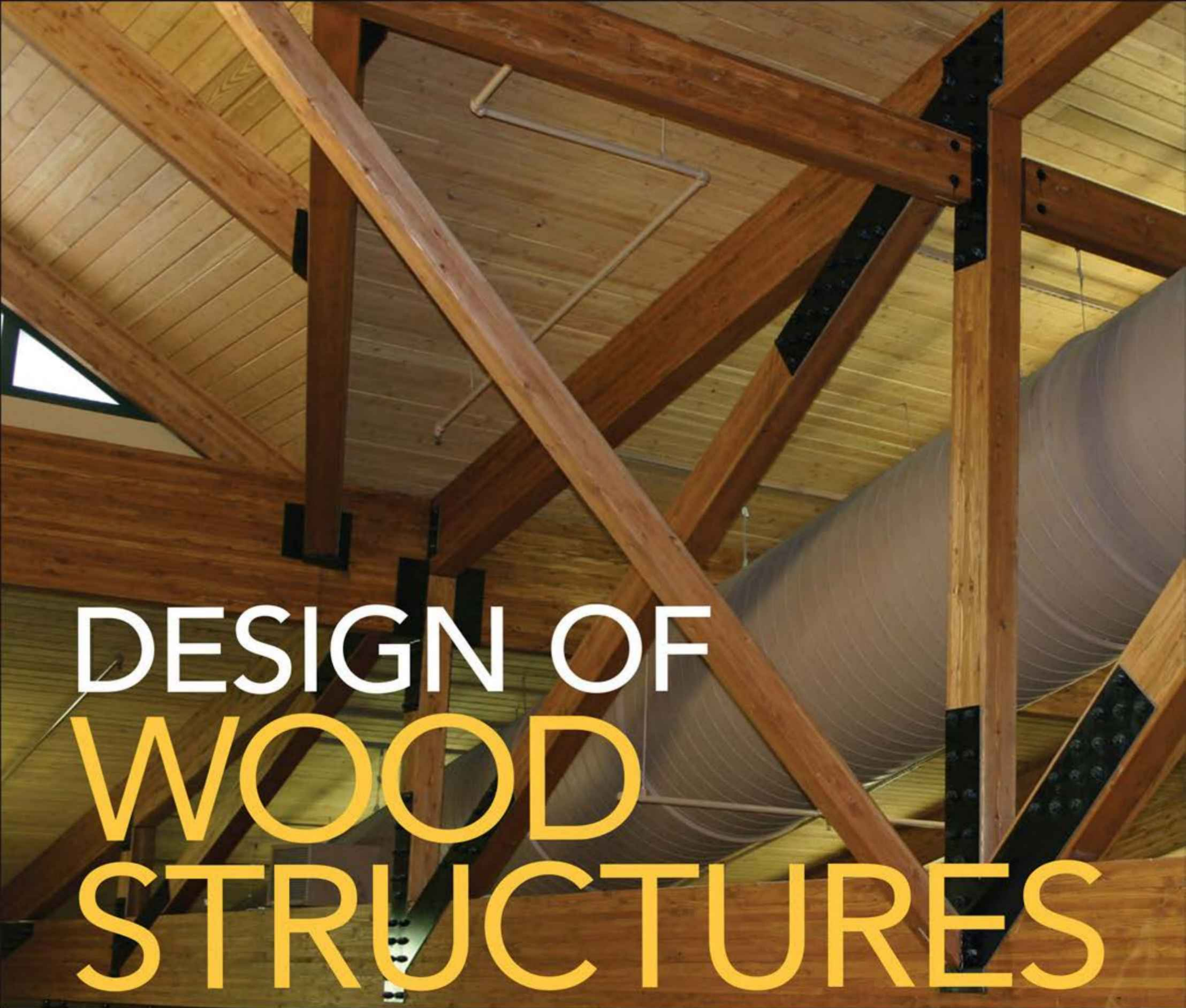

DESIGN OF WOOD STRUCTURES

ASD/LRFD

Eighth Edition

Donald E. Breyer
Kelly Cobeen
Zeno Martin

Mc Graw Hill
ICC INTERNATIONAL CODE COUNCIL

Design of Wood Structures—ASD/LRFD

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Design of Wood Structures—ASD/LRFD

Donald E. Breyer, P.E.

