

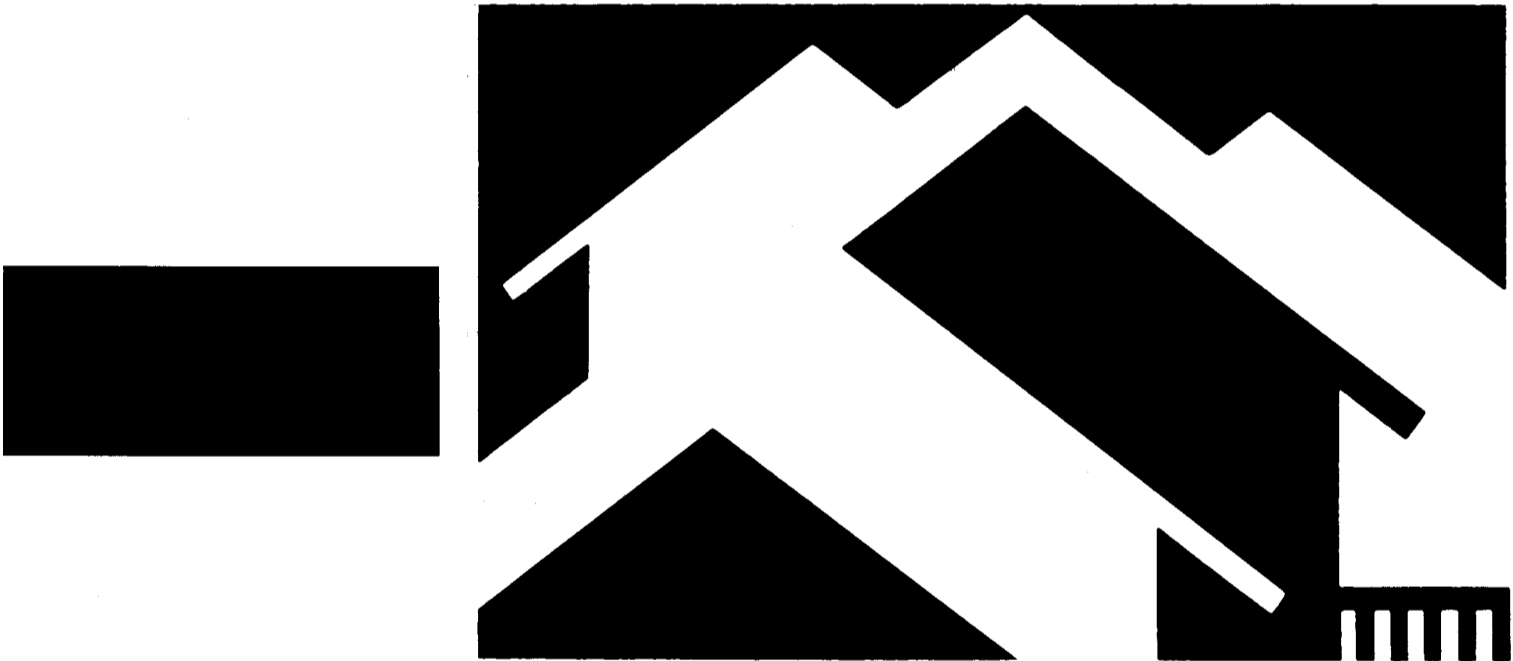


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# Wood-Frame House Construction



## Reference Abstract

This handbook presents sound principles for wood-frame house construction and suggestions for selecting suitable materials to assist the construction of a good house. The organization reflects the general progression of activity in building a wood-frame house, from initial conception to completed structure. Chapter 1 describes matters that should be considered or dealt with before beginning construction. Chapters 2-4 describe steps in laying the groundwork, framing and closing in, and completing the shell, which are usually taken one after another in the order presented. Chapters 5-7 describe later tasks that can often be done in some order other than presented. Chapter 8 discusses special topics often associated with wood-frame construction. Technical notes, annotated list of suggestions for additional reading, and glossary are provided.

**Keywords:** Wood-frame, house, construction, building materials, building codes, foundations, framing, siding, roofing, paints and stains, energy conservation, noise control, decay, termites, maintenance and repair.

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# **Wood-Frame House Construction**

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**CAUTION:** Pesticides can be injurious to humans, domestic animals, desirable plants, and fish or other wildlife—if they are not handled or applied properly. Use all pesticides selectively and carefully. Follow recommended practices for the disposal of surplus pesticides and pesticide containers.



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## PREFACE



The Forest Products Laboratory (FPL), Forest Service, U.S. Department of Agriculture, has conducted research related to wood-frame construction since 1910. Initially this work was reported in technical papers covering specific subjects. Popularized versions of some of the papers were developed to provide guidance to the homeowner as well as the builder. Eventually, the need to gather this information into a single coherent publication became evident. The first complete construction handbook, written entirely by FPL scientists O.C. Heyer and L.O. Anderson, was published in 1955 as U.S. Department of Agriculture Handbook No. 73. The handbook quickly became popular with building professionals and with the public. Educational institutions adopted it as a text and have continued to be major users.

