Manual* addresses the application and interpretation of the seismic provisions of the 2021 *International Building Code*. More specifically, Chapter 16 of the 2021 IBC requires compliance with the provisions of ASCE/SEI 7-16 “Minimum Design Loads and Associated Criteria for Buildings and Other Structures.” The design examples in this volume have been written to include the provisions of Supplements 1, 2, and 3 to ASCE 7. Supplement 1 has been adopted into the 2021 IBC. Supplements 2 and 3 have not been adopted into the 2021 IBC because they were published after the publication of the 2021 IBC.

ASCE 7 generally prescribes the loading and methodology to be used in the analysis of a structure or an element. In order to determine strength to resist the load demands from ASCE 7, the IBC adopts national material design standards (such as ACI, AISC, and NDS) to be used for the design of an element of a particular material. The Volume 1 examples focus on the application of the provisions of ASCE 7, while the examples in Volumes 2, 3, and 4 focus more on the application of the material design standards. The *Manual* is not intended to serve as a building code or to be an exhaustive catalogue of all valid approaches.

Volume 1 presents 62 examples covering most of the key code provisions within ASCE 7 Chapters 2, 11, 12, 13, and 15. Of the 62 examples, 58 have been updated and revised to reflect applicable changes to codes and standards since the 2018 edition of the *Manual*, to provide additional clarification and commentary for the more complex or nuanced provisions, and to incorporate input from the SEAOC Seismology Committee and other practicing engineers regarding the latest SEAOC interpretations and recommended practices. Example 62 has been added to Volume 1; this new example covers the design of shallow foundations on liquefiable soil in compliance with ASCE 7 Section 12.13.9.

Whenever possible, the authors have incorporated lessons learned from actual projects into the examples. Readers are welcome to submit other conditions or provisions not addressed in this edition for consideration in future editions.

Katy Briggs
Volume Manager

Acknowledgments

Volume 1 of the 2021 *IBC SEAOC Seismic Design Manual* was written and reviewed by a group of highly qualified structural engineers, chosen for their knowledge and experience with structural engineering practice and seismic design. The authors are:

Ryan A. Kersting, S.E., Associate Principal, Buehler—2012 & 2015 Volume Manager and Author/Reviewer of Various Previous Examples

Ryan has over 25 years of experience in the analysis, design, and review of structures spanning the spectrum of conventional systems and materials. He is also frequently involved in projects that incorporate innovative structural systems, nonlinear analysis, and performance-based designs. Ryan's industry involvement includes ASCE 7 Seismic Subcommittee member, chair of the Functional Recovery Task Committee for the 2026 NEHRP Seismic Provisions, former SEAOC Seismology Committee Chair, former NEHRP Advisory Committee member, former SEAOC President, and current SEAOC Policy Committee Co-Chair. www.buehlerengineering.com

Kevin S. Moore, S.E., Senior Principal, Simpson Gumpertz & Heger—Author/Reviewer of Various Examples

Kevin has over 28 years of experience in the analysis, design, and evaluation of building structures spanning the spectrum of conventional systems and materials. He is a recognized leader in the use of structural steel systems, nonlinear analysis, and performance-based designs. Kevin has been very active in SEAOC, including serving as Chair of the SEAOC Structural Standards Committee, Chair of the SEAOC Seismology Committee, and leading the production of the modern iteration of the *Blue Book* in 2009. www.sgh.com

Jihong Li, P.E., Project Engineer, Briggs Akalan Structural Engineering—Author of Example 62

Jihong has 7 years of structural engineering experience performing analysis, design, and rehabilitation of a variety of new and existing structures in California, including steel moment-frame and braced-frame buildings, concrete shear wall and moment-frame systems, and common wood-framed buildings. basedesigninc.com/

SEAOC would like to thank the following people for their work authoring and reviewing design examples in this book that were included in past editions and have been updated for the 2021 *International Building Code*: Michael Comaroto, Jennifer Gross, Melissa Vickery, April Buchberger, Timothy S. Lucido, Kevin Morton, Nicolas Rodrigues, and Ali Sumer. This version of the *Structural/Seismic Design Manual* would not be possible without their time and efforts.

Production and art was provided by the International Code Council. SEAOC would specifically like to thank and acknowledge Sandra Hyde, PE and Kathy Osmus for their assistance in the publication of the 2021 SSDM.

References

Standards

- American Concrete Institute. ACI 318: *Building Code Regulations for Reinforced Concrete*, Farmington Hills, Michigan, 2019.
- American Society of Civil Engineers. ASCE 7-16: *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*. Reston, Virginia, 2017.
- American Society of Civil Engineers. ASCE 7-16: *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, Supplement 1. Reston, Virginia, 2018.
- American Society of Civil Engineers. ASCE 7-16: *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, Supplement 2. Reston, Virginia, 2021.
- American Society of Civil Engineers. ASCE 7-16: *Minimum Design Loads and Associated Criteria for Buildings and Other Structures*, Supplement 3. Reston, Virginia, 2021.
- American Society of Civil Engineers. ASCE 41-17: *Seismic Evaluation and Retrofit of Existing Buildings*. Reston, Virginia, 2017.
- International Code Council. 2021 *International Building Code (IBC)*. Washington, D.C., 2021.

Other References

- Building Seismic Safety Council. *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures*: FEMA P-1082-1/2020 Edition. Federal Emergency Management Agency, Washington, DC, 2020.
- SEAOC Seismology Committee. *Recommended Lateral Force Requirements and Commentary (Blue Book)*, Structural Engineers Association of California (SEAOC), Seventh Edition, Sacramento, California, 1999.
- SEAOC Seismology Committee. *SEAOC Blue Book Seismic Design Recommendations*, Structural Engineers Association of California (SEAOC), First Printing, Sacramento, California, 2009.
- SEAOC Seismology Committee. *SEAOC Blue Book Seismic Design Recommendations*, Structural Engineers Association of California (SEAOC), Sacramento, California, 2019.

How to Use This Document

The examples in Volume 1 are written to illustrate the application of a specific section or provision within ASCE 7. Each example is a separate problem (or group of problems) for a unique condition chosen to best address the particular referenced code provision. Examples are stand-alone and do not rely on results from another example.

Each example contains a problem statement with a detailed listing of “given” information and a clear list of items to be determined in order to arrive at the solution. The problem is solved through a logical sequence of steps, and appropriate code references are provided in the right-hand margin of the page. Most examples include an introductory overview to the particular code provision and/or additional commentary following the solution. Readers are referred to applicable *SEAOC Blue Book* articles for additional information when appropriate.

For all examples, ASCE 7 is the default source document for the references, unless another document is specifically included in the reference. The following abbreviations are used within the references:

§—Section T—Table
F—Figure Eq—Equation