WIND DESIGN MANUAL

BASED ON THE 2018 IBC® AND ASCE/SEI 7-16

Examples for Wind Forces on Buildings and Solar Photovoltaic Systems

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Publisher

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Inquiries and Suggestions for Improvement

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Preface to the *Wind Design Manual*

The 2016 edition of ASCE 7 (Minimum Design Loads and Associated Criteria for Buildings and Other Structures) provisions includes refinements to gravity loading, wind, and seismic provisions and an introduction of specific provisions related to solar PV systems. A dedicated design manual related to wind will be of great assistance to the structural engineering profession. The SEAOC Wind Committee appointed a Wind Design Manual (WDM) subcommittee to explore the development of a wind design manual. The recommendation was made and approved by the SEAOC Board to develop this *Wind Design Manual* based on provisions in the 2018 IBC and ASCE 7-16.

This *Design Manual* provides examples on wind force design to illustrate practical requirements of provisions in ASCE 7-16. The examples illustrate code-compliant designs engineered to achieve good performance under wind loading. The *Design Manual* complements SEAOC white papers on solar PV systems PV-1, PV-2, and PV-3 related to seismic, wind, and gravity loading. As such, the *Design Manual* covers seismic and gravity loading in addition to the primary subject on wind engineering. Authors and reviewers practice in different parts of the United States. The *Design Manual* provides succinct interpretation of ASCE 7 provisions by each author individually. Several of the examples extend to multiple sources to better illustrate requirements in ASCE 7. In one example, specifically Design Example 5 on storm shelters, ICC-500-14 together with ASCE 7-10 have been used for illustration.

The *Design Manual* is intended for use by practicing structural engineers and trained designers, building department engineers, other plan review agencies, academia, and structural engineering students. Although the approach in these examples may be considered as guidance for structural design, the methods used do not exclude other approaches or solutions. Although the examples may demonstrate more than one method of design or analysis, no intent is made to favor one method over another. This *Design Manual* should not be construed as the SEAOC solution or the consensus opinion of the WDM Subcommittee or the SEAOC Wind Committee.

The *Design Manual* includes example problems for a balance of geographic areas and is intended for use nationwide. Example problems include a wide range of topics.

General topics	4 examples
Special topics	2 examples
Buildings	3 examples
Solar PV systems	7 examples

The *Design Manual* is intended to complement, where applicable, other related publications such as the ASCE *Guide to the Wind Load Provisions of ASCE 7*.

James S. Lai, SE, F. SEAOC, F. ASCE
Past Chair, SEAOC Wind Committee
Chair, WDM Subcommittee

Acknowledgments

The *Wind Design Manual* was managed by the WDM Subcommittee under the oversight of the SEAOC Wind Committee. Authors of example problems include highly qualified engineers, chosen for their knowledge and experience in structural engineering and wind design practice. The WDM Subcommittee includes

Emily Guglielmo, PE, SE, earned her Bachelor's degree in Civil Engineering from UCLA and her Master's degree in Structural Engineering from UC Berkeley. Emily is currently a Principal with Martin/Martin, Inc., managing their San Francisco Bay Area office. She has lectured on wind provisions across the nation. Emily is the secretary of the NCSEA Wind Engineering Committee and serves on the ASCE 7 Seismic as well as Wind subcommittee. A licensed structural engineer, Emily has received a number of awards, including SEI Fellow and the Susan M. Frey NCSEA Educator Award, for effective instruction for practicing structural engineers.

Stephen Kerr, SE, is a licensed structural engineer with over 22 years of experience in designing and investigating various types of structures. Currently he is a Senior Associate Engineer with the San Diego-based firm of Josephson-Werdowatz and Associates, Inc. Steve has a Bachelor's of Science degree in Architectural Engineering from Cal Poly San Luis Obispo. He has been involved with the SEAOC convention planning for over 10 years, serving as the 2009 and 2017 SEAOC Convention Chair, and has been involved in the Wind and General Engineering (Code) committees, both with SEAOC and NCSEA, and has just completed a term as a director for SEAOSD.

James S. Lai, SE, F. SEAOC, F.ACI, F.ASCE (Chair), is a retired structural engineer having completed over 45 years of consulting structural engineering practice. Throughout his career, he has been active in code development, participating in various technical committees as a member and chair of SEAOC General Engineering, Seismology, and Wind committees. He has served on the Board of Directors of the Structural Engineers Association of California, the Applied Technology Council, and the Structural Engineers Association of Southern California. He has served as a member of the ASCE 7 Main and Seismic committees as well as the Wind Subcommittee.