Professor Emeritus
Department of Engineering Technology
California State Polytechnic University
Pomona, California

Kelly E. Cobeen, S.E.

Associate Principal
Wiss, Janney, Elstner Associates, Inc.
Emeryville, California

Zeno Martin, S.E.

Associate Principal
Wiss, Janney, Elstner Associates, Inc.
Seattle, Washington

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To our families:
Matthew, Kerry, Daniel, and Sarah
Mom, Dad, and Matthew
Patti, Kris, and Pam

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Preface

The purpose of this book is to introduce engineers, technologists, and architects to the design of wood structures. It is intended to serve either as a text for a course in timber design or as a reference for systematic self-study of the subject.

The book will lead the reader through the complete design of a wood structure (except for the foundation). The sequence of the material follows the same general order that it would in actual design:

1. Vertical design loads and lateral forces.
2. Design for vertical loads (beams and columns).
3. Design for lateral forces (horizontal diaphragms and shearwalls).
4. Connection design (including the overall tying together of the vertical- and lateral-force-resisting systems).

The need for such an overall approach to the subject became clear from experience gained in teaching timber design at the undergraduate and graduate levels.

This text pulls together the design of the various elements into a single reference. A large number of practical design examples are provided throughout the text. Because of their widespread usage, buildings naturally form the basis of the majority of these examples. However, the principles of member design and diaphragm design have application to other structures (such as concrete formwork and falsework).

This book relies on practical, current industry literature as the basis for structural design. This includes publications of the American Wood Council (AWC), the International Code Council (ICC), the American Society of Civil Engineers (ASCE), APA—The Engineered Wood Association, and the American Institute of Timber Construction (AITC).

In the writing of this text, an effort has been made to conform to the spirit and intent of the reference documents. The interpretations are those of the authors and are intended to reflect current structural design practice. The material presented is suggested as a guide only, and final design responsibility lies with the structural engineer.

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The eighth edition of this book updates it to be consistent with the 2018 International Building Code and its relevant reference standards that include but are not limited to:

1. The 2018 *National Design Specification for Wood Construction* (NDS).
2. The 2015 *Special Design Provisions for Wind and Seismic* (SDPWS)
3. The 2016 *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE 7-16).

Questions or comments about the text or examples may be addressed to any of the authors. Direct any correspondence to:

Prof. Emeritus Donald E. Breyer
Department of Engineering Technology
California State Polytechnic University
3801 West Temple Avenue
Pomona, CA 91768

Ms. Kelly E. Cobeen
Wiss, Janney, Elstner Associates, Inc.
2000 Powell St., Suite 1650
Emeryville, CA 94608

Mr. Zeno Martin
Wiss, Janney, Elstner Associates, Inc.
960 S Harney St.
Seattle, Washington 98108

Acknowledgment and appreciation for help in writing this text are given to our numerous colleagues in the wood design profession. Suggestions and information were obtained from many engineers and suppliers, and their help is gratefully recognized.

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Nomenclature

Organizations

AITC
American Institute of Timber Construction
P.O. Box 23145
Portland, OR 97281
www.aitc-glulam.org

ALSC
American Lumber Standard Committee, Inc.
P.O. Box 210
Germantown, MD 20875-0210
www.alsc.org
APA—The Engineered Wood Association
P.O. Box 11700
Tacoma, WA 98411-0700
www.apawood.org

ASCE
American Society of Civil Engineers
1801 Alexander Bell Drive
Reston, VA 20191
www.asce.org

ATC
Applied Technology Council
201 Redwood Shores Parkway, Suite 240
Redwood City, CA 94065
www.atcouncil.org

AWC
American Wood Council
222 Catoctin Circle, SE
Leesburg, VA 20175
www.awc.org

AWPA
American Wood Protection Association
P.O. Box 361784
Birmingham, AL 35236
www.awpa.com

BSSC
Building Seismic Safety Council
National Institute of Building Sciences
1090 Vermont Avenue NW, Suite 700
Washington, DC 20005
www.bssconline.org

CANPLY
Canadian Plywood Association
735 West 15 Street
North Vancouver, British Columbia,
Canada V7M 1T2
www.canply.org

CPA
Composite Panel Association
19465 Deerfield Ave., Suite 306
Leesburg, VA 20176
www.compositepanel.org

CWC
Canadian Wood Council
99 Bank Street, Suite 400
Ottawa, Ontario, Canada K1P 6B9
www.cwc.ca

