



Coastal Construction Manual

Principles and Practices of Planning, Siting, Designing,
Constructing, and Maintaining Residential Buildings
in Coastal Areas (Fourth Edition)

FEMA P-55 / Volume II / August 2011



FEMA

Coastal Construction Manual

Principles and Practices of Planning, Siting,
Designing, Constructing, and Maintaining
Residential Buildings in Coastal Areas
(Fourth Edition)

FEMA P-55 / Volume II / August 2011



FEMA

All illustrations in this document were created by FEMA or a FEMA contractor unless otherwise noted.

All photographs in this document are public domain or taken by FEMA or a FEMA contractor, unless otherwise noted.



Preface

The 2011 *Coastal Construction Manual*, Fourth Edition (FEMA P-55), is a two-volume publication that provides a comprehensive approach to planning, siting, designing, constructing, and maintaining homes in the coastal environment. Volume I of the *Coastal Construction Manual* provides information about hazard identification, siting decisions, regulatory requirements, economic implications, and risk management. The primary audience for Volume I is design professionals, officials, and those involved in the decision-making process.

Volume II contains in-depth descriptions of design, construction, and maintenance practices that, when followed, will increase the durability of residential buildings in the harsh coastal environment and reduce economic losses associated with coastal natural disasters. The primary audience for Volume II is the design professional who is familiar with building codes and standards and has a basic understanding of engineering principles.

Volume II is not a standalone reference for designing homes in the coastal environment. The designer should have access to and be familiar with the building codes and standards that are discussed in Volume II and listed in the reference section at the end of each chapter. The designer should also have access to the building codes and standards that have been adopted by the local jurisdiction if they differ from the standards and codes that are cited in Volume II. If the local jurisdiction having authority has not adopted a building code, the most recent code should be used. Engineering judgment is sometimes necessary, but designers should not make decisions that will result in a design that does not meet locally adopted building codes.

The topics that are covered in Volume II are as follows:

- **Chapter 7** – Introduction to the design process, minimum design requirements, losses from natural hazards in coastal areas, cost and insurance implications of design and construction decisions, sustainable design, and inspections.

- **Chapter 8** – Site-specific loads, including from snow, flooding, tsunamis, high winds, tornadoes, seismic events, and combinations of loads. Example problems are provided to illustrate the application of design load provisions of ASCE 7-10, *Minimum Design Loads for Buildings and Other Structures*.
- **Chapter 9** – Load paths, structural connections, structural failure modes, breakaway walls, building materials, and appurtenances.
- **Chapter 10** – Foundations, including design criteria, requirements and recommendations, style selection (e.g., open, closed), pile capacity in soil, and installation.
- **Chapter 11** – Building envelope, including floors in elevated buildings, exterior doors, windows and skylights, non-loading-bearing walls, exterior wall coverings, soffits, roof systems, and attic vents.
- **Chapter 12** – Installing mechanical equipment and utilities.
- **Chapter 13** – Construction, including the foundation, structural frame, and building envelope. Common construction mistakes, material selection and durability, and techniques for improving resistance to decay and corrosion are also discussed.
- **Chapter 14** – Maintenance of new and existing buildings, including preventing damage from corrosion, moisture, weathering, and termites; building elements that require frequent maintenance; and hazard-specific maintenance techniques.
- **Chapter 15** – Evaluating existing buildings for the need for and feasibility of retrofitting for wildfire, seismic, flood, and wind hazards and implementing the retrofitting. Wind retrofit packages that can be implemented during routine maintenance are also discussed (e.g., replacing roof shingles).

For additional information on residential coastal construction, see the FEMA Residential Coastal Construction Web site at <http://www.fema.gov/rebuild/mat/fema55.shtm>.

Acknowledgments

Fourth Edition Authors and Key Contributors

William Coulbourne, Applied Technology Council
 Christopher P. Jones, Durham, NC
 Omar Kapur, URS Group, Inc.
 Vasso Koumoudis, URS Group, Inc.
 Philip Line, URS Group, Inc.
 David K. Low, DK Low and Associates
 Glenn Overcash, URS Group, Inc.
 Samantha Passman, URS Group, Inc.
 Adam Reeder, Atkins
 Laura Seitz, URS Group, Inc.
 Thomas Smith, TlSmith Consulting
 Scott Tezak, URS Group, Inc. – Consultant Project Manager

Fourth Edition Volume II Reviewers and Contributors

Katy Goolsby-Brown, FEMA Region IV
 John Ingargiola, FEMA Headquarters – Technical Assistance and Research Contracts Program Manager
 John Plisich, FEMA Region IV
 Paul Tertell, FEMA Headquarters – Project Manager
 Ronald Wanhanen, FEMA Region VI
 Gregory P. Wilson, FEMA Headquarters
 Brad Douglas, American Forest and Paper Association
 Gary Ehrlich, National Association of Home Builders
 Dennis Graber, National Concrete Masonry Association
 David Kriebel, United States Naval Academy
 Marc Levitan, National Institute of Standards and Technology
 Tim Mays, The Military College of South Carolina
 Sam Nelson, Texas Department of Insurance
 Janice Olshesky, Olshesky Design Group, LLC
 Michael Powell, Delaware Department of Natural Resources and Environmental Control
 David Prevatt, University of Florida
 Timothy Reinhold, Insurance Institute for Business & Home Safety
 Tom Reynolds, URS Group, Inc.
 Michael Rimoldi, Federal Alliance for Safe Homes
 Randy Shackelford, Simpson Strong-Tie
 John Squerciati, Dewberry
 Keqi Zhang, Florida International University

Fourth Edition Technical Editing, Layout, and Illustration

Diana Burke, URS Group, Inc.
 Lee-Ann Lyons, URS Group, Inc.
 Susan Ide Patton, URS Group, Inc.
 Billy Ruppert, URS Group, Inc.

