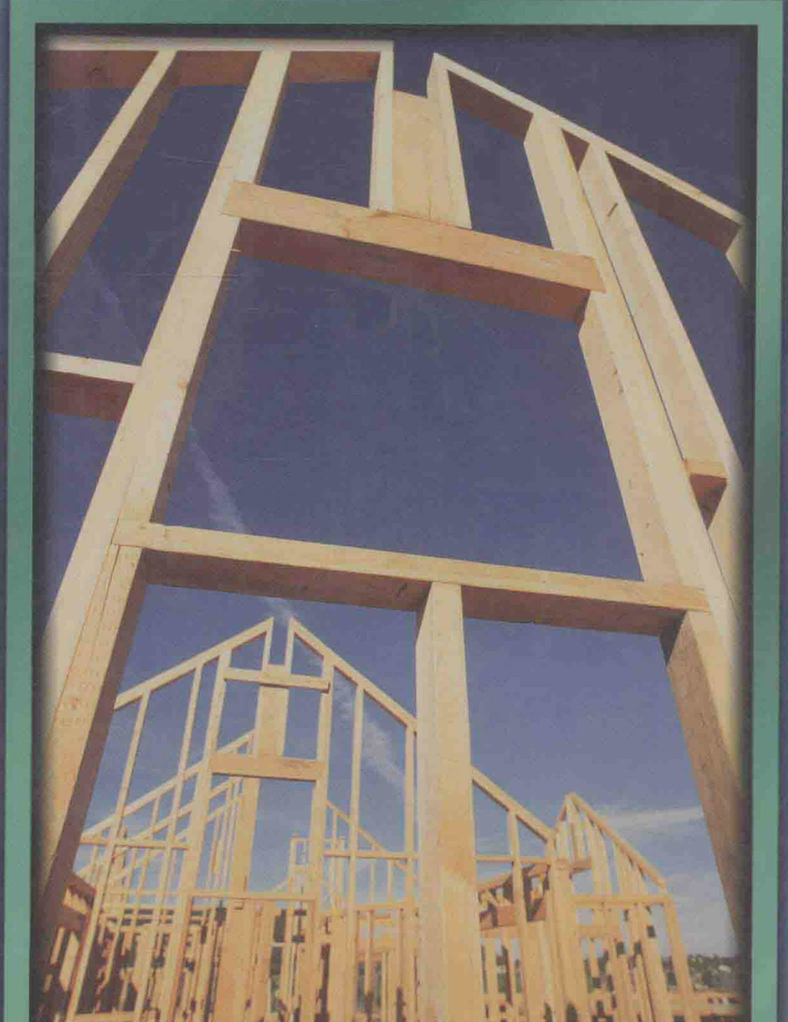
Graphic Guide to Frame Construction

Student Edition



KAFFEE KANG

ased on *Graphic Guide to Frame Construction* by Rob Thallon

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Student Edition

Kaffee Kang

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Prentice Hall
Upper Saddle River, New Jersey   Columbus, Ohio

PREFACE

Almost every year of the nine and a half years that I was with the Architecture Department at Wentworth Institute of Technology in Boston, Massachusetts, I was given the responsibility of coordinating and teaching a freshman course on wood frame construction technology. Sometimes the course was taught in conjunction with an introductory class on architectural contract drawings. Repeatedly I searched for a textbook that would address the subject matter in a manner that suited our students.

First-year students in architecture at Wentworth are probably not unique. The range of skills and life experiences they possessed was diverse. The majority of the students came directly from high school where their most relevant exposure to architecture was a drafting class. There were also some older students who, because they had worked as skilled laborers in the construction industry, were ready to challenge the knowledge of their instructors. Although most students were American, Wentworth had its share of foreign students whose struggle with English made learning new construction terms that much more difficult. With few exceptions, the students needed help in developing their study, learning, organizational, visual, and conceptual thinking skills. The instructor's challenge was to actually teach and not merely present new information. The rudimentary skills and the lack of relevant experiences among our students forced me to identify and extract from the wide body of knowledge of wood frame construction technology the most fundamental aspects and components that could form a foundation upon which further study of architecture could rest. My goal was to teach the ability to visualize and synthesize basic concepts of wood frame construction technology. To this end, I never emphasized the memorization of facts, but stressed working out construction details and thinking through construction problems.

Toward the end of my tenure at Wentworth, I found Rob Thallon's *Graphic Guide to Frame Construction* advertised in the magazine *Fine Homebuilding*. The many lucid and beautifully delineated drawings focus on wood frame construction in great detail and with comprehensiveness. The book, however, was intended for use as a reference text for professionals and practitioners. Although the illustrations were close to exactly what I had been searching for, our students still needed more explanatory text.

When Prentice Hall approached me to write a student edition of *Graphic Guide to Frame Construction*, I saw the opportunity to customize a textbook for the type of students I was accustomed to teaching. The information and organization of the book are derived in large part from my lectures at Wentworth.

SCOPE

This book provides an overview and introduction to the technology of wood frame construction for students of architecture and related fields. It is intended for those with little or no background knowledge in the subject. It is written from an architect's perspective, which places the emphasis on principles and concepts over techniques and methods of construction. Unlike Thallon's book, this book is intended for use as a textbook, to be read in sequence. To this end, only the most common construction details from his book have been included. The reader should refer to Thallon's text for a more extensive selection of details. The scope of the book also diverges from Thallon's in that background information has been added which the Thallon book assumed the reader already knew. Photographs and illustrations have been taken from other sources to accompany this additional information. Like Thallon's original book, the scope of the book is limited to topics related to the structure and protective enclosure of the building. Discussions of mechanical and electrical systems and interior finishes are not included.

ORGANIZATION

The chapter sequence generally corresponds to the sequence of technical divisions established by the Construction Specifications Institute in its Masterformat standard. This sequence also generally corresponds to the sequence of actual construction. Within each chapter, new terms are highlighted in *italic* and listed at the end of the chapter and defined in the Glossary at the end of the book. In addition to the new terms, there are three types of tools for teaching and learning at the end of each chapter. A review outline is provided to assist the student in recalling the main points of the chapter. This outline can be used as a study guide for tests. It can help students organize their notes and can be used as an agenda for a review session. Ten review questions are included to test the students' understanding of the chapter. These questions can be used in review sessions or they can be used to launch classroom discussions. Five exercises are included at the end of each chapter to promote student exploration of new concepts. Exercises can be assigned to individuals or groups of students outside the classroom. Some exercises can be done in the classroom. The exercises emphasize direct experience and visual presentation of the students' experiences.

