



# FUNDAMENTALS OF RESIDENTIAL CONSTRUCTION

FIFTH EDITION

5



EDWARD ALLEN  
ALEXANDER C. SCHREYER  
ROB THALLON

WILEY



---

# **FUNDAMENTALS OF RESIDENTIAL CONSTRUCTION**

Fifth Edition

---



---

# **FUNDAMENTALS OF RESIDENTIAL CONSTRUCTION**

Fifth Edition

---

Edward Allen  
Alexander C. Schreyer  
Rob Thallon

**WILEY**

This book is printed on acid-free paper. ©

Copyright © 2022 by John Wiley & Sons, Inc. All rights reserved.

Published by John Wiley & Sons, Inc., Hoboken, New Jersey.

Published simultaneously in Canada.

No part of this publication may be reproduced, stored in a retrieval system, or transmitted in any form or by any means, electronic, mechanical, photocopying, recording, scanning, or otherwise, except as permitted under Section 107 or 108 of the 1976 United States Copyright Act, without either the prior written permission of the Publisher, or authorization through payment of the appropriate per-copy fee to the Copyright Clearance Center, 222 Rosewood Drive, Danvers, MA 01923, (978) 750-8400, fax (978) 646-8600, or on the web at [www.copyright.com](http://www.copyright.com). Requests to the Publisher for permission should be addressed to the Permissions Department, John Wiley & Sons, Inc., 111 River Street, Hoboken, NJ 07030, (201) 748-6011, fax (201) 748-6008, or online at [www.wiley.com/go/permissions](http://www.wiley.com/go/permissions).

**Limit of Liability/Disclaimer of Warranty:** While the publisher and author have used their best efforts in preparing this book, they make no representations or warranties with the respect to the accuracy or completeness of the contents of this book and specifically disclaim any implied warranties of merchantability or fitness for a particular purpose. No warranty may be created or extended by sales representatives or written sales materials. The advice and strategies contained herein may not be suitable for your situation. You should consult with a professional where appropriate. Neither the publisher nor the author shall be liable for damages arising herefrom.

This publication is designed to provide accurate and authoritative information in regard to the subject matter covered. It is sold with the understanding that the Publisher is not engaged in rendering professional services. If professional advice or other expert assistance is required, the services of a competent professional person should be sought.

The drawings, tables, descriptions, and photographs in this book have been obtained from many sources, including trade associations, suppliers of building materials, governmental organizations, and architectural firms. They are presented in good faith, but the author, illustrator, and Publisher do not warrant, and assume no liability for, their accuracy, completeness, or fitness for any particular purpose. It is the responsibility of users to apply their professional knowledge in the use of information contained in this book, to consult the original sources for additional information when appropriate, and to seek expert advice when appropriate. The fact that an organization or web site is referred to in this work as a citation and/or a potential source of further information does not mean that the author or the Publisher endorses the information that the organization or web site may provide or recommendations it may make. Further, readers should be aware that Internet web sites listed in this work may have changed or disappeared between the time the work was written and the time it was read.

For general information about our other products and services, please contact our Customer Care Department within the United States at (800) 762-2974, outside the United States at (317) 572-3993 or fax (317) 572-4002.

Wiley publishes in a variety of print and electronic formats and by print-on-demand. Some material included with standard print versions of this book may not be included in e-books or in print-on-demand. If this book refers to media such as a CD or DVD that is not included in the version you purchased, you may download this material at <http://booksupport.wiley.com>. For more information about Wiley products, visit [www.wiley.com](http://www.wiley.com).

***Library of Congress Cataloging-in-Publication Data applied for:***

ISBN: 9781119811565 (Hardback)

ISBN: 9781119811589 (ePDF)

ISBN: 9781119811572 (ePub)

Cover Design: Wiley

Cover Images: © Dariusz Jarzabek/Shutterstock

© jhorrocks/Getty Images

# CONTENTS

---

<b>Preface to the Fifth Edition</b>	xi	<b>Chapter 3</b>	
<b>How to Use This Book</b>	xiii	<b>The Construction</b>	
<b>Acknowledgments</b>	xvii	<b>Community: Builders,</b>	
		<b>Contractors, and</b>	
		<b>Developers</b>	<b>57</b>
PART ONE		3.1 History	58
<b>CONTEXT FOR BUILDING</b>	<b>1</b>	3.2 Builders and Contractors	60
<b>Chapter 1</b>		3.3 Obtaining Work	65
<b>The Context for Residential</b>		3.4 The Residential Developer	67
<b>Construction</b>	<b>3</b>	3.5 Green Builders, Contractors,	
1.1 History	4	Remodelers, and Developers	72
1.2 A Culture of Building	7	3.6 Training the Construction	
1.3 Construction Systems	10	Community	73
1.4 Types of Residential Development	12	3.7 Tools of the Trade	74
1.5 Zoning Ordinances, Building Codes,		3.8 Safety	77
and Other Legal Constraints	19		
1.6 Building Costs and Financing	21	<b>Chapter 4</b>	
1.7 Building a House: The Typical Process	24	<b>The Design Community:</b>	
1.8 MasterFormat	29	<b>Architects, Designers,</b>	
		<b>and Consultants</b>	<b>83</b>
<b>Chapter 2</b>		4.1 History	84
<b>Sustainability Aspects</b>		4.2 Residential Designers	84
<b>of Construction</b>	<b>35</b>	4.3 Consultants	87
2.1 Why Sustainability Matters		4.4 The Design Process	90
for Buildings	36	4.5 Design Sources	95
2.2 Environmental Responsibility: Building		4.6 Communication between Designer	
Green	39	and Builder	98
2.3 Comprehensive Certification Systems	49	4.7 High-Performance House	
2.4 Resiliency	49	Designers	101

PART TWO

**MATERIALS** **105**

**Chapter 5**

**Wood, Wood Products, and  
Plastics** **107**

5.1 Building with Wood	108
5.2 Lumber	110
5.3 Wood Products	122
5.4 Protection and Treatment	135
5.5 Wood Fasteners	137
5.6 Wood-Based Building Components	143
5.7 Types of Wood Construction	143
5.8 Plastics in Construction	145

**Chapter 6**

**Masonry** **155**

6.1 Building with Stone	156
6.2 Mortar	158
6.3 Concrete Masonry	160
6.4 Brick Masonry	170
6.5 Stone Masonry	180
6.6 Other Types of Masonry Units	186
6.7 Special Considerations for Masonry Construction	187

**Chapter 7**

**Concrete and Metals** **193**

7.1 Building with Concrete and Metals	194
7.2 Cement and Concrete	196
7.3 Making and Placing Concrete	199
7.4 Formwork	203
7.5 Reinforcing	203
7.6 Metals in Construction	210

PART THREE

**WOOD LIGHT FRAME HOUSE  
CONSTRUCTION** **221**

**Chapter 8**

**Rough Site Work** **223**

8.1 Design Considerations	224
8.2 Organizing the Site for Construction	225
8.3 Site Preparation	225
8.4 Excavation	227
8.5 Site Utilities	229
8.6 Surface Water Drainage	234
8.7 Grading	236