Contents

Chapter 7. Pre-Design Considerations	7-1
7.1 Design Process	7-2
7.2 Design Requirements	7-3
7.3 Determining the Natural Hazard Risk	7-3
7.4 Losses Due to Natural Hazards in Coastal Areas	7-5
7.5 Initial, Long-Term, and Operational Costs	7-6
7.5.1 Cost Implications of Siting Decisions	7-7
7.5.2 Cost Implications of Design Decisions	7-7
7.5.3 Benefits and Cost Implications of Siting, Design, and Construction Decisions	7-11
7.6 Hazard Insurance	7-12
7.6.1 Flood Insurance	7-13
7.6.1.1 Rating Factors	7-13
7.6.1.2 Coverage	7-17
7.6.1.3 Premiums	7-18
7.6.1.4 Designing to Achieve Lower Flood Insurance Premiums	7-20
7.6.2 Wind Insurance	7-21
7.6.2.1 Territory	7-22
7.6.2.2 Fire Protection Class	7-22
7.6.2.3 Building Code Effectiveness Grading Schedule	7-22
7.6.2.4 Construction Type	7-23
7.6.2.5 Protective Devices	7-23
7.6.3 Earthquake Insurance	7-24
7.7 Sustainable Design Considerations	7-24
7.8 Inspection Considerations	7-25
7.9 References	7-26

Chapter 8. Determining Site-Specific Loads..... 8-1

8.1 Dead Loads 8-3

8.2 Live Loads 8-3

8.3 Concept of Tributary or Effective Area and Application of Loads to a Building..... 8-4

8.4 Snow Loads 8-5

8.5 Flood Loads..... 8-5

 8.5.1 Design Flood 8-5

 8.5.2 Design Flood Elevation..... 8-6

 8.5.3 Design Stillwater Flood Depth..... 8-9

 8.5.5 Design Breaking Wave Height 8-15

 8.5.6 Design Flood Velocity..... 8-15

 8.5.7 Hydrostatic Loads 8-17

 8.5.8 Wave Loads..... 8-20

 8.5.8.1 Breaking Wave Loads on Vertical Piles 8-21

 8.5.8.2 Breaking Wave Loads on Vertical Walls 8-22

 8.5.8.3 Wave Slam..... 8-25

 8.5.9 Hydrodynamic Loads..... 8-28

 8.5.10 Debris Impact Loads 8-31

 8.5.11 Localized Scour..... 8-34

 8.5.12 Flood Load Combinations 8-37

8.6 Tsunami Loads..... 8-47

8.7 Wind Loads..... 8-47

 8.7.1 Determining Wind Loads 8-49

 8.7.2 Main Wind Force Resisting System..... 8-52

 8.7.3 Components and Cladding 8-61

8.8 Tornado Loads..... 8-67

8.9 Seismic Loads 8-68

8.10 Load Combinations..... 8-73

8.11 References..... 8-81

Chapter 9. Designing the Building	9-1
9.1 Continuous Load Path.....	9-1
9.1.1 Roof Sheathing to Framing Connection (Link #1)	9-4
9.1.2 Roof Framing to Exterior Wall (Link #2).....	9-8
9.1.3 Wall Top Plate to Wall Studs (Link #3).....	9-10
9.1.4 Wall Sheathing to Window Header (Link #4).....	9-12
9.1.5 Window Header to Exterior Wall (Link #5).....	9-12
9.1.6 Wall to Floor Framing (Link #6)	9-15
9.1.7 Floor Framing to Support Beam (Link #7)	9-17
9.1.8 Floor Support Beam to Foundation (Pile) (Link #8).....	9-18
9.2 Other Load Path Considerations	9-21
9.2.1 Uplift Due to Shear Wall Overturning.....	9-21
9.2.2 Gable Wall Support.....	9-24
9.2.3 Connection Choices.....	9-24
9.2.4 Building Eccentricities	9-27
9.2.5 Framing System	9-27
9.2.5.1 Platform Framing.....	9-27
9.2.5.2 Concrete/Masonry.....	9-27
9.2.5.3 Moment-Resisting Frames	9-28
9.2.6 Roof Shape.....	9-30
9.3 Breakaway Wall Enclosures	9-30
9.4 Building Materials.....	9-33
9.4.1 Materials Below the DFE	9-34
9.4.2 Materials Above the DFE.....	9-35
9.4.3 Material Combinations	9-35
9.4.4 Fire Safety Considerations.....	9-36
9.4.5 Corrosion.....	9-37
9.5 Appurtenances.....	9-38
9.5.1 Decks and Covered Porches Attached to Buildings	9-38
9.5.1.1 Handrails	9-39
9.5.1.2 Stairways	9-39
9.5.2 Access to Elevated Buildings	9-39
9.5.3 Pools and Hot Tubs.....	9-40
9.6 References.....	9-43