Kenneth A. Luttrell, SE, Co-Owner and Vice President of CYS Structural Engineering, Inc., has practiced structural engineering since 1964. Ken has been very active in the Structural Engineers Association of Central California (SEAOCC) and SEAOC, serving as President of both organizations. Ken has served as a member and chair of the SEAOC Wind Committee and initiated the SEAOC Ad Hoc Wind Code Committee that developed the Simplified Wind Design Procedure in the 2015 edition of the *International Building Code*. He has also been active as member and chair on the SEAOC Seismology Committee since 1979 and has served continuously for over 25 years on the SEAOC Existing Buildings Committee.

Norman Scheel, SE, F. SEAOC, F. ASCE is a practicing structural engineer with 45 years of experience. He has served as SEAOC State President, Code Committee Chair, Wind Committee member, and NCSEA Delegate. At NCSEA, he has served as General Engineering Committee Chair and has received the NCSEA Distinguished Service Award. He has been actively involved in NCSEA for 25 years. Norm has been actively representing engineers in the code development process and has served on the *International Building Code* Structural Committee.

The distinguished authors of the *Wind Design Manual* include

Owen Bower, SE, is an Associate Principal and Partner at Lund Opsahl in Seattle, Washington. Licensed as a structural engineer in California and Washington, Owen has been designing structures in the Pacific Northwest and nationwide since 2007. Active in the Structural Engineers Association of Washington (SEAW), he serves as President of the Southwest Chapter and sits on the SEAW Wind Engineering Committee.

Jennifer Carey, PE, is a structural engineer with over six years of experience in the solar industry. She graduated from the University of Illinois at Urbana-Champaign with her Bachelor of Science degree in Civil Engineering. In addition to her work on the *Wind Design Manual*, Jennifer is a co-author of the example problems in the report SEAOC PV2-2017, Wind Design for Solar Arrays.

R. Scott Douglas PE, SE, Owner, Douglas Engineering, is a licensed Structural Engineer in the state of Washington. Scott has over 45 years of experience as a structural engineer on a wide variety of projects in states along the Pacific coast and Alaska. He has participated in earthquake damage assessment teams after the seismic events in Haiti and Nepal. Scott is past-president of the Seattle Chapter of SEAW and an active member on the ANSI Specifications and Standards AISI Committees. He is currently chair and has participated in SEAW's Wind Engineering Committee over the past ten years, interrupted by three years serving with the US Army Corps of Engineers in Afghanistan.

Emily Guglielmo, PE, SE, earned her Bachelor's degree in Civil Engineering from UCLA, and her Master's degree in Structural Engineering from UC Berkeley. Emily is currently a Principal with Martin/Martin, Inc., managing their San Francisco Bay Area office. She has lectured on wind provisions across the nation. Emily is the secretary of the NCSEA Wind Engineering Committee and serves on the ASCE 7 seismic as well as wind subcommittee. A licensed structural engineer, Emily has received a number of awards, including SEI Fellow and the Susan M. Frey NCSEA Educator Award, for effective instruction for practicing structural engineers.

John T. Hutton, PE, SE, Principal, Uzun+Case, LLC, Georgia, has over 35 years of experience in the design of commercial, institutional, and industrial structures. He is a past-president of the Structural Engineers Association of Georgia and is a member of the Georgia Department of Community Affairs' State Codes Advisory Committee. John serves on NCSEA's General Engineering and Wind Code Advisory Committees and is a committee member of the ICC-500 Standard for the Design and Construction of Storm Shelters.

Thomas J. Hadzor, PE, SE, Project Manager, LBYD Engineers, Birmingham, Alabama, has 7 years of structural engineering experience in the analysis, design, and review of building structures in the educational, municipal, commercial, industrial, federal, and healthcare sectors in the southeast United States. He has been involved with multiple projects dealing with the design of storm shelters in K-12 and higher education projects. Tom has a BSE from Duke University in Durham, NC, and an MSE from Auburn University in Auburn, AL, where his thesis focused on non-destructive testing of prestressed concrete beams.

Anurag Jain, PhD, PE, Senior Principal, Thornton Tomasetti, is known for his knowledge of wind engineering, Anurag has performed wind analyses of many structures, including high-rise buildings, airports, hotels, medical facilities, and stadiums. Anurag has been an active member of the SEAOC Wind Committee and also a member of the ASCE 7 Wind committee.