**Chapter 9**

**Foundations** **245**

9.1 Foundation Loads	246
9.2 Foundation Settlement	246
9.3 Soils	247
9.4 Designing Foundations	248
9.5 Footings	251
9.6 Concrete Foundation Walls	253
9.7 Concrete Masonry Foundation Walls	256
9.8 Concrete Slab Foundations	258
9.9 Wood Foundations	264
9.10 Precast Concrete Foundations	264
9.11 Pier Foundations	265
9.12 Anchor Bolts and Hold-Downs	265
9.13 Drainage and Waterproofing	267
9.14 Foundation Insulation	268
9.15 Backfilling	270
9.16 Foundation Design and the Building Codes	271



<b>Chapter 10</b>			
<b>Floor and Wall Framing</b>	<b>275</b>		
10.1 History	276		
10.2 The Platform Frame	277		
10.3 Building the Frame	279		
<b>Chapter 11</b>			
<b>Roof Framing</b>	<b>307</b>		
11.1 History	308		
11.2 Roof Types and Parts	309		
11.3 Building the Roof	311		
11.4 Wood Framing and the Building Codes	327		
11.5 The Uniqueness of Wood Light Frame Construction	332		
<b>Chapter 12</b>			
<b>Finishing the Roof</b>	<b>337</b>		
12.1 Preparation for Roofing	338		
12.2 Roof Slope	338		
12.3 Steep Roofs	340		
12.4 Low-Slope Roofs	350		
12.5 Roof Edge Details	358		
12.6 Roof Drainage	358		
12.7 Roofing and the Building Codes	362		
<b>Chapter 13</b>			
<b>Windows and Exterior Doors</b>	<b>369</b>		
13.1 Windows	370		
13.2 Exterior Doors	379		
<b>Chapter 14</b>			
<b>Finishing the Exterior Walls</b>	<b>393</b>		
14.1 The Weather Barrier Membrane	395		
14.2 Exterior Trim		396	
14.3 Siding		396	
14.4 Exterior Paints and Coatings		405	
14.5 Ladders and Scaffolds		412	
<b>Chapter 15</b>			
<b>Plumbing</b>		<b>419</b>	
15.1 Plumbing Basics		420	
15.2 Planning for Pipes		424	
15.3 Rough-in Plumbing		425	
15.4 Finish Plumbing		428	
15.5 Plumbing Codes		428	
15.6 Other Piping Systems		429	
<b>Chapter 16</b>			
<b>Heating, Cooling, and Ventilation</b>		<b>439</b>	
16.1 Choosing a System		440	
16.2 Forced-Air Systems		442	
16.3 Radiant Panel Systems		447	
16.4 Other Hydronic Heating Systems		453	
16.5 Mini-Split Heat Pumps		453	
16.6 Local Source Heaters and Air-Conditioners		454	
16.7 Ventilation Systems		458	
16.8 Finishing the HVAC System		459	
16.9 Heating, Cooling, and Ventilation Systems and the Building Codes		460	
<b>Chapter 17</b>			
<b>Fireplaces and Stoves</b>		<b>467</b>	
17.1 Selecting a Fireplace or Stove		468	
17.2 Planning for Fireplace or Stove Construction		470	
17.3 The Masonry Fireplace		470	

17.4 Masonry Heaters	479
17.5 Factory-Built Fireplaces	481
17.6 Freestanding Stoves	484
17.7 Fireplaces and Stoves and the Building Codes	485

## Chapter 18

### Electrical Wiring

493

18.1 Wiring Basics	494
18.2 Electrical System Design	499
18.3 Rough-in Electrical Installation	503
18.4 Finish Electrical Work	505
18.5 Electrical Wiring and the Building Codes	506
18.6 Low-Voltage Wiring	506

## Chapter 19

### Thermal Insulation, Air- and Vapor-Control

513

19.1 The Thermal Envelope and Its Components	515
19.2 Thermal Insulation Materials	520
19.3 How Much Insulation?	525
19.4 Installation of Insulation	527
19.5 Control of Water Vapor	528
19.6 Ventilation of Cavities	530
19.7 Control of Air Infiltration	534

## Chapter 20

### Interior Surfaces

543

20.1 Wall and Ceiling Finish	544
20.2 Finish Flooring	552

## Chapter 21

### Finishing the Interior

567

21.1 Interior Doors	568
21.2 Cabinets	571

21.3 Finish Carpentry and Trim	579
21.4 Paints and Coatings	581

## Chapter 22

### Finish Sitework

591

22.1 Paving Systems	592
22.2 Level Changes	594
22.3 Porches, Decks, and Structures	599
22.4 Finish Grading	600
22.5 Fencing	601
22.6 Outdoor Lighting	604
22.7 Irrigation	604
22.8 Planting	605

## PART FOUR

### ALTERNATIVE CONSTRUCTION SYSTEMS

611

## Chapter 23

### Panelized and Prefabricated Off-Site Construction

613

23.1 The Concept of Off-Site Construction	614
23.2 Types of Construction Systems	614
23.3 Framed Panel Systems	616
23.4 Structural Insulated Panels	618
23.5 Prefabricated (Factory-Built) House Construction	628

## Chapter 24

### Timber Frame Construction

641

24.1 The Uniqueness of the Timber Frame	643
24.2 Materials and Structure of the Timber Frame	647
24.3 Building a Timber Frame House	650
24.4 Timber Framing and the Building Codes	653

<b>Chapter 25</b>		PART FIVE	
<b>Loadbearing Masonry and Concrete Construction</b>	<b>661</b>	<b>MULTIFAMILY BUILDING CONSTRUCTION</b>	<b>725</b>
25.1 Loadbearing Masonry	662	<b>Chapter 28</b>	
25.2 Insulating Concrete Forms	668	<b>Multifamily Construction Systems</b>	<b>727</b>
<b>Chapter 26</b>		28.1 History	728
<b>Light-Gauge Steel Construction</b>	<b>679</b>	28.2 Special Considerations	731
26.1 Light-Gauge Steel Frame Construction	680	28.3 Foundations	731
26.2 Hybrid Uses of Light-Gauge Steel	690	28.4 Framing	737
26.3 Advantages and Disadvantages of Light-Gauge Steel Framing	690	28.5 Acoustical Separation	749
<b>Chapter 27</b>		28.6 Fire Protection	752
<b>Low-Tech, Low-Energy Construction</b>	<b>697</b>	28.7 Systems	754
27.1 Earthen Construction	698	28.8 Accessibility	756
27.2 Stacked Log Construction	706	28.9 Site Management	757
27.3 Straw Bale Construction	712	<b>Glossary</b>	767
		<b>Index</b>	793



# PREFACE TO THE FIFTH EDITION

---

The book that you hold in your hands is the fifth edition of what has since its first publication in 2002 become the standard textbook on residential construction. When its preceding book, *Fundamentals of Building Construction, Materials and Methods* (currently in its seventh edition), was first published more than 30 years ago, it filled a void and quickly was adopted by hundreds of colleges and universities as a text for general courses in construction technology. It also precipitated immediately the first of a growing stream of requests from teachers for a companion volume that would concentrate and elaborate on residential construction while retaining the basic qualities of the parent book. The authors were pleased to respond to those requests with this book, *Fundamentals of Residential Construction*.