Chapter 10. Designing the Foundation	10-1
10.1 Foundation Design Criteria	10-2
10.2 Foundation Styles	10-2
10.2.1 Open Foundations	10-3
10.2.2 Closed Foundations.....	10-3
10.2.3 Deep Foundations.....	10-4
10.2.4 Shallow Foundations.....	10-4
10.3 Foundation Design Requirements and Recommendations.....	10-4
10.3.1 Foundation Style Selection.....	10-5
10.3.2 Site Considerations.....	10-5
10.3.3 Soils Data.....	10-5
10.3.3.1 Sources of Published Soils Data.....	10-6
10.3.3.2 Soils Data from Site Investigations	10-6
10.4 Design Process.....	10-10
10.5 Pile Foundations.....	10-11
10.5.1 Compression Capacity of Piles – Resistance to Gravity Loads	10-12
10.5.2 Tension Capacity of Piles	10-15
10.5.3 Lateral Capacity of Piles.....	10-18
10.5.4 Pile Installation	10-20
10.5.5 Scour and Erosion Effects on Pile Foundations	10-21
10.5.6 Grade Beams for Pile Foundations	10-23
10.6 Open/Deep Foundations	10-25
10.6.1 Treated Timber Pile Foundations	10-25
10.6.1.1 Wood Pile-to-Beam Connections	10-26
10.6.1.2 Pile Bracing	10-27
10.6.1.3 Timber Pile Treatment	10-31
10.6.2 Other Open/Deep Pile Foundation Styles	10-31
10.7 Open/Shallow Foundations	10-34
10.8 Closed/Shallow Foundations	10-35
10.9 Pier Foundations.....	10-36
10.9.1 Pier Foundation Design Examples.....	10-37
10.9.2 Pier Foundation Summary	10-45
10.10 References.....	10-46

Chapter 11. Designing the Building Envelope	11-1
11.1 Floors in Elevated Buildings	11-4
11.2 Exterior Doors.....	11-4
11.2.1 High Winds.....	11-6
11.2.1.1 Loads and Resistance	11-6
11.2.1.2 Wind-Borne Debris	11-7
11.2.1.3 Durability	11-7
11.2.1.4 Water Infiltration	11-7
11.3 Windows and Skylights	11-9
11.3.1 High Winds.....	11-9
11.3.1.1 Loads and Resistance.....	11-9
11.3.1.2 Wind-Borne Debris	11-10
11.3.1.3 Durability.....	11-13
11.3.1.4 Water Infiltration	11-14
11.3.2 Seismic.....	11-15
11.3.3 Hail	11-15
11.4 Non-Load-Bearing Walls, Wall Coverings, and Soffits	11-15
11.4.1 High Winds.....	11-16
11.4.1.1 Exterior Walls.....	11-16
11.4.1.2 Flashings	11-21
11.4.1.3 Soffits	11-22
11.4.1.4 Durability.....	11-23
11.4.2 Seismic.....	11-24
11.5 Roof Systems	11-24
11.5.1 Asphalt Shingles.....	11-25
11.5.1.1 High Winds	11-25
11.5.1.2 Hail.....	11-36
11.5.2 Fiber-Cement Shingles	11-36
11.5.2.1 High Winds	11-37
11.5.2.2 Seismic	11-37
11.5.2.3 Hail.....	11-37
11.5.3 Liquid-Applied Membranes.....	11-37
11.5.3.1 High Winds	11-37
11.5.3.2 Hail.....	11-38
11.5.4 Tiles.....	11-38

11.5.4.1	High Winds	11-38
11.5.4.2	Seismic	11-43
11.5.4.3	Hail.....	11-45
11.5.5	Metal Panels and Metal Shingles.....	11-45
11.5.5.1	High Winds	11-45
11.5.5.2	Hail.....	11-46
11.5.6	Slate	11-46
11.5.6.1	High Winds	11-46
11.5.6.2	Seismic	11-47
11.5.6.3	Hail.....	11-47
11.5.7	Wood Shingles and Shakes	11-47
11.5.7.1	High Winds	11-47
11.5.7.2	Hail.....	11-48
11.5.8	Low-Slope Roof Systems	11-48
11.5.8.1	High Winds	11-49
11.5.8.2	Seismic	11-49
11.5.8.3	Hail.....	11-49
11.6	Attic Vents.....	11-49
11.7	Additional Environmental Considerations	11-52
11.7.1	Sun	11-52
11.7.2	Wind-Driven Rain	11-52
11.8	References.....	11-52
	List of Figures.....	11-58
	List of Tables	11-60

Chapter 12. Installing Mechanical Equipment and Utilities..... 12-1

12.1	Elevators	12-1
12.2	Exterior-Mounted Mechanical Equipment.....	12-2
12.2.1	High Winds	12-2
12.2.2	Flooding	12-3
12.2.3	Seismic Events.....	12-6
12.3	Interior Mechanical Equipment.....	12-6
12.4	Electric Utility, Telephone, and Cable TV Systems.....	12-6
12.4.1	Emergency Power.....	12-9