LIMITATIONS

Modern wood frame construction has been in use for over a century. Through the years, construction details and terminology have developed according to local practices. Variations in construction practices are based on regional differences in climate, codes, available materials, topography, and aesthetic traditions. This book makes a good faith effort toward explaining the conceptual bases common to wood frame construction of all regions.

This book is a beginning to the study of wood frame construction technology. A major lesson of this book is the importance of good judgment based on continual learning and research in the practice of architecture. A good designer or builder will draw upon many sources of information and experience in resolving particular conditions and applications. The author and the publisher do not warrant nor assume any liability for the use of any information contained within the book for any particular purpose. Consult additional sources of information and seek expert advice where appropriate.

ACKNOWLEDGMENTS

Finally, I would like to thank the following reviewers for their comments and helpful suggestions: Douglas M. Beitel, College of Lake County; Charles W. Graham, Texas A & M University; Edward Kime, University of Toledo; and Clifford O. Reid, State University of New York at Farmingdale.

CONTENTS

CONTEXT

1

Before entering the very focused realm of wood frame construction technology, it is helpful to understand the context in which it has developed and is practiced today. A brief history of both technology and design highlights the close interrelationship of these two aspects of architecture. A good understanding of technology is invaluable to the student of architecture, for it is only through technology that good design can be realized.

Also in this chapter, an overview of the design and construction process highlights the importance of technology in each phase of the process of realizing a construction project. The roles of the architect and the contractor are distinguished with regard to the understanding of technology that each must possess. And finally, regulatory constraints are presented as additional factors that affect both the design and technology of a building. Codes should always be consulted for a specific project or particular construction application.

HISTORY

Residential wood frame construction constitutes a major sector of the building industry in the United States today. Although wood frame construction is also used for other types of buildings, its predominant use is in houses. In fact, housing starts are a standard indicator used to determine the state of the economy. The history of the development of residential wood frame construction is one that can be traced back to the birth of the nation.

Technology

In the 17th and 18th centuries, when the early settlers began to build homes, barns, and other structures, they utilized the craft of the *braced frame* they brought from Europe *(see Figure 1.1).* Skilled carpenters built structures of heavy *hand-hewn* timbers joined by *mortise and tenon* and other wood joints. The process was a long one that required extensive skill and labor. Trees would first be felled and then the logs formed into *posts* and *beams*. A craftsman, skilled in wood joinery, would direct the design and erection of the structure. Because hand-forged nails were too expensive to use, the design of the wood joints was critical to the structural integrity of the building. The combined strength of members of the entire community was required to erect the structure in the traditional "barn raising" or "house raising."

In the early 19th century, house building in the United States was dramatically and irreversibly changed with the invention of the *balloon frame (see Figure 1.2).* This construction system, nicknamed *stick framing,* utilized smaller pieces of lumber, that were inexpensively mass produced by the new power mills of the Industrial Revolution. These studs, joists, and rafters were light and easy to handle for one or two workers. Cut nails were manufactured and used to join the lumber pieces. Erection of the balloon frame was quick and did not

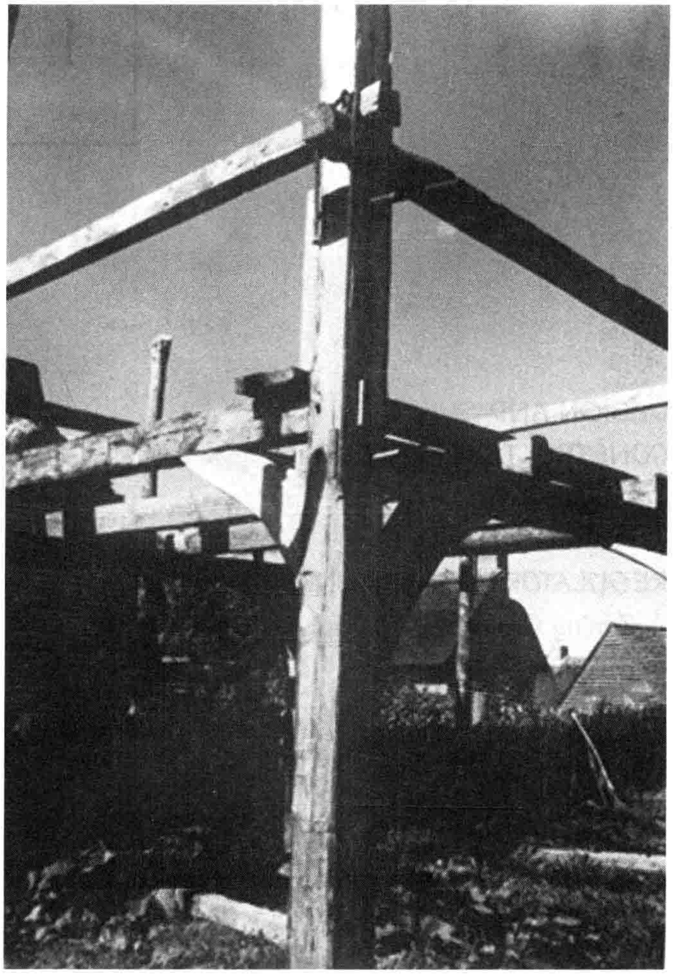

Figure 1.1 *Framing in colonial America was a skilled craft brought over from Europe. Trees were felled on site and hand hewn into timbers. Wood joints instead of nails were used to join timbers.* (Photo of Sturbridge Village, MA by author.)

require many or highly skilled workers. House building soon became an industry.

Platform Frame

The balloon frame was eventually superseded by the platform frame, which is the system used today *(see Figure 1.3)*. In a balloon frame, the wall studs are long and continuous from the foundation to the bottom of the roof. A 1 × 4 *ribbon* is let-in the wall studs to support second floor joists. In the platform frame, wall studs are only one story high. The floor construction of each floor is supported directly by the walls below it. This provides the platform frame with many inherent advantages over the balloon frame. The shorter studs are easier to handle and are less likely to have structurally limiting flaws, such as warping, knotholes, etc. In platform frame construction, a floor platform is completed before the walls of the next floor are erected. In the process, the floor platform becomes a good level working surface for the next stage of construction. Overhangs and large window openings are easier to achieve in platform framing. And there is a natural fire stop at each floor level.