This book has grown steadily over the previous four editions and now—in its fifth edition—provides even more improvements, both in terms of content as well as its delivery. All chapters have been thoroughly edited to reflect the latest in construction technology and describe traditional but also emerging methods. Content has been expanded where needed and where technological changes made it prudent to do so. Building code tables are included where they are required to provide data and where such tables create a linkage between the text's principles and their implementation in the regulatory framework of the building code. This fifth edition continues several important traits from its predecessors: It is straightforward and readable, and it contains an extensive collection of illustrative photographs and drawings, many of which were also updated for this edition. Those elements are blended on attractive pages, and, for the reader's convenience, each illustration appears close to its referencing text. Retained, too, is the concern for both technical and aesthetic matters, because the authors believe that those are important for the quality of buildings and the lives of the people who inhabit them.

New to the fifth edition are two additions to the materials part: Plastics and metals are now covered in this text with their basic properties and various application examples. This now

completes the materials part that formerly only included wood, masonry, and concrete. Those new sections were adapted from the latest edition of *Fundamentals of Building Construction* and thoroughly edited for the residential construction context. Every chapter also now features end-of-chapter building code references to relevant sections in the *International Residential Code (IRC)*. Those make it easier for the reader to link building code content (and its thorough set of regulations) to the more principles-focused text in this book.

The fifth edition continues to place a strong emphasis on green building and sustainability, a topic which has over the past decades grown from a special-request add-on for traditional design and construction to an integral requirement for good building construction. Customers now demand high-performance houses that provide comfort and reduce operating costs, and building codes put increasingly stringent energy-efficiency requirements on every construction project, large and small. The chapter on sustainability provides the reader with a thorough background on this topic, which is then strengthened and enhanced through updated “Building Green with . . .” features in each chapter of the book. Furthermore, chapters on HVAC systems and the building envelope were thoroughly edited and expanded to better cover the multitude of currently available systems, and to describe common approaches to designing and building energy-efficient houses.

With much of today's construction planning and execution based and managed on the computer, this fifth edition features not only more web links for each chapter, but also an expanded set of digital 3D exercises. Those exercises (originally introduced in the fourth edition) allow the reader to virtually practice the presented construction topics and their assemblies without “getting their hands too dirty” (or wasting material). The exercises, which are linked to many locations in the chapters through sidebar icons, are easy-to-accomplish practices for individual or classroom use. In addition to those, each chapter concludes with a set

of task- or project-based exercises that are often hands-on in nature and allow the reader to complete experiments, connect with the design or construction community, or thoroughly observe the covered topics “in real life.”

In the preparation phase for this fifth edition, we saw the passing of this book's original author, Edward Allen. Ed gave generations of students and practitioners in architecture, construction, and engineering a view of building design and construction that was unparalleled in its clarity, educational approach, and thoroughness. He is being deeply missed by his co-authors and the entire editorial team at John Wiley and Sons, who all made the commitment to continue his vision and excellence into the future. In that respect, Alexander Schreyer, who joined this book's team of authors with the fourth edition, has for the current edition taken the reins as leading author. He is committed to carrying the educational legacy of this book into the future with reverence to the original intent and a keen eye for current tendencies in construction. Having this well-written, beautifully illustrated, and comprehensive tome on residential construction as a resource will continue to allow students, practitioners, and laypeople to learn about our dwellings and explore in an approachable and easily comprehensible manner how they are produced.

Although all three authors have taught or are currently teaching in schools of architecture and construction, they are not mere ivory-tower academicians. Edward Allen and Rob Thallon are the architects of well over 200 constructed houses and innumerable remodeling projects. They have spent countless hours on construction sites, working with residential builders, developers, contractors, and craftspeople on the day-to-day minutiae of getting houses built. Both have constructed houses with their own hands, from excavation to finishes. In addition, both have authored books on construction that have found enthusiastic acceptance in the building professions. Alexander Schreyer, Senior Lecturer II and Director of the Building and Construction Technology Program at the University of Massachusetts Amherst, is a structural engineer and a seasoned educator with a background in construction, engineering, wood science, and digital

design. He is the author of *Architectural Design with SketchUp*, the main reference on this popular 3D modeling software. He is also a building materials expert and researcher and sought-after speaker on various aspects of wood structural design and digital planning in construction.

The team of authors has over all five editions brought to the table a breadth of regional backgrounds that includes wintry New England, the damp but mild Pacific Northwest, as well as Canada. To extend the boundaries of their own experiences, the authors have also frequently consulted with colleagues in other regions of the United States and Canada.

---

### New to This Edition

---

- Thoroughly updated content with respect to recent changes in the residential building market, building technologies, materials, code changes, and sustainability in buildings.
- Many new and updated images, renderings, and drawings. In the e-book editions, those are now included in full color.
- Updated and expanded in-chapter tables from the 2021 International Residential Code (IRC).
- New end-of-chapter references throughout the book to relevant sections in the 2021 International Residential Code (IRC).
- A new section on plastics in Chapter 5 and a section on metals in Chapter 7. Those now complete the discussion of building materials in Part Two.
- A more thorough coverage of mechanical ventilation and air-tightness in houses.
- Expanded and illustrated exercise sections for all chapters. Those have also been re-designed to include more hands-on activities.
- Many new interactive 3D exercises that allow the reader to practice assembling buildings in a “virtual construction” approach. Those are now included for all chapters.

# HOW TO USE THIS BOOK

---

---

## Organization

---

This book is organized into five parts, the first of which provides the context in which we design and build our buildings. Topics such as planning and development, building design, sustainability, and the many actors in the process of design and construction and their respective responsibilities are covered in the four chapters (1–4) that make up Part One.

Part Two provides a fundamental background section on the many building materials (and their properties) that we use in our daily professional lives. Chapters 5–7 thus cover wood and wood products, plastics, brick, concrete- and stone-masonry, as well as reinforced concrete and several metals.

Part Three then tells the story of how a light-frame house is built—from beginning to finish—over the space of fourteen chapters (8–22). All relevant steps in this process are presented in topically concise chapters and in the order in which one would encounter them on a construction site, starting with utility work and foundations and ending with finishes and final landscaping.

Part Four pays heed to the many variations that are available to standard construction practices. Contemporary approaches to off-site, prefabricated construction are covered in Chapter 23. Construction using timber-frames, loadbearing masonry, insulated concrete forms, and light-gauge steel are covered in Chapters 24–26. Chapter 27 rounds out this topic by showcasing low-tech, low-energy types of construction such as adobe, cob, straw bale, or log construction.

The book concludes with Part Five, which is solely dedicated to larger residential construction such as multistory apartment buildings. Since those do not fall under the same building code regulations as one- or two-family houses, this topic warrants separate coverage, which is provided in detail in Chapter 28, the final chapter of this book.

The reader is encouraged to approach the material in any manner that suits their interest. Chapters can be read sequentially to progressively learn more and more about the buildings we build,

their context, and all of the materials and methods that are involved. It is also written in a way that specific topics are exhaustively covered in single chapters, which can be sought out in any order or as a reference.