12.5	Water and Wastewater Systems	12-10
12.5.1	Wells	12-10
12.5.2	Septic Systems	12-11
12.5.3	Sanitary Systems	12-11
12.5.4	Municipal Water Connections	12-12
12.5.5	Fire Sprinkler Systems	12-12
12.6	References.....	12-12
Chapter 13. Constructing the Building.....		13-1
13.1	Foundation Construction	13-2
13.1.1	Layout.....	13-2
13.1.2	Pile Foundations	13-5
13.1.3	Masonry Foundation Construction.....	13-8
13.1.4	Concrete Foundation Construction.....	13-10
13.1.5	Wood Foundation Construction	13-12
13.1.6	Foundation Material Durability	13-13
13.1.7	Field Preservative Treatment.....	13-17
13.1.8	Substitutions	13-18
13.1.9	Foundation Inspection Points.....	13-18
13.1.10	Top Foundation Issues for Builders	13-18
13.2	Structural Frame.....	13-19
13.2.1	Structural Connections	13-19
13.2.2	Floor Framing.....	13-23
13.2.2.1	Horizontal Beams and Girders	13-24
13.2.2.2	Substitution of Floor Framing Materials.....	13-25
13.2.2.3	Floor Framing Inspection Points	13-25
13.2.3	Wall Framing.....	13-25
13.2.3.1	Substitution of Wall Framing Materials.....	13-27
13.2.3.2	Wall Framing Inspection Points	13-27
13.2.4	Roof Framing.....	13-27
13.2.4.1	Substitution of Roof Framing Materials.....	13-28
13.2.4.2	Roof Frame Inspection Points.....	13-28
13.2.5	Top Structural Frame Issues for Builders.....	13-28
13.3	Building Envelope	13-29
13.3.1	Substitution of Building Envelope Materials	13-30

13.3.2 Building Envelope Inspection Points13-31

13.3.3 Top Building Envelope Issues for Builders.....13-31

13.4 References..... 13-32

Chapter 14. Maintaining the Building..... 14-1

14.1 Effects of Coastal Environment 14-2

14.1.1 Corrosion14-2

14.1.2 Moisture 14-3

14.1.3 Weathering..... 14-4

14.1.4 Termites 14-4

14.2 Building Elements That Require Frequent Maintenance 14-5

14.2.1 Glazing14-7

14.2.2 Siding.....14-7

14.2.3 Roofs..... 14-8

14.2.4 Exterior-Mounted Mechanical and Electrical Equipment..... 14-9

14.2.5 Decks and Exterior Wood 14-9

14.2.6 Metal Connectors 14-10

14.3 Hazard-Specific Maintenance Techniques14-11

14.3.1 Flooding14-12

14.3.2 Seismic and Wind14-12

14.4 References..... 14-13

Chapter 15. Retrofitting Buildings for Natural Hazards..... 15-1

15.1 Wildfire Mitigation 15-2

15.2 Seismic Mitigation..... 15-5

15.3 Flood Mitigation 15-8

15.3.1 Elevation..... 15-8

15.3.2 Relocation..... 15-10

15.3.3 Dry Floodproofing..... 15-11

15.3.4 Wet Floodproofing..... 15-12

15.3.5 Floodwalls and Levees..... 15-13

15.3.6 Multihazard Mitigation..... 15-14

15.4 High-Wind Mitigation 15-15

15.4.1	Evaluating Existing Homes	15-16
15.4.2	Wind Retrofit Mitigation Packages	15-16
15.4.2.1	Basic Mitigation Package	15-17
15.4.2.2	Intermediate Mitigation Package	15-19
15.4.2.3	Advanced Mitigation Package	15-19
15.4.2.4	Additional Mitigation Measures	15-19
15.4.3	FEMA Wind Retrofit Grant Programs	15-19
15.5	References	15-21
Acronyms		A-1
Glossary		G-1
Index		I-1

List of Figures

Chapter 7

Figure 7-1.	Design framework for a successful building, incorporating cost, risk tolerance, use, location, materials, and hazard resistance	7-3
Figure 7-2.	Average damage per structure vs. distance from the Florida Coastal Construction Control Line for Bay County, FL	7-4
Figure 7-3.	Basic benefit-cost model	7-12

Chapter 8

Figure 8-1.	Summary of typical loads and characteristics affecting determination of design load	8-2
Figure 8-2.	Examples of tributary areas for different structural elements	8-4
Figure 8-3.	Flowchart for estimating maximum likely design stillwater flood depth at the site	8-7
Figure 8-4.	Erosion's effects on ground elevation	8-8
Figure 8-5.	Parameters that are determined or affected by flood depth	8-9
Figure 8-6.	Velocity versus design stillwater flood depth	8-17
Figure 8-7.	Lateral flood force on a vertical component	8-19

Figure 8-8.	Vertical (buoyant) flood force.....	8-20
Figure 8-9.	Breaking wave pressure distribution against a vertical wall.....	8-23
Figure 8-10.	Wave crests not parallel to wall.....	8-24
Figure 8-11.	Water depth versus wave height, and water depth versus breaking wave force against, a vertical wall	8-25
Figure 8-12.	Lateral wave slam against an elevated building.....	8-26
Figure 8-13.	Hydrodynamic loads on a building	8-28
Figure 8-14.	Scour at single vertical foundation member, with and without underlying scour resistant stratum.....	8-34
Figure 8-15.	Deep scour around foundation piles, Hurricane Ike.....	8-35
Figure 8-16.	Scour around a group of foundation piles.....	8-36
Figure 8-17.	Effect of wind on an enclosed building and a building with an opening.....	8-48
Figure 8-18.	Distribution of roof, wall, and internal pressures on one-story, pile-supported building	8-49
Figure 8-19.	Variation of maximum negative MWFRS pressures based on envelope procedures for low-rise buildings.....	8-51
Figure 8-20.	Components and cladding wind pressures.....	8-62
Figure 8-21.	Effect of seismic forces on supporting piles.....	8-69
Chapter 9		
Figure 9-1.	Load path failure at gable end	9-2
Figure 9-2.	Load path failure in connection between home and its foundation.....	9-2
Figure 9-3.	Roof framing damage and loss due to load path failure at top of wall/roof structure connection	9-3
Figure 9-4.	Load path failure in connections between roof decking and roof framing.....	9-3
Figure 9-5.	Newer home damaged from internal pressurization and inadequate connections	9-4
Figure 9-6.	Example load path for case study building	9-5
Figure 9-7.	Connection of the roof sheathing to the roof framing (Link #1).....	9-6
Figure 9-8.	Connection of roof framing to exterior wall (Link #2)	9-8
Figure 9-9.	Connection of truss to wood-frame wall	9-10