FPL
U.S. Forest Products Laboratory
USDA Forest Service
One Gifford Pinchot Drive
Madison, WI 53726-2398
www.fpl.fs.fed.us

ICC
International Code Council
500 New Jersey Avenue NW
Washington, DC 20001
www.iccsafe.org

ISANTA
International Staple, Nail and Tool Association
512 West Burlington Avenue, Suite 203
La Grange, IL 60525-2245
www.isanta.org

MSRLPC
MSR Lumber Producers Council
6300 Enterprise Lane
Madison, WI 53719
www.msrlumber.org

NELMA
Northeastern Lumber Manufacturers Association
272 Tuttle Road
P.O. Box 87A
Cumberland Center, ME 04021
www.nelma.org

NFBA
National Frame Building Association
8735 W. Higgins Rd., Suite 300
Chicago, IL 60631
www.nfba.org

NHLA
National Hardwood Lumber Association
P.O. Box 34518
Memphis, TN 38184-0518
www.nhla.com

NLGA
National Lumber Grades Authority
13401 108th Ave., Suite 105
Surrey, British Columbia, Canada V3T 5T3
www.nlga.org

NSLB
Northern Softwood Lumber Bureau
272 Tuttle Road
P.O. Box 87A
Cumberland Center, ME 04021
www.nelma.org

PLIB
Pacific Lumber Inspection Bureau
1010 S. 336th St., Suite 300
Federal Way, WA 98003-6214
www.plib.org

SBCA
Structural Building Components Association
6300 Enterprise Lane
Madison, WI 53719
www.sbcindustry.com

SEAOC
Structural Engineers Association of California
1400 K Street, Suite 212
Sacramento, CA 95814
www.seaoc.org

SFPA
Southern Forest Products Association
6660 Riverside Dr., Suite 212
Metairie, LA 70003
www.sfpa.org
www.southernpine.com

SLMA
Southeastern Lumber Manufacturers Association
200 Greencastle Road
Tyrone, GA 30290
www.slma.org

SPIB
Southern Pine Inspection Bureau, Inc.
4709 Scenic Highway
Pensacola, FL 32504-9094
www.spib.org

TPI
Truss Plate Institute
218 N. Lee Street, Suite 312
Alexandria, VA 22314
www.tpinst.org

WCLIB
West Coast Lumber Inspection Bureau
P.O. Box 23145
Portland, OR 97281-3145
www.wclib.org

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WIJMA
Wood I-Joist Manufacturing Association
200 East Mallard Drive
Boise, ID 83706
www.i-joist.org

WRCLA
Western Red Cedar Lumber Association
1501-700 West Pender Street
Vancouver, British Columbia, Canada
V6C 1G8
www.realcedar.com

WWPA
Western Wood Products Association
522 Southwest Fifth Avenue, Suite 500
Portland, OR 97204-2122
www.wwpa.org

Publications

ASCE 7: American Society of Civil Engineers (ASCE). 2016. *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (ASCE/SEI 7-16), ASCE, Reston, VA.

ASD/LRFD Manual: American Wood Council (AWC). 2018. *ASD/LRFD Manual for Engineered Wood Construction*, 2018 ed., AWC, Leesburg, VA.

IBC: International Code Council (ICC). 2018. *International Building Code* (IBC), 2018 ed., ICC, Washington, DC.

NDS: American Wood Council (AWC). 2018. *National Design Specification for Wood Construction* (NDS), ANSI/AWC NDS-2018, AWC, Leesburg, VA.

SDPWS: American Wood Council (AWC). 2015. *Special Design Provisions for Wind and Seismic* (SDPWS), AWC, Leesburg, VA.

TCM: American Institute of Timber Construction (AITC). 2012. *Timber Construction Manual*, 6th ed., John Wiley & Sons Inc., Hoboken, NJ.

Additional publications are given at the end of each chapter.

Units

ft	foot, feet
ft^2	square foot, square feet
in.	inch, inches
$in.^2$	square inch, square inches
k	1000 lb (kip, kilopound)
ksi	kips per square inch ($k/in.^2$)
mph	miles per hour
pcf	pounds per cubic foot (lb/ft^3)
plf	pounds per lineal foot (lb/ft)
psf	pounds per square foot (lb/ft^2)
psi	pounds per square inch ($lb/in.^2$)
sec	second

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CHAPTER 1

Wood Buildings and Design Criteria

1.1 Introduction

There are probably more buildings constructed with wood than any other structural material. Many of these buildings are single-family residences, but many larger apartment buildings as well as commercial and industrial buildings also use wood framing. Wood is currently moving into mid-rise construction, with buildings of four to six stories being increasingly common. In addition, while the majority of wood-frame construction has in the past been light-frame systems, cross-laminated timber (CLT) systems are now emerging.