---

## Building Code References

---

All references to the *International Residential Code* (IRC) or —where applicable—the *International Building Code* (IBC) are based on the most recent 2021 edition of those codes. This was done to provide the most up-to-date version of code-related information that was available at the time of writing this book. However, the reader should be cautioned that the model code edition that is applicable in their jurisdiction may be a different one since state or municipal building code updates happen infrequently and may even skip a particular edition of the model codes (which are themselves updated every three years). Therefore, if the reader is working with a local building code edition that is *not* based on the 2021 codes, they are cautioned that some sections or information may not exist or that some references (e.g. table numbers) may be different. The online IRC code text highlights changes between the current and previous editions in blue, which makes it easier to track down when a particular code rule change was implemented and whether it is currently applicable in the reader's jurisdiction. For the IRC, the full code text for the current and the two most recent editions can be found and viewed freely online at these links:

**IRC 2021:** [codes.iccsafe.org/content/IRC2021P1](https://codes.iccsafe.org/content/IRC2021P1)

**IRC 2018:** [codes.iccsafe.org/content/IRC2018](https://codes.iccsafe.org/content/IRC2018)

**IRC 2015:** [codes.iccsafe.org/content/IRC2015](https://codes.iccsafe.org/content/IRC2015)

This fifth edition introduces end-of-chapter building code references for relevant sections and chapters in the International Residential Code (IRC). Those are intended to provide a direct reference for the reader to look up the relevant sections in the

## XIV How to Use This Book

freely available online version of the applicable model code. It is important to keep in mind that those also reference the 2021 IRC edition, however.

Several chapters of this book include tables from the IRC, which have been provided to allow the reader to look up relevant data and practice working with the code tables. It is important to note, however, that the included tables are typically abridged and often omit several rows (e.g. those for non-standard cases). Also, footnotes have been omitted for clarity. Therefore, the reader is always encouraged to look up the respective “original” table at the IRC links included here instead of fully relying on the in-chapter tables.

---

### Review Questions and Exercises

---

Each chapter concludes with several review questions that test comprehension of the covered material. Those can be used in the classroom context or for comprehension self-check. A list of key terms that appears next to these questions aids in knowing which topics were covered in the respective chapter. Those lists can then also be used together with the glossary at the end of the book for creating self-study flashcards.

The set of exercises that rounds out each chapter goes beyond the book’s text and encourages the reader to explore actual construction sites or connect with the design and construction community to learn from their daily practice. Other exercises allow the reader to explore various aspects in a more hands-on fashion, where they can build small assemblies (physically or virtually) or where basic building-inspection tasks can be performed. Some of those rely on equipment, which fortunately has become much cheaper over the past years and may now be available in a classroom or studio.



---

### Interactive 3D Exercises and Online Resources

---

This fifth edition of *Fundamentals of Residential Construction* again comes with online resources for students and instructors, which can be found by going to:

[www.wiley.com/go/resconstruction5e](http://www.wiley.com/go/resconstruction5e)

### Interactive 3D Virtual Construction Exercises

A set of interactive 3D exercises are linked to specific locations in the text via an icon (shown as a sample next to this paragraph). The reader is encouraged to seek those exercises out and practice constructing specific building details virtually in 3D on their computer when this would allow for a better understanding of the presented content.



As an example, in a section about window framing, there is an exercise where the framing around a window opening (including all studs and headers) needs to be assembled by copying, placing (moving and rotating), and cutting (stretching) provided pre-modeled items. This exercise allows the reader to understand where cuts would need to be made and how all the elements spatially relate to each other. Doing this virtually in a 3D modeling environment removes the mess, waste, and safety-requirements of doing the same as a physical laboratory exercise, while still retaining the educational benefit that comes from completing such an exercise.

By default, all exercises are provided in a file format that works with Trimble’s SketchUp web app and software, but they can also be imported into many other software packages. To work with the SketchUp exercises, it is easiest to open them with the freely available online app, which can be found at [app.sketchup.com](http://app.sketchup.com). Those exercises require only minimal understanding of 3D modeling software and all of the necessary knowledge to complete them can be acquired easily by watching an introductory video or by reading the *Interactive 3D Exercise Student Manual* (both are provided on the book companion website). For the instructor, they provide pre-made, “hands-on” exercises that can be assigned to even large classes or as part of an online course.





## Links and Websites

All chapters feature a collection of web links to relevant sites and online resources, which the reader is encouraged to peruse. Often, such sites feature sample project collections, detail images and drawings (in common CAD formats), and technical data, which are typically openly accessible (sometimes requiring a free registration). When assembling those link collections, the authors prioritized material or product industry associations and similar educational resources. Sample companies were intentionally omitted from those lists, but a collection of those can be found on the book companion website mentioned above.

Some of the authors also maintain various blogs and other relevant web resources, which the reader is encouraged to consult. Those are:

- alexschreyer.net: Alex Schreyer's blog
- visual.construction: A construction-focused site with an emphasis on visual media
- sketchupfordesign.com: The companion site to *Architectural Design with SketchUp* (also published by John Wiley & Sons)



# ACKNOWLEDGMENTS

---

Together, Alexander Schreyer, Edward Allen, and Rob Thallon are extremely grateful to everyone at John Wiley & Sons, Inc., who have given so much of themselves to producing this book over all the previous and current editions. We thank especially Publisher Amanda Miller, Editors Margaret Cummins and Kalli Schulte, Developmental Editor Lauren Olesky, and Senior Production Editors Amy Odum and Doug Salvemini. Like the quality of a house, the quality of a book is proportional to the skill and dedication of the individuals on the production team.

---

## For Alexander Schreyer

Alex thanks former Wiley editor Paul Drougas for originally championing his joining the team of authors of this book. He also thanks his colleagues L. Carl Fiocchi, Ben Weil, and Ho-Sung Kim for their technical reviews and very helpful feedback on the manuscript. He acknowledges and thanks the many builders that allowed him to take photographs on their construction sites, including Tedd Benson's and Kent Hicks' companies, and UMass Amherst's Design and Construction Management group. Other images in this book were supplied by his colleagues and various alumni of the BCT program at UMass Amherst, with special mention (and much thanks) going to Bob Hastings (of Bayview Builders, MD) and Alison Moynihan (of Foard Panel, NH).

He is eternally grateful to his wife, Dr. Peggy Clouston, for her encouragement, support, love, and the many discussions about buildings, a topic which they both are highly passionate about. Finally, he thanks his two beautiful girls, Sophia and Mackenzie, for their patience while he was working on this manuscript.

Alex dedicates his contributions to this book to his wife, Peggy and his daughters Sophia and Mackenzie.

---

## For Edward Allen (from the 4th Edition)

Edward Allen is grateful to be teamed with Rob Thallon, a gifted teacher, accomplished author, and award-winning architect of

some of the loveliest, most livable houses ever constructed. He offers apologies to Dee Etwiler and Carter and Claire Thallon for involving their husband and father, respectively, in an enterprise that kept him holed up in his office for many hours over a period of several years. He thanks Rob for sharing his vision of excellence and making this book so special. He is grateful to Joseph Iano, whose ideas and innovations for the parent book still shine in this book. And he thanks Mary M. Allen for her support and encouragement.