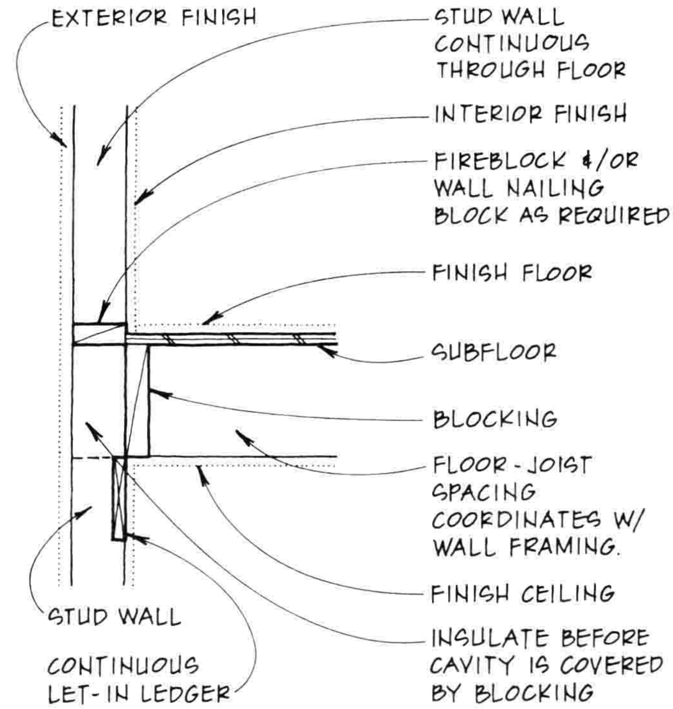

Figure 1.2 *The balloon frame is characterized by the use of long continuous studs and a ribbon or ledger to support second floor joists.*

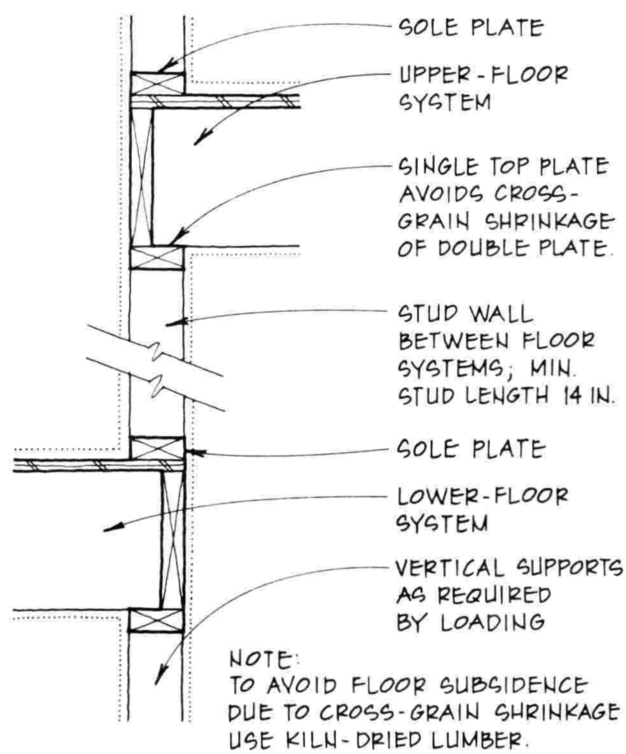

Figure 1.3 *With the platform frame, multiple floors are possible because wall studs are only one floor high, supporting the floor platform above it.*

Design

Equally important, and parallel to the development of construction technology, was the evolution of the architecture of the American house. In the 17th and 18th centuries, some of the wealthier settlers built houses that mimicked those they had left in England. These houses were usually very formal, symmetrical, and decorated to match the lifestyle and social standing of the privileged class. But the majority of the new American settlers were not wealthy or did not believe in the social structures they left behind in Europe. From the beginning, they wanted to pioneer a new life for themselves in their new land. The lifestyle of most of the early Americans was frugal and unpretentious. The houses they built were simple, functional, and unadorned. Wood was often left natural and unpainted. Room arrangements were open and flowing. Rooms were added as the family grew, leading to asymmetrical, meandering floor plans *(see Figure 1.4)*. A deep and close bond existed between these early Americans and their land. A family's survival depended on its land, its only abundant possession. Their houses expressed this connection to the land through porches and verandas from which they could view their land.

These characteristics of early American houses were carried into the *Shingle Style*, the first uniquely American style of architecture, developed in the late 19th century. It is significantly appropriate that the Shingle Style is a style of residential architecture that utilized light wood frame construction. Without the invention of the balloon frame, the Shingle Style would not have been possible. This technology liberated house building. The light framing elements made possible the faceted sheltering roofs and the wall bulges and indentations that created a sense of volume instead of mass. With their unadorned and natural materials of fieldstone and wood shingles, Shingle Style houses perched on their sites as natural outcroppings of the land *(see Figure 1.5)*.

The American tradition continued to develop through the 20th century in the work of Frank Lloyd Wright, one of the first great modern American architects. Wright's *Prairie Style* homes captured the essence of Midwestern life and shared many of the traditions of American residential architecture *(see Figure 1.6)*. Today, residential architecture continues to be a pioneering segment of American architecture. And the architects who master the principles of wood frame construction have a versatile and powerful tool of knowledge to help them create the innovative designs of the future.