The widespread use of wood in the construction of buildings has both an economic and an aesthetic bases. The ability to construct wood buildings with a minimal amount of specialized equipment has kept the cost of wood-frame buildings competitive with other types of construction. On the other hand, where architectural considerations are important, the beauty and the warmth of exposed wood are difficult to match with other materials.

Wood-frame construction has evolved from a method used in primitive shelters into a major field of structural design. However, in comparison with the time devoted to steel and reinforced concrete design, timber design is not given sufficient attention in most colleges and universities.

This book is designed to introduce the subject of timber design as applied to wood light-frame building construction. Although the discussion centers on building design, the concepts also apply to the design of other types of wood-frame structures. Final responsibility for the design of a building rests with the structural engineer. However, this book is written to introduce the subject to a broad audience. This includes engineers, engineering technologists, architects, and others concerned with building design. A background in statics and strength of materials is required to adequately follow the text. Most wood-frame buildings are highly redundant structures, but for design simplicity they are assumed to be made up of statically determinate members. The ability to analyze simple trusses, beams, and frames is also necessary.

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1.2 Types of Buildings

There are various types of framing systems that can be used in wood buildings. The most common type of wood-frame construction uses a system of horizontal diaphragms and vertical shearwalls to resist lateral forces, and this book deals specifically with the design of this basic type of building. At one time building codes classified a shearwall building as a *box system*, which was a good physical description of the way in which the structure resists lateral forces. However, building codes have dropped this terminology, and most wood-frame shearwall buildings are now classified as *bearing wall systems*. The distinction between the shearwall and diaphragm system and other systems is explained in Chap. 3.

Other types of wood building systems, such as glulam arches, and post-frame (or pole) buildings, are beyond the specific scope of this book. It is felt that the designer should first have a firm understanding of the behavior of basic shearwall buildings and the design procedures that are applied to them. With a background of this nature, the designer can acquire from currently available sources (e.g., Refs. 1.2, 1.8, and 1.12) the design techniques for other systems.

The basic bearing wall system can be constructed entirely from wood components. See Figure 1.1. Here the *roof, floors, and walls* use wood framing. The calculations necessary to design these structural elements are illustrated throughout the text in comprehensive examples.

In addition to buildings that use only wood components, other common types of construction make use of wood components in combination with some other type or types of structural material. Perhaps the most common mix of structural materials is in buildings that use *wood roof and floor systems* and *concrete tilt-up* or *masonry (concrete block or brick) shearwalls*. See Figure 1.2. This type of construction is common, especially in one-story commercial and industrial buildings. This construction is economical for small buildings, but its economy improves as the size of the building increases. Trained crews can erect large areas of *panelized* roof systems in short periods of time. See Figure 1.3.

Design procedures for the wood components used in buildings with concrete or masonry walls are also illustrated throughout this book. The connections between wood and concrete or masonry elements are particularly important and are treated in considerable detail.

This book covers the *complete* design of wood-frame *box*-type buildings from the roof level down to the foundation. In a complete building design, *vertical loads and lateral forces* must be considered, and the design procedures for both are covered in detail.

Wind and seismic (earthquake) are the two lateral forces that are normally taken into account in the design of a building. In recent years, design for lateral forces has become a significant portion of the design effort. The reason for this is an increased awareness of the effects of lateral forces. In addition, the building codes have substantially revised the design requirements for both wind and seismic forces. These changes are the result of extensive research in wind engineering and earthquake-resistant design.