Russell Larsen, PE, SE, is a Senior Associate with Magnusson Klemencic Associates, Seattle, Washington. Russell has worked on office and housing projects throughout the U.S., often in regions with high seismicity. He leads both MKA's Wind and Analysis Specialist Teams and is also a key member of the firm's BIM, Concrete, and Steel Specialist Teams. Russell is a Task Force Member of the Applied Technology Council (ATC) 58 project, where he is part of a committee developing guidelines for seismic performance assessment of buildings and performance-based seismic design.

Brian K. Pietras, PE, Project Structural Engineer, Rickborn & Associates, LLC. Brian has over 17 years of experience in the analysis, design, investigation, and repair of building structures in high-risk areas for wind, flood, and seismic-related events. He is a past president of the Structural Engineers Association of South Carolina (SEA of SC) and has also served as Chair of the SEA of SC Code Advisory Committee.

Timothy W. Rickborn, MS, PE, SECB, Senior Structural Engineer, Rickborn & Associates, LLC. Tim has over 25 years of experience in the analysis, design, retrofit, and review of low-rise building structures of wood, steel, concrete, and masonry construction in high wind areas. He has been involved in the investigation and repair of numerous building structures following tropical storms and hurricanes along the South Carolina coast. He is a founding member of SEA of South Carolina and has served on the Building Code Advisory Committee for SEA of SC.

Donald R. Scott, SE, F SEI, F ASCE, is the Vice President and Director of Engineering at PCS Structural Solutions and has been a Principal of the firm since 1986. He has led many of the firm's educational, commercial, institutional, and private projects for new and renovated construction. Don is proficient in high-end structural analysis. He has been a member of the ASCE 7 Wind Load Committee since 1996, shaping future *International Building Code* provisions for wind design and currently serves as Chairman. He is also a member of the ASCE 7 General Provisions committee, a member of the ASCE 7 Steering Committee, Chairman of the NCSEA Wind Committee, and a former Chair of the SEAW Wind Load Committee.

Karl Telleen, SE, is a Senior Engineer with Maffei Structural Engineering in San Francisco. He has 13 years of professional experience, including a wide range of project types such as design of new steel and concrete structures, seismic evaluation and retrofit of existing buildings, seismic peer review of high-rise buildings, and design and analysis of solar arrays subjected to wind and seismic forces. He contributed to design guidelines and analysis approaches for solar arrays, including the SEAOC Solar Photovoltaic Systems Committee documents SEAOC PV1 (seismic design) and SEAOC PV2 (wind design). He has worked with manufacturers on product development of solar support structures, and he has performed technical investigations into wind-related failures. Karl served on the Board of Directors of SEAONC from 2015–2017 and as Treasurer in 2016–2017.

Shaun Walters, SE, Associate, KPFF Consulting Engineers, received a BSCE from San Diego State University and a MS in Structural Engineering from the University of California, San Diego. He is a registered Structural Engineer in the State of California and has been involved in the design of over 300 solar projects across 32 states and 4 countries. In addition to overseeing many solar projects, Mr. Walters has received awards for his work on the 16-story Sempra Energy Headquarters office building in San Diego and for his work on Hotel Churchill, the first historic building retrofit in San Diego using Fluid Viscous Dampers. His specialties include solar structures, concrete construction, and performance-based seismic design.

John Wolfe, SE, is a founding partner of Mar Structural Design. In addition to leading numerous building design projects, John has a special interest in the structural support of solar arrays. He was the lead structural consultant for California's *Solar Permitting Guidebook*, and is the principal author of the *Structural Criteria for Residential Rooftop Solar Energy Installations*, the Structural Technical Appendix for Residential Rooftop Solar Installations, and the *Structural Commentary for the National Simplified Residential Roof Photovoltaic Array Permit Guidelines*, which have become key references for the engineering community and solar industry. He is a structural consultant to several solar support-component manufacturers, helping those firms to develop and test innovative products and navigate the complex world of codes and standards.

Additionally, a number of SEAOC members and other structural engineers helped reviewed 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. In addition to members of WDM Subcommittee, the reviewers include the following:

Annika Chase, Christopher Kamp, Scott Douglas, SK Ghosh, Kari Klaboe, Kevin Moore, Scott Mulligan, and Mason Walters.

A special thanks to Sandra Hyde of the International Code Council for her painstaking review of general format and editing, and to SK Ghosh and his colleagues for their technical review of the manuscript.

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How to Use This Document

Equation numbers in the right-hand margin refer to one of the standards (e.g. ASCE 7, IBC or NDS). 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.

The following abbreviations are used within the references:

§ – Section

T – Table

F – Figure

Eq – Equation

Symbols

Refer to ASCE 7 Standards and References Cited for symbols unless otherwise described under each example.