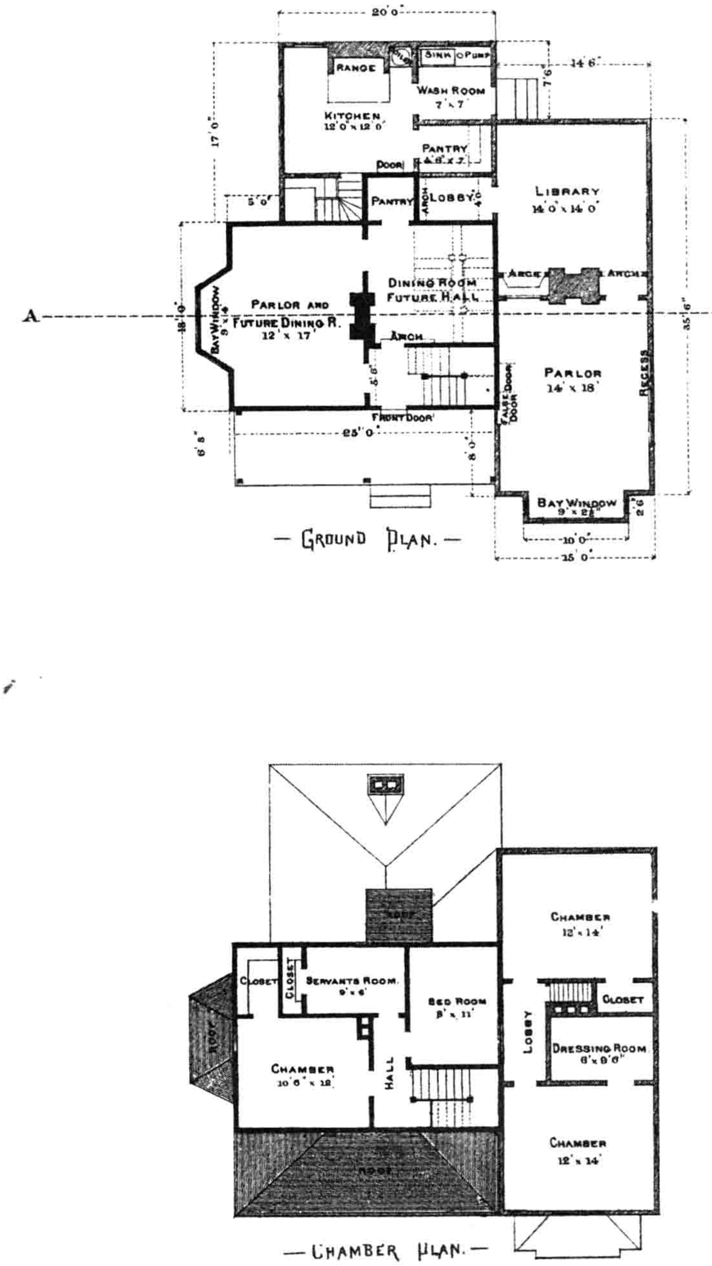

Figure 1.4 *American houses were distinctly different from European ones. Floor plans were assymmetrical and less formal. Porches and verandas were an important element of the American house. Additions were common as the family grew. This 19th-century house plan included the basic house and two potential additions, one to the side and one in the back.* (Drawing from Woodward's National Architect of 1869, courtesy of Dover Publications, Inc.)

Figure 1.5 *The W. Watts Sherman house in Newport, Rhode Island, as designed by H. H. Richardson in 1874, is a good example of the Shingle Style of architecture. Characteristics that were distinctly American include the use of materials in their natural state, the informal and assymmetrical floor plan, and porches and verandas. The Shingle Style's very volumetric appearance was made possible by the development of stick framing.* (Photo by author.)

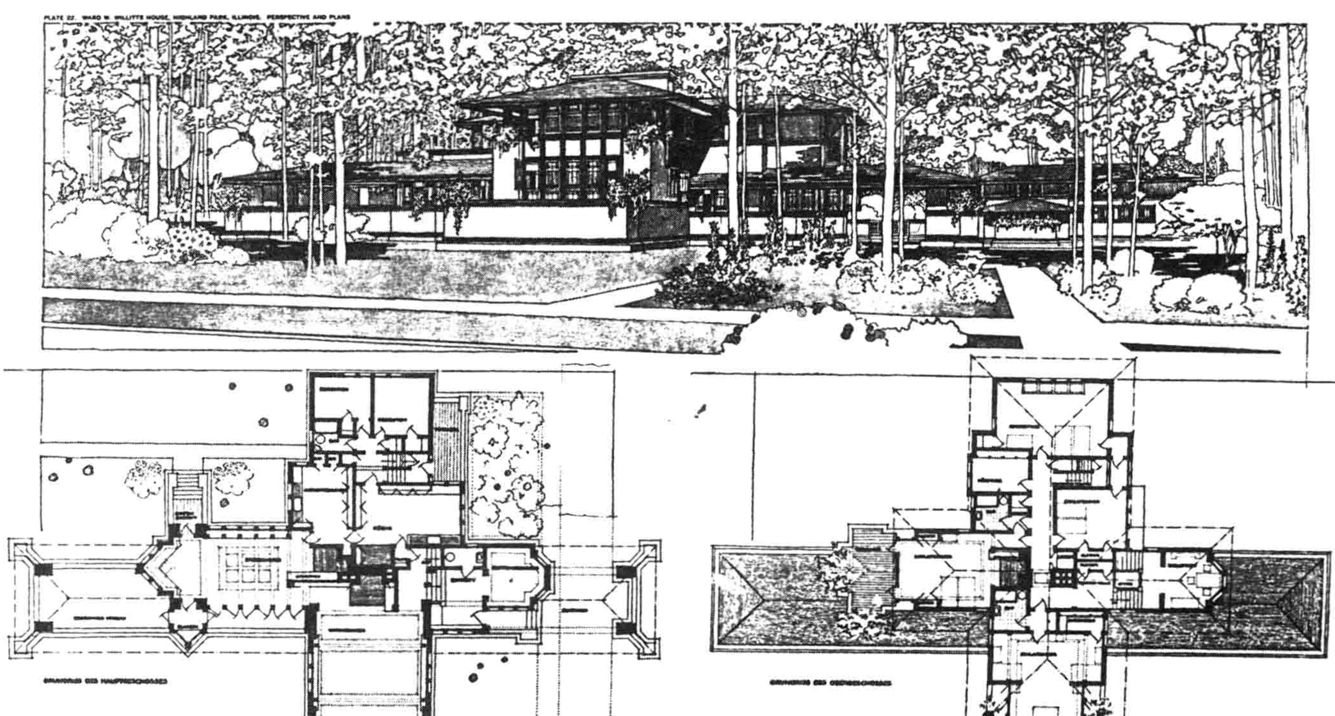

Figure 1.6 *The Willitts house in Highland Park, Illinois, as designed by Frank Lloyd Wright in 1902, is a good example of the architect's Prairie Style. It exhibits many elements characteristic of American residential architecture: the meandering informal floor plan, porches, and the use of materials in their natural state. Its affinity to its natural surroundings was one of the primary design goals of Wright's "organic architecture."* (Frank Lloyd Wright Drawings are Copyright © 1997 The Frank Lloyd Wright Foundation, Scottsdale, AZ.)

DESIGN AND CONSTRUCTION PROCESS

The current conventional process of design and construction involves three major participants: the owner, the architect, and the general contractor. (Although not recommended by the American Institute of Architects, many houses are built without the benefit of an architect because many states do not require one for small buildings.) The owner hires both the architect and the general contractor. There is no contractual relationship between the architect and the general contractor in the conventional project. There are other types of relationships which have evolved and gained popularity. Consult *The Architect's Handbook of Professional Practice,* published by the American Institute of Architects, for detailed explanations of alternate contractual relationships.