1.3 Required and Recommended References

The *eighth* edition of this book was primarily prompted by the publication of the 2018 edition of the *National Design Specification for Wood Construction* (NDS) (Ref. 1.4) as well as by *Minimum Design Loads and associated criteria for Buildings and Other Structures*

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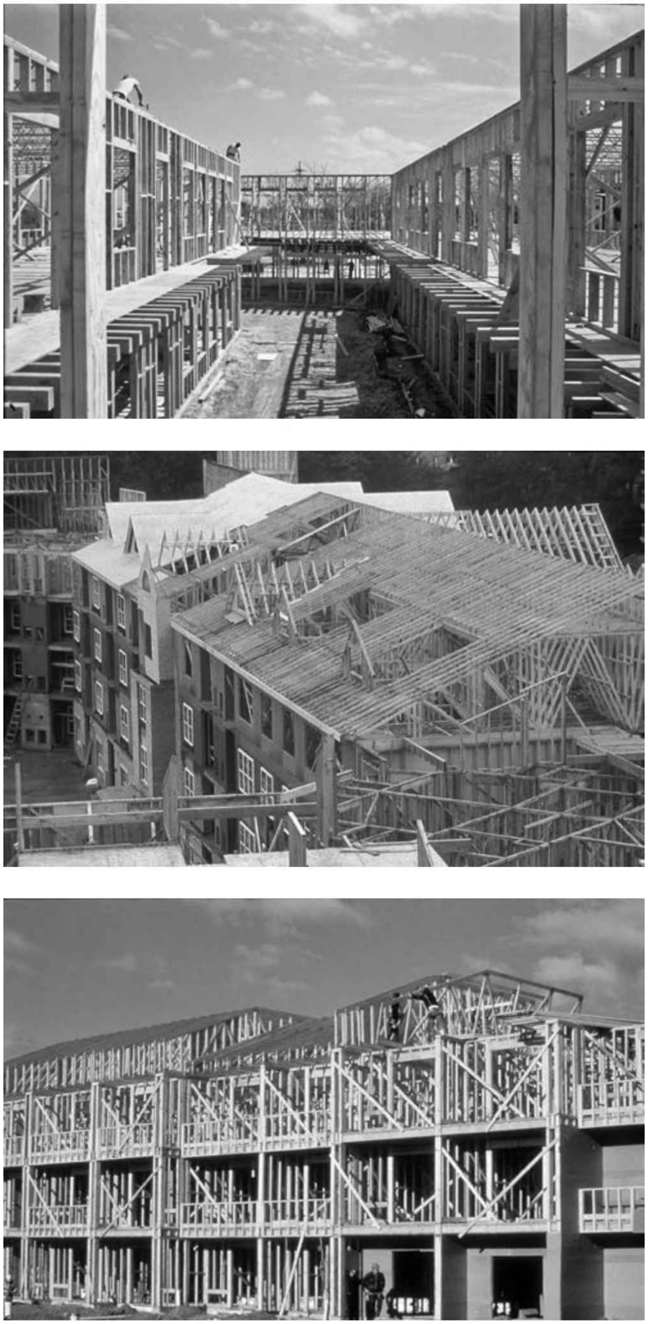

Figure 1.1 Multistory wood-frame buildings. (*Photo courtesy of Southern Pine Council*.)

Figure 1.2a *Foreground:* Office portion of wood-frame construction. *Background:* Warehouse with concrete tilt-up walls and wood roof system. (*Photo courtesy of Mike Hausmann.*)

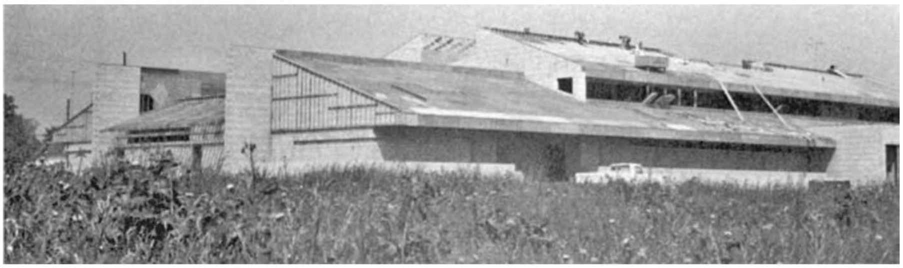

Figure 1.2b Building with reinforced-masonry block walls and a wood roof system with plywood sheathing. (*Photo courtesy of Mark Williams.*)

(ASCE 7-16) (Ref. 1.3) and the 2018 *International Building Code* (IBC) (Ref. 1.9). The 2018 NDS, like previous editions, is in a *dual format*, including both *allowable stress design* (ASD) and *load and resistance factor design* (LRFD) provisions. Editions of the NDS prior to the 2012 edition had been in ASD only.