---

## For Rob Thallon (from the 4th Edition)

Rob Thallon is especially thankful to Edward Allen, his mentor and friend, for selecting him to work on this important project. He also thanks his coauthor for having been his keenest critic and most fervent champion during his previous writing projects, and he notes that their collaboration on this book has deepened his appreciation for the clarity of Edward Allen's vision and his language. He wishes to thank the talented illustrators Mu-Yun Chang, Lisa Ferretto, Laura Houston, and Dave Bloom, who helped develop and render drawings for the original edition; and Ben Rippe and John Arnold, who contributed illustrations and organizational brilliance to the second edition. Finally, thanks and a deep appreciation to Jesse Crupper, Dee Etwiler, and Hank Warneck, whose research, photography, and illustrations were instrumental to the quality of the third edition.

Edward Allen  
*South Natick, Massachusetts*

Alexander Schreyer  
*Amherst, Massachusetts*

Rob Thallon  
*Eugene, Oregon*



# PART ONE

## Context for Building







---

# THE CONTEXT FOR RESIDENTIAL CONSTRUCTION

---

1

- 1.1 History
- 1.2 A Culture of Building
- 1.3 Construction Systems
- 1.4 Types of Residential Development
- 1.5 Zoning Ordinances, Building Codes, and Other Legal Constraints
- 1.6 Building Costs and Financing
- 1.7 Building a House: The Typical Process
- 1.8 MasterFormat

Review Questions

Exercises

Key Terms and Concepts

Web Links

Selected References

### 1.1 History

People have been building houses for thousands of years. These houses have provided shelter, afforded privacy, defined territory, enhanced status, and, in some cases, provided defense. The earliest houses were

opportunistic uses of naturally sheltered places like caves and were more like nests than houses. As time passed, people learned to assemble materials collected from nature to make simple freestanding structures. In many cultures, these structures have evolved into highly crafted

houses that are elegant expressions of cultural patterns and values (Figures 1.1 and 1.2). In the past 200 years, technology has afforded us conveniences such as electricity, plumbing, and automatic heating and air conditioning that have made houses, in the words of the famous architect Le

FIGURE 1.1

The Roman domus, developed more than 2000 years ago, had individual rooms for common daily functions and was built around a central courtyard that helped to cool the rooms naturally.

Source: Reproduced with permission of John Wiley & Sons, Inc.

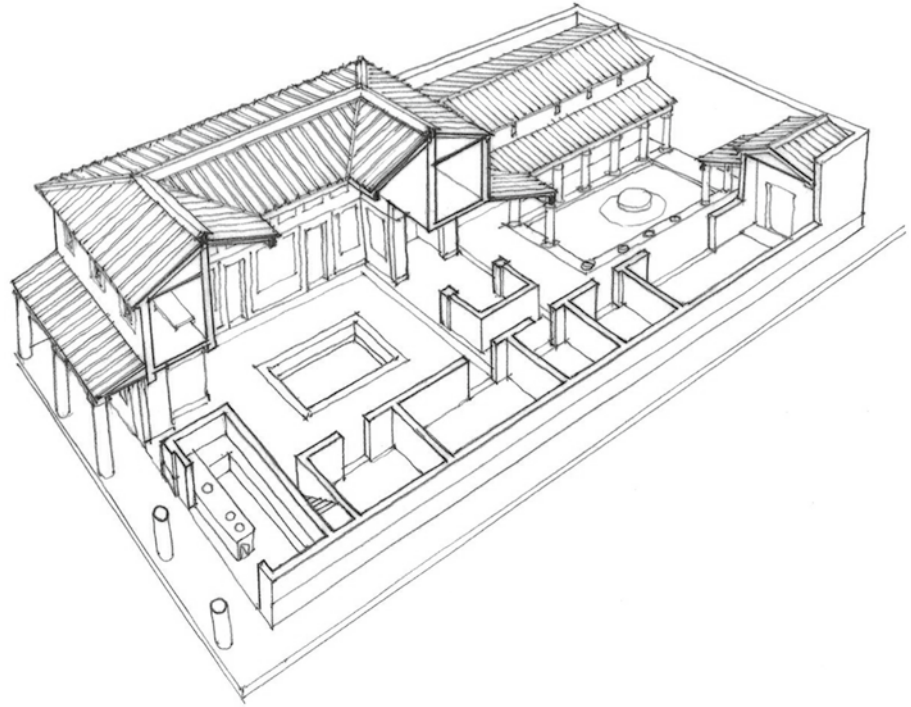
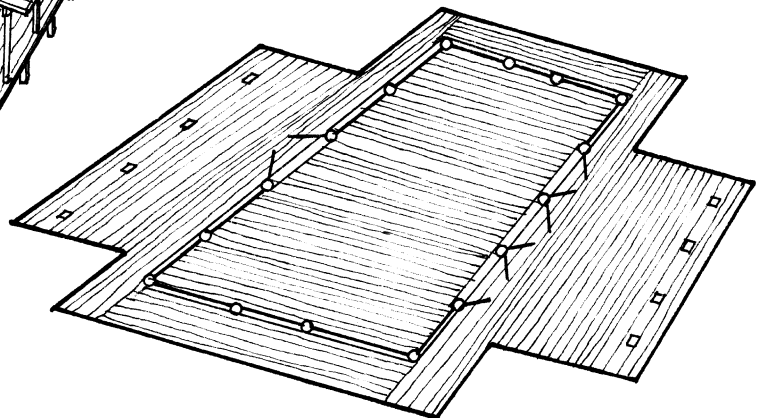
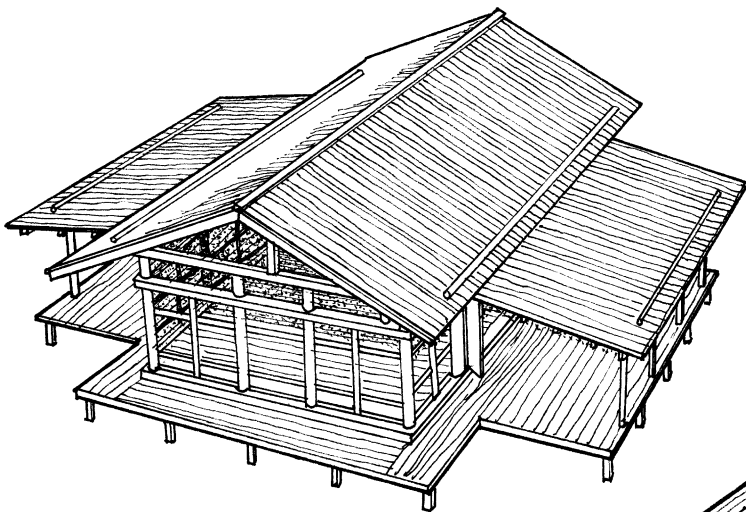


FIGURE 1.2

A traditional Japanese house from the Nara period, AD 710–784. The house had both open and closed spaces, and the enclosed indoor space had no permanent partitions. Houses such as this have influenced traditional Japanese house design and construction to the present day.