Figure 9-10.	Roof truss-to-masonry wall connectors embedded into concrete-filled or grouted masonry cell.....	9-11
Figure 9-11.	Connection of wall top plate-to-wall stud (Link #3).....	9-11
Figure 9-12.	Wall top plate-to-wall stud metal connector.....	9-12
Figure 9-13.	Connection of wall sheathing to window header (Link #4).....	9-13
Figure 9-14.	Connection of window header to exterior wall (Link #5).....	9-13
Figure 9-15.	Connection of wall to floor framing (Link #6).....	9-15
Figure 9-16.	Connection of floor framing to support beam (Link #7).....	9-17
Figure 9-17.	Metal joist-to-beam connector.....	9-17
Figure 9-18.	Connection of floor support beam to foundation (Link #8).....	9-19
Figure 9-19.	Diaphragm stiffening and corner pile bracing to reduce pile cap rotation.....	9-20
Figure 9-20.	Shear wall holddown connector with bracket attached to a wood beam.....	9-24
Figure 9-21.	Gable-end failure.....	9-25
Figure 9-22.	Gable-end bracing detail; nailing schedule, strap specification, brace spacing, and overhang limits should be adapted for the applicable basic wind speed.....	9-26
Figure 9-23.	Example of two-story platform framing on a pile-and-beam foundation.....	9-28
Figure 9-24.	Two-story masonry wall with wood floor and roof framing.....	9-29
Figure 9-25.	Steel moment frame with large opening.....	9-29
Figure 9-26.	Gable-end failure caused by high winds.....	9-31
Figure 9-27.	Hip roof that survived high winds with little to no damage.....	9-31
Figure 9-28.	Typical failure mode of breakaway wall beneath an elevated building.....	9-32
Figure 9-29.	Breakaway wall panel prevented from breaking away cleanly by utility penetrations....	9-32
Figure 9-30.	Lattice beneath an elevated house in Zone V.....	9-33
Figure 9-31.	House being constructed with a steel frame on wood piles.....	9-36
Figure 9-32.	Townhouse framing system.....	9-37
Figure 9-33.	Recommendations for orientation of in-ground pools.....	9-41
Figure 9-34.	Recommended contraction joint layout for frangible slab-on-grade below elevated building.....	9-42

Chapter 10

Figure 10-1.	Closed foundation failure due to erosion and scour undermining.....	10-4
Figure 10-2.	Near collapse due to insufficient pile embedment.....	10-13
Figure 10-3.	Surviving pile foundation.....	10-13
Figure 10-4.	Deflected pile shape for an unbraced pile	10-19
Figure 10-5.	Pier installation methods.....	10-20
Figure 10-6.	Scour and erosion effects on piling embedment.....	10-21
Figure 10-7.	Column connection failure	10-24
Figure 10-8.	Scour around grade beam.....	10-25
Figure 10-9.	Profile of timber pile foundation type.....	10-26
Figure 10-10.	Diagonal bracing using dimensional lumber	10-28
Figure 10-11.	Diagonal bracing schematic.....	10-28
Figure 10-12.	Knee bracing.....	10-30
Figure 10-13.	Section view of a steel pipe pile with concrete column and grade beam foundation type.....	10-32
Figure 10-14.	Section view of a foundation constructed with reinforced concrete beams and columns to create portal frames.....	10-33
Figure 10-15.	Profile of an open/shallow foundation	10-34
Figure 10-16.	Stem wall foundation design	10-36
Figure 10-17.	Performance comparison of pier foundations.....	10-37
Figure 10-18.	Pier foundation and spread footing under gravity loading	10-38
Figure 10-19.	Pier foundation and spread footing exposed to uplift forces.....	10-38
Figure 10-20.	Pier foundation and spread footing exposed to uplift and lateral forces	10-39

Chapter 11

Figure 11-1.	Good structural system performance but the loss of shingles, underlayment, siding, housewrap, and soffts resulted in significant interior water damage.....	11-2
Figure 11-2.	Numerous wind-borne debris scars and several missing asphalt shingles.....	11-3

