

2015 IBC[®]

SEAOC STRUCTURAL/SEISMIC DESIGN MANUAL

Volume 1: CODE APPLICATION EXAMPLES



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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

International Code Council

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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 2015 <i>IBC SEAOC Structural/Seismic Design Manual</i>	xi
Preface to Volume 1	xiii
Acknowledgements	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 §11.4.5	3
Design Example 3	
Site-Specific Ground Motion Procedures §11.4.7	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	§12.2.5.128
Design Example 11	
Introduction to Horizontal Irregularities	§12.3.2.131
Design Example 12	
Horizontal Irregularity Type 1a and Type 1b	§12.3.2.132
Design Example 13	
Horizontal Irregularity Type 2	§12.3.2.136
Design Example 14	
Horizontal Irregularity Type 3	§12.3.2.138
Design Example 15	
Horizontal Irregularity Type 4	§12.3.2.140
Design Example 16	
Horizontal Irregularity Type 5	§12.3.2.142
Design Example 17	
Introduction to Vertical Irregularities	§12.3.2.243
Design Example 18	
Vertical Irregularity Type 1a and Type 1b	§12.3.2.244
Design Example 19	
Vertical Irregularity Type 2	§12.3.2.248
Design Example 20	
Vertical Irregularity Type 3	§12.3.2.250
Design Example 21	
Vertical Irregularity Type 4	§12.3.2.252
Design Example 22	
Vertical Irregularity Type 5a/5b – Concrete Wall	§12.3.2.254

Design Example 23	
Vertical Irregularity Type 5a/5b – Steel Moment Frame	§12.3.2.256
Design Example 24	
Elements Supporting Discontinuous Walls or Frames	§12.3.3.360
Design Example 25	
Elements Supporting Discontinuous Walls or Frames – Light-Frame	§12.3.3.364
Design Example 26	
Redundancy Factor ρ	§12.3.467
Design Example 27	
Seismic Load Combinations: Strength Design	§12.4.2.372
Design Example 28	
Minimum Upward Force for Horizontal Cantilevers for SDC D through F . . .	§12.4.475
Design Example 29	
Interaction Effects	§12.7.478
Design Example 30	
Seismic Base Shear	§12.8.180
Design Example 31	
Approximate Fundamental Period	§12.8.2.183
Design Example 32	
Vertical Distribution of Seismic Forces	§12.8.387
Design Example 33	
Horizontal Distribution of Forces	§12.8.491
Design Example 34	
Amplification of Accidental Torsion	§12.8.4.396
Design Example 35	
Story Drift	§12.8.6100

Design Example 36	
<i>P</i> -delta Effects	§12.8.7 103
Design Example 37	
Scaling Design Values of Combined Response	§12.9.4 108
Design Example 38	
Diaphragm Design Forces, F_{px} : One-story Building	§12.10.1.1 112
Design Example 39	
Diaphragm Design Forces, F_{px} : Multi-story 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	§12.13.5.2, §12.13.6.2, 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

Preface to the 2015 *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 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

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 1

Volume 1 of the 2015 *IBC SEAOC Structural/Seismic Design Manual* addresses the application and interpretation of the seismic provisions of the 2015 *International Building Code*. More specifically, Chapter 16 of the 2015 IBC requires compliance with the provisions of ASCE/SEI 7-10 "Minimum Design Loads for Buildings and Other Structures" with Supplement #1, except for Chapter 14 of ASCE 7.

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 to the load demands from ASCE 7, the IBC adopts national material design standards (such as ACI, AISC, MSJC, 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 58 examples covering most of the key code provisions within ASCE 7 Chapters 11, 12, 13, and 15. These examples have been updated and revised to reflect applicable changes to codes and standards since the 2012 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.

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.

Ryan A. Kersting
Volume Manager

Acknowledgements

Volume 1 of the 2015 *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:

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Ryan has over 19 years of experience in the analysis, design, and review of building 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 has been very active in SEAOC, including being 2014-2015 SEAOC President, previously serving as Chair of the SEAOC Seismology Committee, co-authoring / reviewing Blue Book articles, and serving as Chair of the 2007 SEAOC Convention. www.bbse.com

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The additions and revisions incorporated in the 2015 edition of Volume 1 are the result of thoughtful review from and close collaboration with the SEAOC Seismology Committee. The review, input, and assistance from the following individuals is gratefully acknowledged and appreciated.

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References

Standards

American Concrete Institute. *ACI 318: Building Code Regulations for Reinforced Concrete*, Farmington Hills, Michigan, 2014.

American Society of Civil Engineers. *ASCE 7-10: Minimum Design Loads for Buildings and Other Structures*. Third Printing with Supplement #1 and Expanded Seismic Commentary. Reston, Virginia, 2013.

American Society of Civil Engineers. *ASCE 41-13: Seismic Evaluation and Retrofit of Existing Buildings*. Reston, Virginia, 2014.

International Code Council. *International Building Code (IBC)*. Washington, D.C., 2015.

Other References

Building Seismic Safety Council. *NEHRP Recommended Seismic Provisions for New Buildings and Other Structures: FEMA P-1050-1/2015 Edition*. Federal Emergency Management Agency, Washington, DC, 2015.

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.
www.seaoc.org/bluebook

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