Source: From Nishi Kazuo and Hozumi Kazuo, *What Is Japanese Architecture?* Kodansha International, Ltd., Tokyo, 1985





Corbusier, “machines for living.” Most recently, housing in the industrialized world has emphasized energy conservation and efficient production. Today, residential designers have a rich history from which to draw, and residential builders have the best tools and most complete palette of quality materials with which to build that have ever existed. The challenge for this new generation of designers and builders will be to sustain and improve the built environment in the face of decreasing natural resources, a changing climate, and increasing population.

Throughout history, the forms of houses have differed from region to region. House form varies primarily in relation to climate, to available building materials and tools, and to the culture of the people being housed. The influence of climate on house form is dramatically demonstrated by the comparison of the igloo in polar regions with the open-sided palm-thatched structure in tropical zones. The forms of houses in the same climate can vary also, however, because of the use of different building materials. In Mexico, for example, the introduction of reinforced concrete has spawned a collection of flat-roofed houses that contrast sharply with the traditional sloped roof made of timber covered with clay tiles. The culture of the people being housed also has considerable influence on house form. Native American tribes, who were nomadic, built dwellings such as *tepees* that were easily folded and transported, while rooted tribes (even from the same region) built stationary houses of earth, stone, and wood (Figure 1.3 is only one of many examples of a *longhouse*).

The modern North American house has evolved largely from sixteenth-century timber-framed houses that had been developed in response to the climate, materials, and culture of northern and central Europe (Figure 1.4). Early pioneers landing on the eastern shores of North America found a new homeland rich with timber that had to be cleared to make way for development, so it was



FIGURE 1.3

A Wampanoag longhouse, used mainly as a winter dwelling by native tribes in the Northeast, was constructed using a frame of lashed branches. Weather protection was provided by a covering of bark layers.

Source: Photo by Alexander Schreyer

logical to use wood for the construction of new houses. The settlers soon discovered, however, that the European tradition of exposed timber frame was inadequate in the harsher climate of the New World, so they developed an exterior skin of clapboards to protect the frame (Figure 1.5). This wooden structure and its details evolved over the years in response to changes in tools, transportation, and social norms. Other building materials and systems such as brick and stone masonry developed simultaneously but were never as prevalent in North America as the clapboard-clad, timber-framed building.

Then, in the 1840s, after more than 300 years of development, the heavy timber frame yielded its preeminence almost overnight to a new system of construction, the *wood light frame*. The emergence of the light frame was made possible by two technological developments: mass production of the inexpensive wire nail

and the ability of water-powered sawmills to cut large quantities of consistently dimensioned lumber. These developments allowed the large timbers and complicated connections of the traditional timber-framed buildings to be replaced with numerous small structural pieces, simply connected (Figure 1.6). The advantages of the wood light frame over its predecessor are so numerous and compelling that it has dominated residential and other small-scale construction for the 150 years since its introduction, and it still shows no sign of giving way to other systems. Today, the wood light frame accounts for over 90 percent of all new site-built residential construction and is the basis for most factory-built housing as well. The system has even found international popularity due to its material efficiency (especially when compared to masonry and concrete construction) and its ability to cope well with earthquake loads (Figure 1.7).

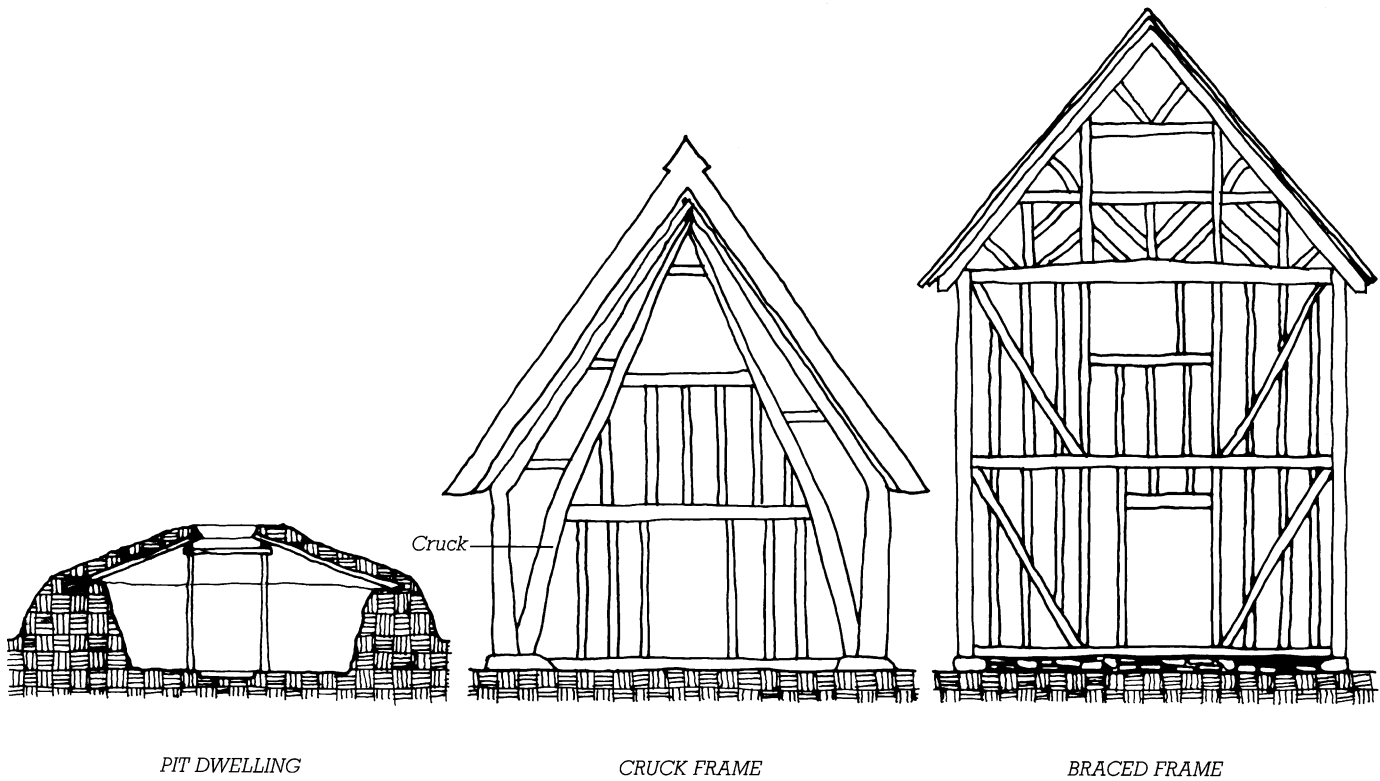


FIGURE 1.4

European timber house forms generally followed a progression of development from crude pit dwellings, made of earth and tree trunks, to cruck frames to braced frames.



FIGURE 1.5

The North American climate was more severe than the European climate, so early pioneers found a way to wrap the wooden frame with cladding, protecting it more securely from the weather than the exposed half-timbers of European houses. This example, built in 1716 in Lexington, Massachusetts, is still standing. Note also the traditional central location of the hearth and chimney.