Project Roles

The relationships the owner has with the architect and with the general contractor are quite distinct. The architect serves as an agent to the owner, representing the owner's interests throughout the progress of the project. The general contractor is a vendor to the owner, representing the general contractor's own interests in the project.

The architect is responsible for the design of the building, including the construction details, but not for construction techniques, methods, or sequences. The architect must describe in drawings and words, the finished result desired. In order to do this, the architect must be able to draw upon stored knowledge and evaluate available information to find the best solution for any given technological problem. It is the contractor's responsibility to produce the desired result utilizing his knowledge of technology. The contractor must understand the sequence of construction and be skilled in the techniques of the construction trades. The knowledge of the architect and the contractor are overlapping, but their perspectives are quite distinct.

The architect may need to hire specialists, known as *consultants*, to help with the work. Engineers, landscape architects, and interior designers are examples of consultants. The architect and her consultants form the *design team.* The general contractor may also need to hire specialists, known as *subcontractors*, to help him with the work. Carpenters, electricians, and masons are examples of subcontractors. The owner may also hire her own professional consultants under separate contracts to help with the project. Together, the owner and her consultants, the architect and her consultants, and the general contractor form the *project team.* Because of the contractual relationships between the members of the project team, all communication must follow prescribed channels to prevent miscommunication and misappropriation of responsibility.

Project Process

The conventional project process consists of four phases of work: *design, contract documents, bidding and negotiations,* and *contract administration.* During the design phase, the architect explores alternative designs with the owner, respecting the owner's budgetary, functional, and design goals. Many quick sketches are made during this phase to both help the architect think and work out ideas and to help the architect communicate with members of the design team and with the owner. A good understanding of construction technology will prevent the inception of "unbuildable" designs during this phase. And a design that respects the principles of technology can be developed and built with minimal divergence from the initial design concept.

Once a design is accepted, the architect prepares documents for construction in the contract documents phase. During this phase, very precise drawings and written specifications are produced to allow general contractors to accurately price the construction and to communicate the design intent to the builder. The value of a good understanding of construction technology during this phase is obvious.

When contract documents are completed, they are distributed to contractors for bidding. In the public sector, there are no negotiations of the price after bidding. In the private sector, there is room for negotiation after bids are submitted. The architect reviews the bids with the owner and makes a recommendation for the award of the construction contract.

During the construction phase, the architect visits the site periodically to ensure that the general contractor builds the project in accordance with the contract documents and the design intent. Again, the value of a good understanding of construction technology during this phase is immeasurable.

REGULATORY CONSTRAINTS

Every construction project, no matter how small, must meet two types of government regulations: the local *zoning ordinance* and the state *building code.* There are, of course, other regulations that may apply to some buildings, such as an architectural barriers code, but these are the only two that apply to each and every construction project.

Zoning Ordinance

The primary purpose of a zoning ordinance (also known as a zoning code or zoning bylaw in some communities) is to regulate land use. It is the mechanism by which municipalities (towns and cities) plan for development in their communities. With this purpose in mind, it is sensible that the *jurisdiction* of zoning ordinances be municipal. Each town or city needs to be able to regulate its own land use and development.

The zoning ordinance demarcates many land use zones within a municipality. Each zone has its own set of requirements regarding land use and construction. Zoning requirements may be highly restrictive, as is usually the case with special historic districts or single-family residential zones, or they can be less restrictive, as is usually the case with industrial zones. Zones are normally defined in a hierarchical fashion so that within any one zone, you may build anything allowed in that zone as well as anything allowed in a more restrictive zone, but not anything allowed in a less restrictive zone. For instance, in a commercial district, a single-family residential use (more restrictive) would be allowed, but a factory use (less restrictive) would not be allowed.

In addition to the types of buildings that may occupy a site, zoning ordinances also regulate the physical characteristics of each land use zone. The density of buildings, for instance, can be controlled by lot size, *setbacks*, height limitations, and floor area ratios (FARs). Setbacks are the distances from the property lines which must be maintained clear of buildings. The FAR is the ratio of a building's total floor area (all floors combined) to the area of the property. As an example, if the allowed FAR is one and there are no setback requirements or height limitations for a particular property, you may build a single story building that occupies the entire property, or alternatively you may build a two story building that occupies half the site, or a three story building that occupies a third of the site, etc. Parking and signs are other items that are often regulated in zoning ordinances.

Sometimes special districts are created to preserve the historic character of a particular area. These districts can often be very restrictive, dictating colors, materials, and styles of architecture. With the exception of these special districts, zoning regulations must stop short of infringing upon individuals' rights. A zoning ordinance can be used to ensure that houses in a certain neighborhood are set back a minimum distance from the street, creating a suburban or rural character. But if your neighbor wants to build a house which you consider detractive to the neighborhood, there is very little recourse to prevent it.

Building Codes

Unlike zoning ordinances, building codes are applicable statewide. However, there are codes that have been adopted independently by more than one state. The Uniform Building Code (UBC) has been adopted by many western states and the Building Officials and Code Administrators (BOCA) code has been adopted by many eastern states. A statewide building code or, in some cases, a regional building code is sensible because there are regional factors such as snow loads, seismic (or earthquake) loads, and heating and cooling loads that vary from region to region.

The primary purpose of a building code is to ensure public safety. To this end, the building code regulates all construction as it might affect safety. Typical items that building codes regulate are *egress* (exits), fire ratings, and ventilation requirements. There are some items that building codes and zoning ordinances both regulate. Floor areas and building heights are usually regulated by both. Whenever more than one code regulates the same item, the more restrictive requirement applies.

In construction, both the building code and the zoning ordinance take precedence over any textbook or reference standard. It is important, then, that codes be reviewed in the early phases of a project to understand their impact on design and construction.