Figure 11-3.	House that survived a wildfire due in part to fire-resistant walls and roof while surrounding houses were destroyed	11-3
Figure 11-4.	Plywood panels on the underside of a house that blew away because of excessive nail spacing	11-5
Figure 11-5.	Sliding glass doors pulled out of their tracks by wind suction	11-5
Figure 11-6.	Garage door blown from its track as a result of positive pressure	11-6
Figure 11-7.	A 3/8-inch gap between the threshold and door which allowed wind-driven rain to enter the house	11-8
Figure 11-8.	Window frame pulled out of the wall because of inadequate window frame attachment	11-9
Figure 11-9.	Very old building with robust shutters constructed of 2x4 lumber, bolted connections, and heavy metal hinges.....	11-10
Figure 11-10.	Unprotected cupola window that was broken	11-11
Figure 11-11.	Design pressure and impact-resistance information in a permanent window label	11-12
Figure 11-12.	Roll-up shutter slats that detached from the tracks	11-12
Figure 11-13.	Shutter punctured by roof tile	11-13
Figure 11-14.	House in Puerto Rico with metal jalousie louvers.....	11-14
Figure 11-15.	Blown-off vinyl siding and foam sheathing; some blow-off of interior gypsum board.....	11-17
Figure 11-16.	Blown-off fiber cement siding; broken window.....	11-18
Figure 11-17.	Four brick veneer failure modes; five corrugated ties that were not embedded in the mortar joints	11-18
Figure 11-18.	Typical EIFS assemblies	11-19
Figure 11-19.	Blown-off EIFS, resulting in extensive interior water damage; detachment of the gypsum board or stud blow off; two windows broken by debris	11-20
Figure 11-20.	Collapse of the breakaway wall, resulting in EIFS peeling	11-21
Figure 11-21.	EIFS with a barrier design: blown-off roof decking; severely rotted OSB due to leakage at windows.....	11-22
Figure 11-22.	Blown-away soffit, which allowed wind-driven rain to enter the attic	11-23
Figure 11-23.	Blow-off of several newer shingles on a roof that had been re-covered by installing new asphalt shingles on top of old shingles.....	11-25

Figure 11-24. Small area of sheathing that was exposed after loss of a few shingles and some underlayment 11-26

Figure 11-25. Typical underlayment attachment 11-26

Figure 11-26. Enhanced underlayment Option 1, first variation: self-adhering modified bitumen over the sheathing 11-27

Figure 11-27. Enhanced underlayment Option 1, second variation: self-adhering modified bitumen over the felt 11-28

Figure 11-28. House that used enhanced underlayment Option 3 with taped sheathing joints. The self-adhering modified bitumen tape was stapled because of bonding problems 11-29

Figure 11-29. Underlayment that was not lapped over the hip 11-30

Figure 11-30. Loss of shingles and underlayment along the eave and loss of a few hip shingles..... 11-31

Figure 11-31. Loss of shingles and underlayment along the rake 11-31

Figure 11-32. Incorrect installation of the starter course 11-32

Figure 11-33. Uplift loads along the rake that are transferred to the ends of the rows of self-sealing adhesive..... 11-33

Figure 11-34. A bleeder strip that was used at a rake blow-off 11-34

Figure 11-35. Inadequate sealing of the self-sealing adhesive at a hip 11-34

Figure 11-36. Proper and improper location of shingle fasteners (nails) 11-35

Figure 11-37. Proper and improper location of laminated shingle fasteners (nails)..... 11-35

Figure 11-38. Shingles that unzipped at the band lines 11-36

Figure 11-39. Blow-off of eave and hip tiles and some broken tiles in the field of the roof..... 11-39

Figure 11-40. Large area of blown-off underlayment on a mortar-set tile roof 11-39

Figure 11-41. Blow-off of wire-tied tiles installed over a concrete deck..... 11-39

Figure 11-42. Extensive blow-off of mortar-set tiles..... 11-40

Figure 11-43. Blown-off adhesive-set tile..... 11-40

Figure 11-44. Adhesive that debonded from the cap sheet..... 11-41

Figure 11-45. Blow-off of mechanically attached tiles..... 11-41

Figure 11-46. Blow-off of hip tiles that were nailed to a ridge board and set in mortar..... 11-42

Figure 11-47.	Damage to field tiles caused by tiles from another area of the roof, including a hip tile.....	11-42
Figure 11-48.	The fastener heads on this mechanically attached tile roof had corroded	11-43
Figure 11-49.	Area of the roof where tiles were not nailed to batten strips.....	11-44
Figure 11-50.	Tiles that were nailed to thin wood sheathing	11-44
Figure 11-51.	Tile that slipped out from under the hip tiles	11-45
Figure 11-52.	Blow-off of one of the nailers caused panels to progressively fail; cantilevered condenser platform; broken window.....	11-46
Figure 11-53.	Damaged slate roof with nails that typically pulled out of the deck.....	11-47
Figure 11-54.	Loss of wood shingles due to fastener corrosion.....	11-48
Figure 11-55.	Method for maintaining a continuous load path at the roof ridge by nailing roof sheathing.....	11-50
Figure 11-56.	Holes drilled in roof sheathing for ventilation and roof diaphragm action is maintained.....	11-51

Chapter 12

Figure 12-1.	Condenser damaged as a result of insufficient elevation, Hurricane Georges (U.S. Gulf Coast, 1998)	12-4
Figure 12-2.	Proper elevation of an air-conditioning condenser in a floodprone area; additional anchorage is recommended.....	12-4
Figure 12-3.	Small piles supporting a platform broken by floodborne debris	12-5
Figure 12-4.	Electric service meters and feeders that were destroyed by floodwaters during Hurricane Opal (1995).....	12-7
Figure 12-5.	Recommended installation techniques for electric and plumbing lines and utility elements.....	12-8
Figure 12-6.	Damage caused by dropped overhead service, Hurricane Marilyn (U.S. Virgin Islands, 1995).....	12-9