Source: Photo by Alexander Schreyer

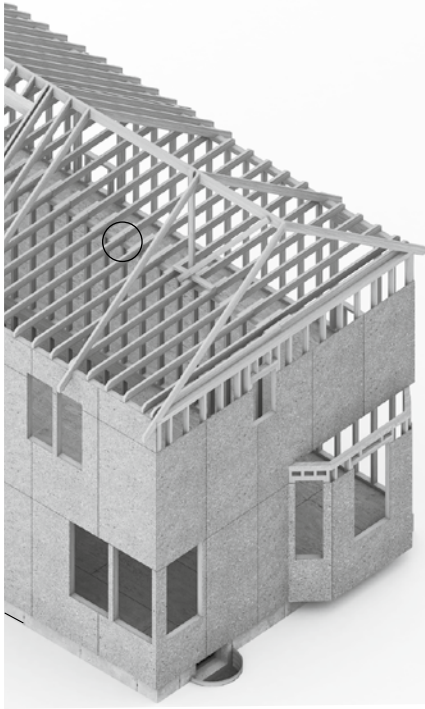


FIGURE 1.6  
The wood light frame uses less material and less labor to construct than does its predecessor, the timber frame. For lateral stability, light framing relies on sheathing such as plywood applied to the exterior of the frame.



FIGURE 1.7  
The North American wood light frame building system is now used extensively in Japan, where its resistance to earthquakes makes it most practical.  
*Source: Photo by Rob Thallon*

## 1.2 A Culture of Building

Houses are built within the context of the many individuals and institutions that affect their design and construction. In primitive and vernacular societies, the context was relatively local and involved few people. The head of a household

might acquire a piece of land through the family, formulate a simple design based on local traditions, consult with a local builder about schedule and cost, arrange for the purchase of local building materials, and work together with the builder using traditional methods to build the house. The building of a house today in

North America involves a much more complex process and many more participants. Nonetheless, all these participants are instrumental to the success of the project, and all are connected to what can be called a residential building culture—a network of people and institutions, which we will call “subcultures,” that are directly or indirectly dedicated to the production of houses. The principal actors in these subcultures are discussed in the following paragraphs and in later chapters of this book.

### 1.2.1 Contractors and Subcontractors

At the center of today’s residential building culture are the *contractors* and *subcontractors* whose job it is to construct houses. These people—carpenters, plumbers, masons, electricians, and myriad others—devote their professional lives to assembling materials in concert with one another to make houses. Their work depends on direct contributions from many other sectors of the building culture such as designers, material suppliers, and code enforcement agencies. Indirect contributions from realtors, financial institutions, educators, and publishers also play an important role in their work. Contractors and subcontractors are discussed extensively in Chapter 3.

### 1.2.2 Builders and Developers

*Builders* bring together and coordinate the numerous parts of an entire building project for the purpose of offering it for sale or rent. The builder purchases a building lot, obtains financing, hires the designers and other consultants to produce plans, hires the contractor to do the construction, markets the project, and sells or rents it. Builders can work on one house at a time or can build large tracts of houses or large multifamily structures.

Whereas builders are the entrepreneurs who produce houses for sale, *developers* are entrepreneurs who produce building lots. Developers purchase large tracts of land, contract for the design of roads and utilities, obtain the necessary governmental permissions to develop the

## 8 Part One • Context for Building

land, contract for the installation of roads and utilities, and sell the divided land as building lots. Developers often expand their operation to become builder/developers, and builders likewise can expand in the other direction. Nonprofit builder/developers produce affordable housing for rent or sale to low-income families or individuals. Builders and developers are discussed further in Chapter 3.

### 1.2.3 Designers and Consultants

The members of the building culture most responsible for creative solutions and communication are the *designers*. This group includes architects, building designers, engineers of several kinds, landscape architects, landscape designers, and interior designers. They are responsible for being knowledgeable about current building practices, understanding and interpreting the various codes and laws that regulate building design, having a current understanding of the availability and performance of building materials, and integrating all these factors into designs that are appreciated by their clients.

Whenever a higher degree of specialization is sought than a primary designer can provide, *consultants* are engaged who perform services for the designer in a certain specialty, such as structure, building systems and performance, code and environmental compliance, and others. The number of consultants on a project typically increases with the size of the project.

These various participants in the role of residential design are discussed further in Chapter 4.

### 1.2.4 Material Manufacturers and Distributors

There are thousands of companies, large and small, many of which operate internationally, that manufacture and sell the materials and assemblies used to construct houses. The *manufacturers* generally sell their goods wholesale to retail stores, which, in turn, sell to contractors and to the general public (Figures 1.8 and 1.9). Contractors usually are offered a discount at retail outlets because they are frequent customers who often buy in volume.



FIGURE 1.8

Large retail outlets such as this one provide one-stop shopping for professional builders and homeowners alike. Because of the large volume of building materials, tools, and books sold at these outlets, prices are usually competitive, and building professionals receive an additional discount.

Source: Photo by Alexander Schreyer



FIGURE 1.9

Local lumberyards play an important role in residential construction. Based on a set of building plans, an employee of the yard will estimate the quantity of lumber that is required to build a project and will furnish a competitive bid for the entire package of lumber, delivered to the building site. Yards prefer doing business with contractors who organize their work so that deliveries can be concentrated into five or six truckloads for an average-sized house.

Source: Photo by Alexander Schreyer

Product information in both printed and electronic form is distributed to contractors and designers and is disseminated to the general public via commercial advertising in periodicals and on manufacturer's websites.

Building material manufacturers have also formed a large number of organizations that work toward the development of technical standards and the dissemination of information in relation to their respective products. The Western Wood Products Association (WWPA), for example, is made up of producers of lumber and wood products. It carries out programs of research on wood products, establishes uniform standards of product quality, certifies mills and products that conform to its standards, and publishes authoritative technical literature concerning the use of lumber and related products. Associations with a similar range of activities exist for virtually every material and product used in building, and for several major geographic areas. All of them publish technical data relating to their fields of interest, and many of these publications are indispensable references for the builder, architect, or engineer. A considerable number are incorporated by reference into various building codes and standards and are therefore legally binding.

Each upcoming chapter features the relevant associations in the Web Links section at the end of the chapter. The reader is encouraged to browse websites and download relevant information and thereby build up a reference library.

### 1.2.5 Realtors

*Realtors* are the salespeople of the building culture and play a critical role in marketing houses built for sale. They are responsible for knowing what the buying public wants in a house and for selling or renting houses as they are built. Because realtors have direct contact with consumers and are in a position to learn their desires, they are frequently queried by resourceful builders who are trying to discover new design features that will make their houses more marketable.

New speculative houses are typically advertised and sold by realtors via a *listing agreement* under which realtors assume numerous responsibilities, including negotiating the price of the house, the terms of the sale, and the conditions of the contract, with particular attention paid to the aspect of financing. For this service, realtors are generally paid a percentage of the cost of each house sold. Large builder/developers will often create their own real estate company for the purpose of marketing and selling their own houses.