The NDS is published by the American Wood Council (AWC) and represents the latest structural design recommendations by the wood industry. In addition to basic design provisions for both ASD and LRFD, the 2018 NDS contains chapters specific to

Figure 1.3 Interior of a building with a panelized roof system. (*Photo courtesy of Southern Pine Council.*)

sawn lumber, glued-laminated timber, poles and piles, wood I-joists, structural composite lumber, wood structural panels, cross-laminated timber, mechanical connections, dowel-type fasteners, split ring and shear plate connectors, timber rivets, shearwalls and diaphragms, special loading conditions, and fire design.

The NDS is actually the formal design section of what is a series of interrelated design documents. There are two primary companion documents that support and complete the dual-format *National Design Specification for Wood Construction*. The first companion document is the *NDS Supplement: Design Values for Wood Construction*, which is often referred to simply as the *Supplement* or the *NDS Supplement* as this was the original and for many years the only supplement to the NDS. The NDS Supplement contains all the reference design values for various species groupings of structural lumber and glued-laminated timber. The NDS Supplement is updated at the same time as the NDS, so the current Supplement edition is 2018.

The second companion design document to the NDS is the *Special Design Provisions for Wind and Seismic* (Ref. 1.6), also called the *Wind and Seismic Supplement* or *SDPWS*. The Wind and Seismic Supplement is the newest supplement and is maintained as a separate document due to the unique requirements related to wind- and seismic-resistant design. Included in the SDPWS are reference design values for shearwalls and diaphragms, which comprise the primary lateral-force-resisting system (LFRS) in most wood structures. SDPWS is updated on a different cycle than the NDS, and the current edition is 2015. A new edition will be published in 2021.

The NDS along with both the NDS Supplement and the SDPWS comprises the core of what is needed to design engineered wood structures. Because of the subject matter, the reader must have a copy of the NDS to properly follow this book. Additionally, the numerous tables of member properties, design values, fastener capacities, and unit shears for shearwalls and diaphragms are lengthy. Rather than reproducing these tables in this book, the reader is better served to have copies of both supplements as well. Having a copy of the *NDS*, the *NDS Supplement: Design Values for Wood Construction*, and the *NDS Supplement: Special Design Provisions for Wind and Seismic* is analogous to having a copy of the AISC Steel Manual (Ref. 1.1) in order to be familiar with structural steel design.

Commentary on the NDS provisions is provided in the NDS document. This commentary provides additional guidance and other supporting information for the design provisions included in the NDS.

In addition to the NDS and its two supplements, another associated document is available from the American Wood Council. This document is the *ASD/LRFD Manual for Engineered Wood Construction.* The ASD/LRFD Manual for Engineered Wood Construction was first introduced for ASD in 1999 for the 1997 NDS, and for the first time brought together all necessary information required for the design of wood structures. Prior to this, the designer referred to the NDS for the design of solid sawn lumber and glulam members, as well as the design of many connection details. For the design of other wood components and systems, the designer was required to look elsewhere. The 2018 Manual contains supporting information for both LRFD and ASD, including non-mandatory design information such as span tables, load tables, and fire assemblies. The Manual is organized to parallel the NDS.

All or part of the design recommendations in the NDS are incorporated into the wood design portions of U.S. building codes. With recent codes, this adoption has occurred through adopting by reference (citing as adopted) a particular edition of the

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NDS, NDS Supplement, and SDPWS. However, the code change process can take considerable time. This book deals specifically with the design provisions of the 2018 NDS, and the designer should verify local building code acceptance before basing the design of a particular wood structure on these criteria.

This book also concentrates heavily on understanding the loads and forces required in the design of a structure. Emphasis is placed on both gravity loads and lateral forces. Toward this goal, the design loads and forces in this book are taken from the 2018 *International Building Code* (IBC) (Ref. 1.9). The IBC is published by the International Code Council (ICC), and it is highly desirable for the reader to have a copy of the IBC to follow the discussion in this book.