Chapter 13

Figure 13-1.	Site layout	13-3
Figure 13-2.	Typical pile notching process.....	13-4
Figure 13-3.	Improper overnotched wood pile.....	13-4

Figure 13-4. Properly notched pile..... 13-5

Figure 13-5. Typical wood pile foundation..... 13-6

Figure 13-6. Open masonry foundation 13-10

Figure 13-7. Concrete foundation 13-11

Figure 13-8. Concrete house..... 13-11

Figure 13-9. Wood decay at the base of a post supported by concrete..... 13-14

Figure 13-10. Examples of minimizing the least dimension of wood contact surfaces 13-15

Figure 13-11. Drip cut to minimize horizontal water movement along the bottom surface of a wood member..... 13-15

Figure 13-12. Exposure of end grain in stair stringer cuts..... 13-16

Figure 13-13. Deterioration in a notched stair stringer 13-16

Figure 13-14. Alternative method of installing stair treads 13-17

Figure 13-15. Connector failure caused by insufficient nailing..... 13-20

Figure 13-16. Reinforcement of overnotched piles..... 13-21

Figure 13-17. Beam support at misaligned piles 13-22

Figure 13-18. Proper pile notching for two-member and four-member beams..... 13-22

Figure 13-19. Proper use of metal twist strap ties; solid blocking between floor joists..... 13-23

Figure 13-20. Engineered joists used as floor joists with proper metal brace to keep the bottoms of the joists from twisting; engineered wood beam 13-24

Figure 13-21. Acceptable locations for splices in multiple-member girders..... 13-25

Figure 13-22. Full-height sheathing to improve transfer of shear 13-26

Chapter 14

Figure 14-1. Pile that appears acceptable from the exterior but has interior decay..... 14-1

Figure 14-2. Wood decay behind a metal beam connector 14-3

Figure 14-3. Severely corroded deck connectors 14-11

Figure 14-4. Deteriorated wood sill plate..... 14-12

Chapter 15

Figure 15-1.	The three concentric zones of defensible space	15-2
Figure 15-2.	The building envelope	15-3
Figure 15-3.	Fire spreads vertically through vegetation.....	15-3
Figure 15-4.	FEMA P-737, <i>Home Builder’s Guide to Construction in Wildlife Zones: Technical Fact Sheet Series</i>	15-4
Figure 15-5.	FEMA 232, <i>Homebuilders Guide to Earthquake Resistant Design and Construction</i>	15-5
Figure 15-6.	A house with severe damage due to cripple wall failure.....	15-6
Figure 15-7.	Common open-front configurations in one- and two- family detached houses.....	15-7
Figure 15-8.	FEMA 530, <i>Earthquake Safety Guide for Homeowners</i>	15-8
Figure 15-9.	Home elevated on piles.....	15-9
Figure 15-10.	Preparing a building for relocation	15-10
Figure 15-11.	Dry floodproofed structure	15-11
Figure 15-12.	Wet floodproofed structure	15-13
Figure 15-13.	Home protected by a floodwall and a levee.....	15-15
Figure 15-14.	FEMA P-804, <i>Wind Retrofit Guide for Residential Buildings</i>	15-15
Figure 15-15.	Wind Retrofit Mitigation Packages	15-17
Figure 15-16.	Bracing gable end overhangs.....	15-18
Figure 15-17.	Sprayed polyurethane foam adhesive to secure roof deck panels	15-18
Figure 15-18.	Continuous load path for wind-uplift of a residential, wood-frame building	15-20
Figure 15-19.	HMA grant process.....	15-21

List of Tables

Chapter 7

Table 7-1.	Examples of Flood and Wind Mitigation Measures.....	7-8
Table 7-2.	Sample NFIP Flood Insurance Premiums for Buildings in Zone A	7-19

Table 7-3.	Sample NFIP Flood Insurance Premiums for Buildings in Zone V Free of Obstruction Below the Lowest Floor.....	7-19
Table 7-4.	Sample NFIP Flood Insurance Premiums for Buildings in Zone V with Obstruction Below the Lowest Floor.....	7-20

Chapter 8

Table 8-1.	Value of Dynamic Pressure Coefficient (C_p) as a Function of Probability of Exceedance	8-23
Table 8-2.	Drag Coefficients for Ratios of Width to Depth (w/d_f) and Width to Height (w/h).....	8-29
Table 8-3.	Depth Coefficient (C_D) by Flood Hazard Zone and Water Depth	8-33
Table 8-4.	Values of Blockage Coefficient C_B	8-33
Table 8-5.	Selection of Flood Loads for F_a in ASCE 7-10 Load Combinations for Global Forces	8-37
Table 8-6.	Roof Uplift Connector Loads at Building Edge Zones.....	8-53
Table 8-7.	Lateral Diaphragm Load from Wind Perpendicular to Ridge.....	8-53
Table 8-8.	Roof and Wall Sheathing Suction Loads	8-63
Table 8-9.	Lateral Connector Loads from Wind at Building End Zones	8-63

Chapter 9

Table 9-1.	General Guidance for Selection of Materials	9-33
------------	---	------