REVIEW OUTLINE

I. History
- A. Technology
  1. Braced frame
  2. Balloon frame
  3. Platform frame
- B. Design
  1. American residential architecture

II. Design and construction process
- A. Project roles
  1. Owner
  2. Architect
  3. General contractor
  4. Consultants
  5. Subcontractors
- B. Project process
  1. Design
  2. Contract documents
  3. Bidding and negotiations
  4. Contract administration

III. Regulatory constraints
- A. Zoning ordinance
  1. Jurisdiction: municipal
  2. Purpose: to regulate land use
- B. Building code
  1. Jurisdiction: statewide
  2. Purpose: to protect public safety

NEW TERMS

balloon frame
beam
bidding and negotiations phase
braced frame
building code
consultant
contract administration phase
contract documents phase
design phase
design team
egress
hand hewn
jurisdiction
mortise and tenon
post
Prairie Style
project team
ribbon
setback
Shingle Style
stick framing
subcontractor
zoning ordinance

REVIEW QUESTIONS

1. What characteristics of the braced frame made house building a highly skilled and time-consuming craft?
2. How did the balloon frame transform house building into an industry?
3. How is the platform frame different from the balloon frame?
4. What were the characteristics of early American homes that made them distinct from European homes?
5. Who are the three major participants in a construction project?
6. Who are the members of the design team?
7. Who are the members of the project team?
8. What are the four phases of a conventional construction project and what is the architect's role in each of these phases?
9. Name three examples of regulations which might be found in zoning ordinances.
10. Name three examples of regulations which might be found in building codes.

EXERCISES

1. Investigate the requirements of the residential zoning districts in a nearby municipality. Zoning ordinances are usually available for purchase at a reasonable cost at a town's or city's administrative offices. Zoning ordinances are also usually available for reference at local libraries. Examine the zoning map that is part of the zoning ordinance. Locate the residential districts. There may be one or there may be several. They are often designated by the letter R. Read about the requirements of each residential zone. Make a chart illustrating the results of your research. Use diagrams and graphic symbols as much as possible.
2. Find a buildable site in your area. If there are no buildable sites, pick a property that already has a building on it. Find the site on the zoning map. Determine in which zone the property lies. Read about the requirements of that zone in the zoning ordinance. If your property already has a building on it, determine if the building conforms to the zoning ordinance. Draw a site plan showing the restrictions imposed by the zoning ordinance. Locate a proposed building or the existing building on the site plan. Be sure the proposed building conforms to the zoning ordinance.
3. Make an organizational chart showing the relationships of the owner, architect, general contractor, consultants, and subcontractors for a conventional building project. Draw lines between parties that would have contractual relationships. On the organizational chart or as an overlay, draw the paths of communication during each of the four phases of a project—design, contract documents, bidding and negotiations, and contract administration.
4. Sketch floor plans of a residence to which you have access. Quick freehand sketches can be made neatly and to scale with the aid of graph paper. Find the appropriate sections of the building code that apply to the building. Building codes are usually available for purchase from a state's administrative offices and for reference at local libraries. Identify and highlight on the plans those features that are not in compliance with the current building code.
5. In a residential neighborhood, find a house that exhibits design characteristics of traditional American residential architecture. Find another house that does not. Sketch both houses and do a side-by-side comparison of design characteristics of the two houses in a graphic or visual manner.

FOUNDATION MATERIALS 2

The foundation serves the critical structural function of tying a building to the ground. The foundation is in constant contact with the soil and the moisture in the ground. As at least a partially underground structure, the foundation is very difficult to modify once it is built. For these reasons, permanence should be a primary objective of foundation construction and materials selection. In the 19th century and the early part of the 20th century, foundations were constructed of stone or brick. Now the most widely used foundation materials are concrete and concrete block. And more recently, wood foundations have been introduced.

CONCRETE

Concrete is a strong, durable, and versatile construction material made from cement, aggregates, and water. *Cement* is a fine powdery substance manufactured from a variety of mineral ingredients. It is the *fine aggregate*, consisting of sand, and *course aggregate,* consisting of gravel or crushed stone, that accounts for most of the volume and strength of concrete. *Potable water* mixes with the cement to produce a paste that surrounds and coats the aggregate particles.

In mixing concrete, the proportions of the ingredients are important in determining final strength. A *well-graded aggregate* contains a range of aggregate sizes to achieve a close and even packing of aggregate particles in the concrete. Small aggregate particles fill in the spaces between large aggregate particles, and each aggregate particle is completely coated with the cement paste. The desired result is no voids, because voids translate into weak spots in the concrete.

The *water/cement (w/c) ratio* affects the *workability* of concrete as well as its strength. A higher w/c ratio makes for a more pliable mix that can be handled, placed, and finished more easily. A lower w/c ratio is less workable, but achieves a greater ultimate strength. In addition to these essential ingredients, *admixtures* may be added to the concrete mix which alter various characteristics of the concrete. Admixtures can be used to alter color, durability, workability, strength, and curing time.

Cast-in-Place Concrete Construction

The concrete construction system used in foundations is known as *cast-in-place concrete* because the concrete is constructed at the site, in its final position.

When first mixed, concrete is a semifluid material. Forms are required to contain the mixture until it has hardened or set. Wooden *formwork,* which is constructed at the site, can be made into any shape and size, but must be dismantled after use. Formwork can be prefabricated from wood or metal into panels that are erected at the site and can be reused for other projects. Prefab formwork is more cost effective and less labor intensive than site-built formwork. But prefab wood formwork is usually limited to a predetermined height of 8 ft. which corresponds to its wood components. When forming a wall, *form ties* are required to keep the formwork evenly spaced along the entire height of the wall. Before the concrete is placed, *form releasing compound* is applied to keep the concrete from bonding to the surface of the formwork.

More recently, prefabricated rigid foam formwork has been developed for residential construction. In this system, the rigid foam panels are left in place permanently to provide insulation below grade. The foam panels are easy to cut into any desired size. Plastic form ties are used, eliminating the sometimes unsightly rust stains caused by conventional form ties. This type of formwork is more expensive than traditional formwork. The rigid foam insulation on the exterior of the foundation wall requires a protective layer to prevent damage to the insulation. This would certainly impact the construction details and likely the cost of construction.

Concrete should be placed, and not "poured," from a height of no more than 3 to 4 ft. above its final resting place to prevent *segregation* of its ingredients. After it is placed, concrete should be vibrated by hand or by machine to eliminate air pockets which will compromise its strength.

Finally, concrete must be left to *cure* for 28 days to achieve its design strength. During the curing process, the water and cement in the concrete undergo a chemical reaction known as *hydration*. Because this is a chemical reaction, it requires the full 28 days to complete, regardless of the environmental conditions. As it is curing, concrete may require protection from environmental conditions that are unsuitable for hydration and potentially damaging to the concrete. The ideal temperature range for curing is 50°–70°F. If the air temperature falls below this range, the concrete may be protected with plastic sheeting. The sheeting helps to keep the *heat of hydration*, the heat produced during the curing process, close to the surface so the water within does not freeze. A freeze-thaw cycle has a devastating effect on the strength of concrete before it is cured. If air temperatures are too high, curing concrete must be protected from drying. Spraying or sprinkling the concrete with water will keep the water within from evaporating before the curing process is complete.