Frequent references are made in this book to the NDS, the NDS Supplements, SDPWS, the ASD/LRFD Manual for Engineered Wood Construction, and the IBC. In addition, a number of cross references are made to discussions or examples in this book that may be directly related to a particular subject. The reader should clearly understand the meaning of the following references:

Examples Reference	Refers to	Where to Look
NDS Section 15.1	Section 15.1 in 2018 NDS	2018 NDS (required reference)
NDS Supplement Table 4A	Table 4A in 2018 NDS Supplement	2018 NDS Supplement (comes with NDS)
SDPWS Supplement Table 4.2A	Table 4.2A in the 2015 Wind and Seismic Supplement	NDS Supplement: Special Design Provisions for Wind and Seismic
IBC Chapter 16	Chapter 16 in 2018 IBC	2018 IBC (recommended reference)
IBC Table 1607.1	Table 1607.1 in 2018 IBC	2018 IBC (recommended reference)
Section 4.15	Section 4.15 of this book	Chapter 4 in this book
Example 9.3	Example 9.3 in this book	Chapter 9 in this book
Figure 5.2	Figure 5.2 in this book	Chapter 5 in this book

Another reference that is often cited in this book is the *Timber Construction Manual* (Ref. 1.2), abbreviated as TCM. This handbook can be considered the basic reference on structural glued-laminated timber. Although it is a useful reference, it is not necessary to have a copy of the TCM to follow this book.

1.4 Building Codes and Design Criteria

Cities and counties across the United States typically adopt a building code to ensure public welfare and safety. Until recently, most local governments used one of the three *regional model codes* as the basic framework for their local building code. The three regional model codes were the

1. *Uniform Building Code* (Ref. 1.10)
2. *The BOCA National Building Code* (Ref. 1.7)
3. *Standard Building Code* (Ref. 1.11)

Generally speaking, the *Uniform Building Code* was used in the western portion of the United States, *The BOCA National Building Code* in the north, and the *Standard*

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Building Code in the south. The model codes were revised and updated periodically, usually on a 3-year cycle.

While regional code development had been effective, engineering design now transcends local and regional boundaries. The ICC was created in 1994 to develop a single set of comprehensive and coordinated national model construction codes without regional limitations. IBC is one of the products of the ICC. The first edition of the IBC was published in 2000, with newer editions published every three years. Most regions of the United States have adopted all or part of the IBC at either the state or local level.

The ASCE/SEI standard *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (Ref. 1.3) is commonly referred to as ASCE 7-16 or simply ASCE 7. It serves as the basis for some of the loading criteria in the IBC. The IBC directly references ASCE 7, as does this book.

The IBC is used throughout the text to establish the loading criteria for design. The IBC was selected because it is widely used throughout the United States, and because it represents the latest national consensus with respect to load and force criteria for structural design.

Throughout the text, reference is made to the *Code* and the *IBC*. As noted in the previous section, when references of this nature are used, the design criteria are taken from the 2018 edition of the *International Building Code*.

Although the NDS is used in this book as the basis for determining the allowable (for ASD) or strength level (for LRFD) loads for wood members and their connections, note that the IBC also has a chapter that deals with wood design and construction. While the NDS primarily addresses engineered design provisions, the IBC chapter primarily provides requirements for minimum design, construction, and durability.

The designer should be aware that the local building code is the legal authority, and the user should verify acceptance by the local code authority before applying new principles. This is consistent with general practice in structural design, which is to follow an approach that is both rational and conservative. The objective is to produce structures which are economical and safe.

1.5 ASD and LRFD

The ASD format compares *allowable stresses* of a material to calculated *working stresses* resulting from *service loads.* A single *factor of safety* is applied to the *nominal design value* to arrive at the allowable design value. In the LRFD method, *adjusted capacities* (resistance) are compared to the effects of *factored loads*. The factors are developed for both resistance and loads such that uncertainty and consequences of failure are explicitly recognized.

Basic behavioral equations form the basis for both ASD and LRFD provisions. Therefore, the basic behavior of wood is presented in this text first, followed by ASD and LRFD provisions. The reader should be careful when referencing any equations or examples and confirm that the correct format, whether ASD or LRFD, is being reviewed.

All examples in the text are located in shaded boxes. Where examples are specifically using ASD, the example title includes "using ASD" and where using LFRD, the example title includes "using LFRD".

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1.6 Organization of the Text

The text has been organized to present the complete design of a wood-frame building in an orderly manner. The subjects covered are presented roughly in the order that they would be encountered in the design of a building.

In a building design, the first items that need to be determined are the design loads. The Code requirements for vertical loads and lateral forces are reviewed in Chap. 2, and the distribution of these in a building with wood framing is described in Chap. 3.