Chapter 10

Table 10-1.	Foundation Styles in Coastal Areas	10-3
Table 10-2.	ASTM D2487 10-Soil Classifications	10-8
Table 10-3.	Advantages and Special Considerations of Three Types of Pile Materials.....	10-12
Table 10-4.	Bearing Capacity Factors (N_q)	10-14
Table 10-5.	Earth Pressure Coefficients.....	10-14
Table 10-6.	Friction Angle Between Soil and Pile (δ).....	10-15
Table 10-7.	Allowable Compression and Tension of Wood Piles Based on Varying Diameters, Embedments, and Installation Methods.....	10-18
Table 10-8.	Values of n_b Modulus of Subgrade Reaction	10-19

Table 10-9.	Advantages and Special Considerations of Pile Installation Methods.....	10-21
Table 10-10.	Example Analysis of the Effects of Scour and Erosion on a Foundation.....	10-23

Chapter 11

Table 11-1.	Allowable Basic Wind Speed as a Function of Class	11-31
-------------	---	-------

Chapter 13

Table 13-1.	Foundation and Floor Framing Inspection Points	13-18
Table 13-2.	Wall Inspection Points	13-27
Table 13-3.	Roof Frame Inspection Points	13-29
Table 13-4.	Building Envelope Inspection Points	13-31

Chapter 14

Table 14-1.	Maintenance Inspection Checklist	14-5
-------------	--	------

Chapter 15

Table 15-1.	Advantages and Disadvantages of Elevation	15-9
Table 15-2.	Advantages and Disadvantages of Relocation	15-10
Table 15-3.	Advantages and Disadvantages of Dry Floodproofing	15-12
Table 15-4.	Advantages and Disadvantages of Wet Floodproofing	15-13
Table 15-5.	Advantages and Disadvantages of a Floodwall or Levee.....	15-14

List of Equations

Chapter 8

Equation 8.1.	Design Stillwater Flood Depth.....	8-10
Equation 8.2.	Design Flood Velocity	8-16
Equation 8.3.	Lateral Hydrostatic Load.....	8-18
Equation 8.4.	Vertical (Buoyant) Hydrostatic Force	8-19
Equation 8.5.	Breaking Wave Load on Vertical Piles.....	8-21

Equation 8.6. Breaking Wave Load on Vertical Walls	8-22
Equation 8.7. Lateral Wave Slam.....	8-26
Equation 8.8. Hydrodynamic Load (for All Flow Velocities)	8-29
Equation 8.9. Debris Impact Load	8-32
Equation 8.10. Localized Scour Around a Single Vertical Pile.....	8-35
Equation 8.11. Total Localized Scour Around Vertical Piles	8-36
Equation 8.12. Total Scour Depth Around Vertical Walls and Enclosures	8-37
Equation 8.13. Velocity Pressure	8-50
Equation 8.14. Design Wind Pressure for Low-Rise Buildings.....	8-50
Equation 8.15. Seismic Base Shear by Equivalent Lateral Force Procedure.....	8-69
Equation 8.16. Vertical Distribution of Seismic Forces.....	8-70

Chapter 10

Equation 10.1. Sliding Resistance	10-10
Equation 10.2. Ultimate Compression Capacity of a Single Pile.....	10-14
Equation 10.3. Ultimate Tension Capacity of a Single Pile.....	10-15
Equation 10.4. Load Application Distance for an Unbraced Pile.....	10-19
Equation 10.5. Determination of Square Footing Size for Gravity Loads	10-40
Equation 10.6. Determination of Soil Pressure.....	10-43

Chapter 13

Equation 13.1. Pile Driving Resistance for Drop Hammer Pile Drivers.....	13-8
--	------

List of Examples

Chapter 8

Example 8.1. Design Stillwater Flood Depth Calculations	8-11
Example 8.2. Wave Slam Calculation	8-27
Example 8.3. Hydrodynamic Load on Piles versus Breaking Wave Load on Piles	8-30

Example 8.4.	Flood Load Example Problem	8-38
Example 8.5.	Roof Uplift Connector Loads.....	8-54
Example 8.6.	Lateral Diaphragm Loads from Wind Perpendicular to Ridge	8-57
Example 8.7.	Roof Sheathing Suction Loads	8-64
Example 8.8.	Lateral Connection Framing Loads from Wind	8-66
Example 8.9.	Seismic Load	8-70
Example 8.10.	Load Combination Example Problem	8-75

Chapter 9

Example 9.1.	Roof Sheathing Nail Spacing for Wind Uplift.....	9-6
Example 9.2.	Roof-to-Wall Connection for Uplift	9-9
Example 9.3.	Uplift and Lateral Load Path at Window Header	9-14
Example 9.4.	Uplift and Lateral Load Path at Wall-to-Floor Framing	9-15
Example 9.5.	Uplift Load Path at Floor to Support Beam Framing	9-18
Example 9.6.	Uplift Load Path for Support Beam-to-Pile	9-19
Example 9.7.	Uplift and Compression Due to Shear Wall Overturning	9-21

Chapter 10

Example 10.1.	Calculation for Allowable Capacities of Wood Piles	10-16
Example 10.2.	Diagonal Brace Force	10-29
Example 10.3.	Pier Footing Under Gravity Load.....	10-40
Example 10.4.	Pier Footing Under Uplift Load	10-42
Example 10.5.	Pier Footing Under Uplift and Lateral Loads	10-44

List of Worksheets

Chapter 8

Worksheet 1.	Flood Load Computation Non-Tsunami Coastal A Zones (Solid Foundation)	8-44
--------------	---	------

Worksheet 2. Flood Load Computation Non-Tsunamic Zone V and Coastal A Zone
(Open Foundation) 8-46

Worksheet 3. Load Combination Computation 8-80