Concrete Foundations

In residential wood frame construction, an 8- to 10-in. concrete wall foundation is usually sufficient to carry building loads and resist soil pressures. Depending on specific loading and soil conditions, steel reinforcement may be required. Building codes and expert advice should be consulted. Round or square piers of varying sizes can be constructed for concentrated load conditions. Round piers are easily formed using inexpensive prefabricated fiber forms which can be left in place after construction is complete.

There are many advantages to using concrete for foundations. It is a very versatile material that can be formed into any size and almost any desired shape, including curves. Its surface can be finished in a variety of textures. And because it is a monolithic material, cracks in the properly constructed concrete wall are rare. Although water will not penetrate, moisture will migrate through the porous material. Dampproofing on the outside surface of concrete foundation walls will protect interior basement spaces from the accumulation of excessive moisture. The major shortcomings of concrete foundations are the need for and cost of formwork and the dependence on environmental conditions during construction.

CONCRETE BLOCK

The *concrete masonry unit (CMU)* is commonly called concrete block. This building material is manufactured from concrete, cast and formed in reusable forms. A variety of different shapes, styles, and sizes are made for various applications *(see Figure 2.1)*. The most typical is the standard hollow core CMU. The hollow cells at the center of these blocks make them light and easy to handle and allow the insertion of steel reinforcing bars and *grout* for added strength.

The *nominal size* of a standard CMU is 16 in. long and 8 in. high. The *actual size* of the block is 15 5/8 in. long and 7 5/8 in. high. Mortar joints account for the difference of 3/8 in. in both length and height dimensions. Several standard widths of CMUs are available. Common nominal widths are 4, 6, 8, 10, and 12 in. Again, the corresponding actual widths are 3 5/8, 5 5/8, 7 5/8, 9 5/8, and 11 5/8 in. Each *course*, or horizontal row, of CMU construction measures 8 in., consisting of a row of 7 5/8-in. blocks and a 3/8-in. mortar joint. A *wythe* is a single thickness of CMU.

Concrete Block Foundations

In wood frame construction, the most common concrete block foundation wall consists of a single 8-in. wythe of CMU. Sometimes a 6-in. wythe is used when the wall is of limited height and building loads and soil pressures are light. A 10-in. or 12-in. wythe is required if the wall is very high or deep and subject to great building loads or soil pressures. Concrete block piers are usually 12 in. square. Window and door openings must be spanned with *lintels* which act like beams to distribute loads from above to either side of the opening. Common lintel materials are steel, precast concrete, and special reinforced U-shaped concrete blocks called *bond beams*.

The major advantage of CMU construction is that no formwork is required as in concrete construction. Walls can be erected quickly in almost any weather. To benefit fully from the ease of construction, foundations should be designed using the 8-in. module of CMU. The

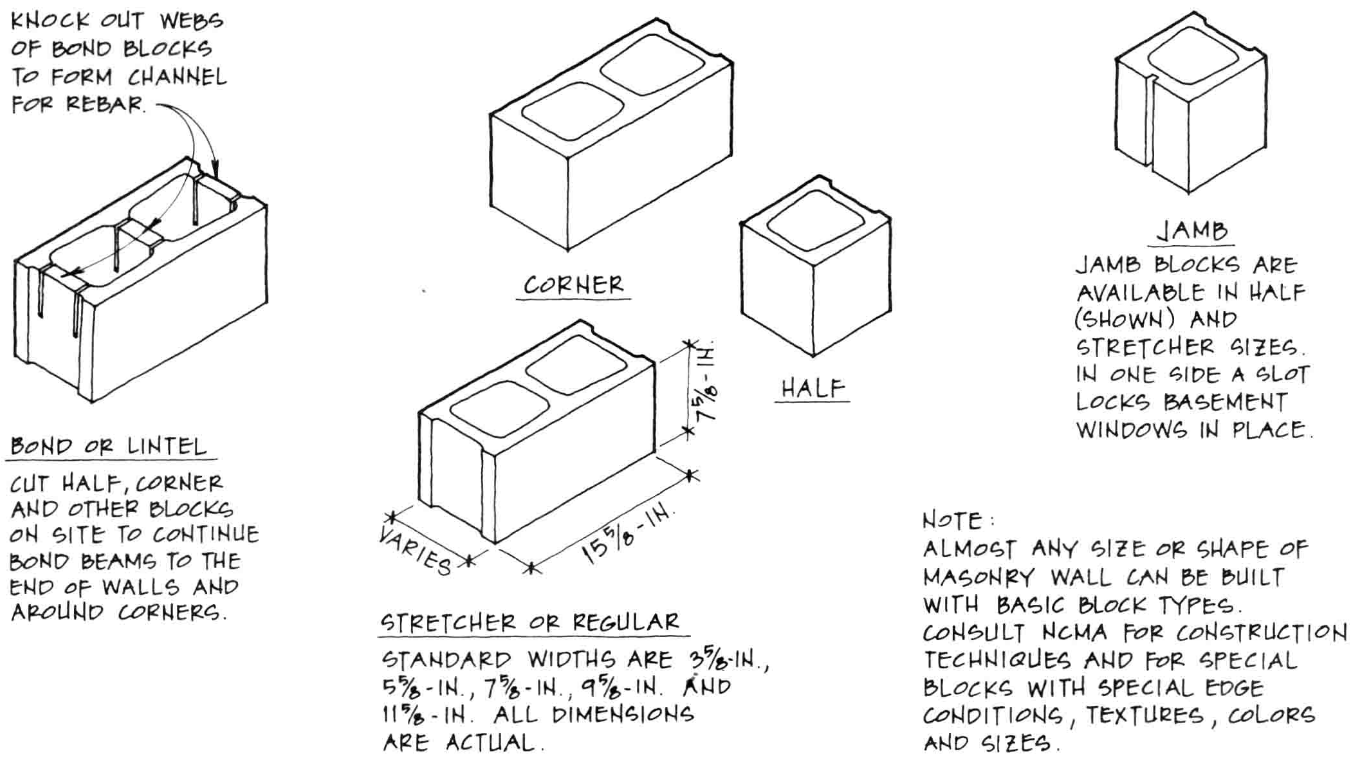

Figure 2.1 *Some basic concrete block types.*

lengths and heights of walls should be multiples of 8 in., as well as the widths and heights of window and door openings. Designing in this module minimizes the need for cutting blocks and for special sizes.