Following the distribution of loads and forces, attention is turned to the design of wood elements. As noted previously, there are basically two systems that must be designed, one for *vertical loads* and one for *lateral forces*.

The vertical-load-carrying system is considered first. In a wood-frame building, this system is basically composed of beams and columns. Chapters 4 and 5 cover the characteristics and design properties of these wood members. Chapter 6 then outlines the design procedures for beams, and Chap. 7 treats the design methods for columns and members subjected to combined axial and bending loads.

As one might expect, some parts of the vertical-load-carrying system are also part of the lateral-force-resisting system (LFRS). The sheathing for wood roof and floor systems is one such element. The sheathing distributes the vertical loads to the supporting members, and it also serves as the *skin* or *web* of the diaphragm for resisting lateral forces. Chapter 8 introduces the grades and properties of wood-structural panels and essentially serves as a transition from the vertical-load- to the lateral-force-resisting system. Chapters 9 and 10 deal specifically with the LFRS. In the typical bearing wall type of buildings covered in this text, the LFRS is made up of a diaphragm that spans horizontally between vertical shear-resisting elements known as shearwalls.

After the design of the main elements in the vertical-load- and lateral-force-resisting systems, attention is turned to the design of the connections. The importance of proper connection design cannot be overstated, and design procedures for various types of wood connections are outlined in Chaps. 11 through 14.

Chapter 15 describes the anchorage requirements between horizontal and vertical diaphragms. Basically, anchorage ensures that the horizontal and vertical elements in the building are adequately tied together.

Chapter 16 addresses building code requirements for seismically irregular structures. Chapter 16 also expands the coverage of overturning for shearwalls.

1.7 Structural Calculations

Structural design is at least as much an *art* as it is a *science*. This book introduces a number of basic structural design principles. These are demonstrated through a large number of practical numerical examples and sample calculations. These should help the reader understand the technical side of the problem, but the application of these tools in the design of wood structures is an art that is developed with experience.

Equation-solving software or *spreadsheet* computer programs can be used to create a *template* that can easily generate the solutions of many wood design equations. Using the concept of a template, the design equations need to be entered only once. Then they can be used, time after time, to solve similar problems by changing certain variables.

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Equation-solving software and spreadsheet applications relieve the user of many of the tedious programming tasks associated with writing dedicated software. Dedicated computer programs certainly have their place in wood design, just as they do in other areas of structural design. However, equation-solving software and spreadsheets have leveled the playing field considerably. Templates can be simple, or they can be extremely sophisticated. Regardless of programming experience, it should be understood that a simple template can make the solution of a set of bolt equations easier than looking up a design value in a table.

It is highly recommended that the reader become familiar with one of the popular equation-solving or spreadsheet application programs. It is further recommended that a number of the sample problems be solved using such applications. With a little practice, it is possible to create templates which will solve problems that are repetitive and tedious on a hand-held calculator.

Although the power and convenience of equation-solving and spreadsheet applications should not be overlooked, all the numerical problems and design examples in this book are shown as complete hand solutions.

With this in mind, an expression for a calculation is first given in general terms (i.e., a formula is first stated), then the numerical values are substituted in the expression, and finally the result of the calculation is given. In this way, the designer should be able to readily follow the sample calculation.

Note that the conversion from pounds (lb) to kips (k) is often made without a formal notation. This is common practice and should be of no particular concern to the reader. For example, the calculations below illustrate the adjusted axial load capacity of a tension member:

$$
\begin{aligned}
T &= F_t'A \\
&= (1200\ \text{lb/in.}^2)(20\ \text{in.}^2) \\
&= 24\ \text{k}
\end{aligned}
$$

where T = tensile force
F_t' = adjusted tensile design value
A = cross-sectional area

The following illustrates the conversion for the above calculations, which is normally done mentally:

$$
\begin{aligned}
T &= F_t'A \\
&= (1200\ \text{lb/in.}^2)(20\ \text{in.}^2) \\
&= (24{,}000\ \text{lb})\left(\frac{1\text{k}}{1000\text{lb}}\right) \\
&= 24\ \text{k}
\end{aligned}
$$

The appropriate number of significant figures used in calculations should be considered by the designer. When structural calculations are done on a calculator or computer, there is a tendency to present the result with too many significant figures. Variations in loading and material properties make the use of a large number of significant figures inappropriate. A false degree of *accuracy* is implied when the stress in a