### 1.2.6 Regulatory Agencies

Building design and construction are regulated by zoning ordinances and building codes written for the purpose of providing safe and healthy built environments. *Zoning ordinances* are local laws that divide the locality into zones and regulate such things as what kinds of buildings may be built in each zone and to what uses these buildings may be put. For example, these regulations restrict the use of buildings within residential zones so that dangerous or obnoxious activities do not get mixed in with houses. Within residential zones, the minimum size of lots, the distance a house must be from the property line, requirements for off-street parking, and maximum fence heights are typically regulated. *Building codes* are designed to ensure structural and fire safety and a healthy living environment within the house itself. The sizes of structural members, minimum standards for plumbing and wiring, minimum ceiling heights, the design of stairs and handrails, and provision for emergency escape are all examples of the regulations found in building codes. Zoning ordinances and building codes are further discussed later in this chapter.

### 1.2.7 Financial Institutions

Most residential construction projects require financial resources beyond the immediate means of the owner. Banks and other financial institutions provide capital for the projects in the form of long-term loans to qualified owners. The ability to

resell a house if the owner defaults on payments is a primary concern of lending institutions, which results in them being rather risk-averse and conservative. As a result, banks may be less inclined to loan money for the purchase of houses that appear to be very different from the norm. Financial institutions are further discussed later in this chapter.

### 1.2.8 Educational and Research Institutions

Most designers and builders have some formal training from a technical school or university. Architects are required to have at least a 5-year professional degree, and most plan service drafters have taken courses in drafting and residential construction. Many courses in both the business and the physical skills required in their specialties are offered to contractors and subcontractors. Some contractors and subcontractors are required to be licensed, and there are sanctioned courses offered by different institutions for this purpose.

In addition to providing education for the building community, universities also commonly engage in building-related research. Examples of such research are new materials and structural systems, performance of existing building methods, energetic performance of materials and systems, construction management practices, and cost of building. Often, outcomes of this research provide the market with new materials and solutions, and can inform the regulatory community about more adequate guidelines, which then make their way into building codes.

The training of residential designers is explored in Chapter 4, and that of builders and contractors is discussed in Chapter 3.

### 1.2.9 Associations

There are many associations that relate to the design and construction of houses. The *American Institute of Architects (AIA)* and the *National Association of Home Builders (NAHB)* are two of the largest

such associations, and there are numerous other organizations of manufacturers, building trades, and other groups within the building culture. Their Canadian equivalents are the *Royal Architectural Institute of Canada (RAIC)* and the *Canadian Home Builders' Association (CHBA)*. Hybrid groups that include members from several disciplines also exist. For example, the International Code Council (ICC), which is responsible for writing building codes, includes architects, builders, and building code officials.

### 1.2.10 Publishers and Media

The publishing industry has long been an integral part of the residential building culture. For hundreds of years, periodicals have advertised the latest building materials, tools, and other products (Figure 1.10). Popular magazines such as *Dwell*, *Better Homes and Gardens*, and *Home* have carried articles about design, while others

such as *Journal of Light Construction* and *Fine Homebuilding* have focused on construction. Many books and journals are devoted to a variety of related topics. There has also been a proliferation of how-to books for the do-it-yourself (DIY) market, which is mirrored online and on TV. Shows like *This Old House* and cable channels like the *DIY Network* and *HGTV* deliver not only housing ideas and built examples (often in the form of yet another makeover show) but also education in the involved techniques to the broader public and builders alike.

Whether the motive is advertising or education, the most successful published materials come from sources with strong connections to the building culture and especially to the design and construction processes.

### 1.3 Construction Systems

For the past 200 years, most houses in North America have been built using wood light frame construction, which is the most flexible of all building systems. There is scarcely a shape it cannot be used to construct, from a plain rectilinear box to cylindrical towers to complex roofs with dormers of every description (Figure 1.11). Since it first came into use, wood light framing has served to construct buildings in styles ranging from reinterpretations of nearly all the historical fashions to uncompromising expressions of every architectural philosophy of the last 100 years. It has assimilated without difficulty a succession of technical improvements in building: gas lighting, electricity, indoor plumbing, central heating, air conditioning, thermal insulation, prefabricated components, and electronic communications.

Wood light frame buildings are easily and swiftly constructed with a minimal investment in tools. Many observers of the building industry have criticized the supposed inefficiency of wood light frame construction, which is carried out largely by hand methods on the building site, yet it has successfully fought off competition from industrialized building

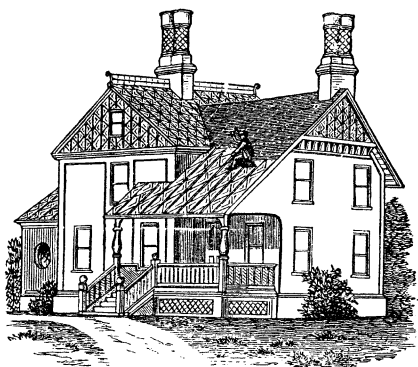
systems of every sort, partly by incorporating their best features, to remain the least expensive form of durable construction for houses and even multistory, multifamily buildings.

However, wood light frame construction has its deficiencies: If ignited, the unprotected frame burns rapidly; if exposed to dampness, it can decay. It expands and contracts by significant amounts in response to changes in humidity, sometimes causing chronic difficulties such as cracking plaster, sticking doors, and buckling floors. The framing itself is so unattractive to the eye that it is seldom left exposed in a building. These problems can be controlled, however, by appropriate design (e.g., with a covering of gypsum board that increases fire resistance), using adequate materials (e.g., using engineered wood products instead of solid wood to reduce swelling) and careful workmanship. There is no arguing with success: Frames made by the monotonous repetition of wooden joists, studs, and rafters are likely to remain the number one system of building in North America for a long time to come. The wood light frame system is described in detail in Chapters 8 to 22.

If 90 percent of all site-built residential construction consists of light wood frame, the remaining 10 percent is divided among several other residential construction systems. In some regions of the South, loadbearing masonry is the dominant system. Throughout the continent, other systems such as timber frame, light-gauge steel frame, insulating concrete forms, insulated masonry, and panelized construction are used in significant numbers of dwellings. These systems are important for their roles in developing new materials and building methods and for inducing innovation in the dominant wood light frame system. These less common systems are discussed in Chapters 23 to 27.

The *manufactured housing* industry factory-builds entire houses as finished boxes, often complete with furnishings, and trucks them to prepared foundations where they are set in place and made ready for occupancy in a matter of hours (Figure 1.12, and Chapter 23). If the

## METALLIC SHINGLES



make the most durable and ornamental roof in the world. The only shingle manufactured from metal that makes an absolutely tight roof. Send for full descriptive circular and new prices to

**ANGLO-AMERICAN ROOFING CO.,**  
22 Cliff Street NEW YORK.

FIGURE 1.10

Ads such as this one from the year 1882 have appeared in popular journals for as long as the journals have existed. Many modern ads refer to Web pages and/or offer free demonstration videos and downloadable material.

Source: From *Builder and Wood-Worker*, Vol. XVIII, Chas. D. Lakey, New York, 1882