There are, however, precautions to be taken in CMU construction. Because CMU walls are not monolithic, they are subject to joint cracks. Cracks can be reduced with the addition of steel reinforcing. Even in the absence of cracks, CMUs and mortar are very porous materials, permitting the easy passage of water. For these reasons, waterproofing and a perimeter drainage system are essential. Insect infestation is another threat in CMU foundations. Soil treatment and filling the cells of the blocks can be effective in guarding against insect infestation.

STEEL REINFORCEMENT

Both concrete block and concrete can be strengthened with the addition of steel reinforcement. Concrete block and concrete are both very strong in *compression,* a force which acts on a material to squeeze it together. Steel is a good complement to these materials because its strength lies in *tension*, a force which acts on a material to pull it apart. State building codes usually specify requirements for steel reinforcement. In wall foundations, vertical steel *rebars* should be placed toward the interior faces, where tension is greatest. Horizontal rebars should be placed continuously at the tops of walls and, if required, at intermediate points along their heights *(see Figures 2.2 and 2.3).*

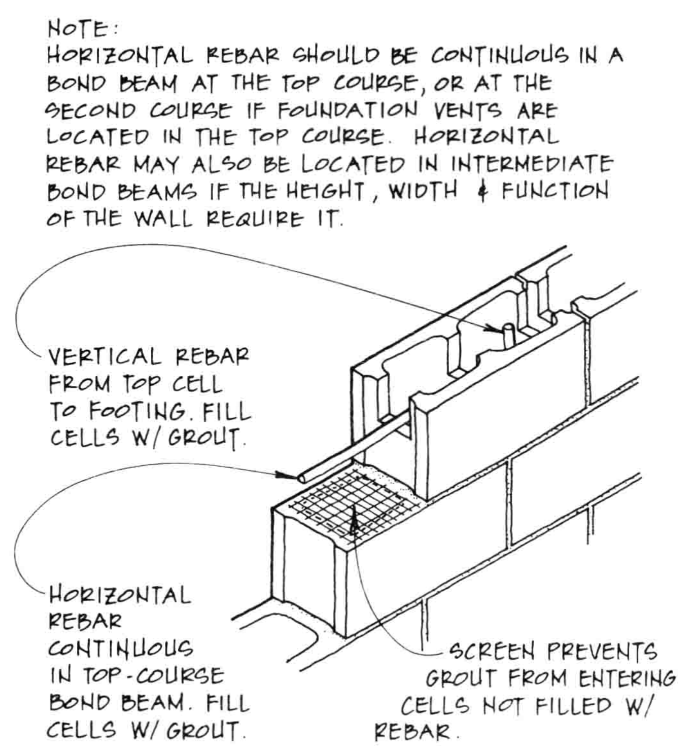

Figure 2.2 *Where lateral forces exerted by soils are high or earthquakes are possible, CMU can be reinforced vertically and horizontally. Vertical rebars are easily inserted into block cores and grouted in place. Horizontal rebars are grouted in continuously in the top course of CMU, forming a bond beam. Intermediate bond beams can be used if required.*

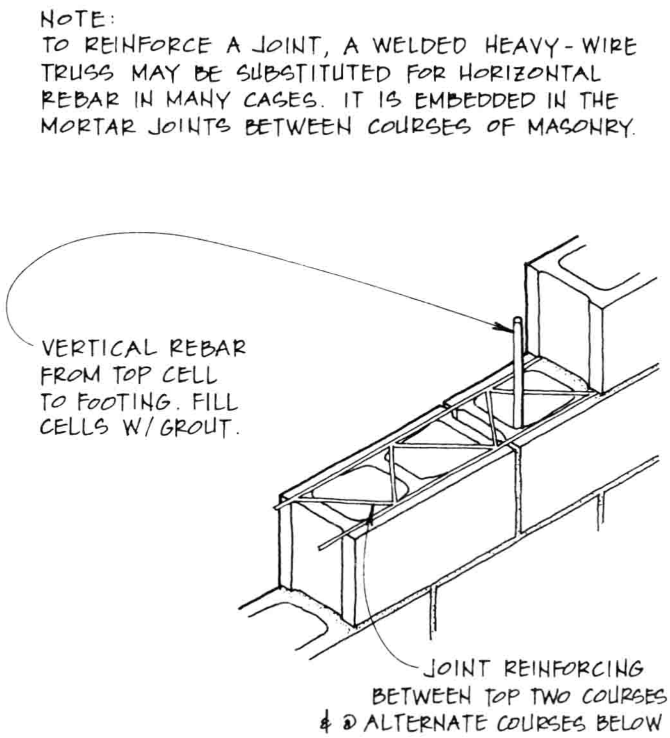

Figure 2.3 *Horizontal CMU reinforcing can also be provided with wire trusses or ladders set in mortar joints.*

WOOD FOUNDATIONS

More recently, wood has been introduced as an alternative to concrete and concrete block. Wood foundation walls are framed with pressure treated lumber and plywood. *(See chapter 4 for a discussion of wood.)* Footings are typically 2 × 8 or 2 × 10 lumber. Walls are typically 2 × 6's or 2 × 8's spaced 16 in. on center.

Wood foundations boast many advantages. They are less expensive than either of the conventional foundation materials. They can be quickly constructed in any weather. Wood foundation walls are easier to insulate and finish. The spaces between the studs can be filled with inexpensive fiberglass batt insulation, and finish materials can be secured directly to foundation wall studs. Concrete and concrete block foundation walls require additional framing for interior finishes, and more expensive rigid board insulation is recommended when contact with concrete or CMU is made. *(See chapter 10 for a discussion of insulation materials.)*

The greatest danger to wood foundations is water. Even pressure treated wood is susceptible to rot when subject to adverse moisture conditions. To protect against water damage, several precautions are required as part of the wood foundation system. Foundations must rest on a prepared gravel base to drain water away from the structure. Perimeter foundation drains must be installed to direct water away from the building. A *sump* located in the basement is required to drain basement water. Joints between plywood panels must be caulked with a high-performance sealant. A sheet of 6-mil polyethylene applied to the exterior of the foundation wall helps direct moisture away from the building. As a final precaution, although wood foundations have worked in well-draining soils, they have not been in place long enough to testify to their permanence, particularly in nonideal conditions.