As new technology became available and construction practices changed, the handbook became dated. It was revised by FPL scientist L.O. Anderson and published again in 1970. Slight revisions were made in 1975.

By the early **1980's** the need was recognized for a full revision. The existing text increasingly failed to reflect advances in home building brought about by the availability of new materials, the use of more manufactured components, and changes in construction techniques. Accordingly, this new edition, incorporating the up-to-date knowledge and expertise of all participants in the project, has been prepared as a cooperative effort between the NAHB National Research Center (a wholly owned subsidiary of the National Association of Home Builders) and the Forest Products Laboratory (U.S. Department of Agriculture, Forest Service), with active assistance and cooperation from organizations forming the steering committee acknowledged above.

As with previous editions, the handbook emphasizes the platform construction technique popular in North America. Information on other techniques and systems, such as the truss-framed system developed at the Forest Products Laboratory, is available from both the NAHB National Research Center and the Forest Products Laboratory.

# INTRODUCTION



This book presents sound principles for wood-frame house construction and suggestions for selecting suitable materials to assist the construction of a good house. It can be used as a working guide to modern construction practice and techniques, as a textbook, or as a standard to judge the quality of house construction. Dimensions of wood are always stated as nominal, as explained in the technical note on lumber grades.

The book's organization reflects the general progression of activity in building a wood-frame house, from initial conception to completed structure. Certain steps inevitably cut across categories or fail to fit neatly into any scheme, but the order of presentation reflects the broad sequence of the building procedure.

The first chapter describes matters that should be considered or dealt with before beginning construction.

The next three chapters—on laying the groundwork, framing and closing in, and completing the shell—describe steps that are usually taken one after the other in the order that they are set forth.

Chapters 5 through 7—on specialty items, working inside, and finishing touches—describe tasks that increasingly branch out from the ordered requirements of basic construction and can often be done in some order other than that presented here, or in parallel with each other.

Chapter 8 discusses some special topics, questions, and considerations that are often associated with wood-frame construction.

An annotated list of suggestions for additional reading and a glossary are provided at the end of the book. Many of the terms in the glossary appear in the text.



## Chapter 1

# BEFORE CONSTRUCTION STARTS



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## Before Construction Starts

### Regulation

The construction of a house is a complex process and requires detailed planning. It is often advisable to engage the services of an architect or experienced builder to assist in the process.

#### *Local regulations*

A site may be selected first, or the desired house plan may be developed first and a site then selected. In either case, both must conform to local requirements for house construction and land use. If a site will not be served by a sewer system, local codes governing septic systems need to be followed. A building permit must be obtained before construction starts, and periodic inspections by local officials are required during building of the house.

Building code regulations generally include criteria for structural, plumbing, electrical, and mechanical design, and also cover light and ventilation, egress, fire safety, sanitary equipment, and security. Local jurisdictions sometimes modify model codes to reflect particular requirements in matters such as snow loads, strong winds, and seismic activity.

In many communities, zoning and subdivision ordinances and regulations govern the type, density, and use of the buildings permitted and such matters as setback from the property line.

Administration and enforcement of building codes and ordinances is coordinated through the local building inspection department, and land use matters are handled by the zoning department. In many instances, a house plan must be submitted to the building inspection department and a site plan to the zoning department, and they must be approved, by issue of a building permit, before construction begins. The staffs of these offices are available to confer with and assist the house builder prior to such formal submissions. It is good practice to meet with them at an early stage of the planning process to assure that the formal submission, when it is made, conforms to local requirements.

#### *Model codes*

Local codes, standards, and ordinances are generally derived from model documents. The majority of local building codes are based on or adapted from codes developed by one or more of four major code organizations.

The organizations and the types of codes they have developed are as follows:

- BOCA—Building Officials & Code Administrators International, Inc.  
4051 West Flossmoor Road  
Country Club Hills, IL 60477-5795  
(312) 799-2300  
*Basic/National Code Series: building, plumbing, mechanical, fire prevention, energy, and other specialty codes.*
- SBCCI—Southern Building Code Congress International, Inc.  
900 Montclair Road  
Birmingham, AL 35213  
(205) 591-1853  
*Standard Code Series: building, plumbing, mechanical, fire prevention, and other specialty codes.*
- ICBO—International Conference of Building Officials  
5360 South Workman Mill Road  
Whittier, CA 90601  
(213) 699-0451  
*Uniform Code Series: building, plumbing, mechanical, fire, and other specialty codes.*
- CABO—Council of American Building Officials  
5203 Leesburg Pike  
Falls Church, VA 22041  
(703) 931-4533  
*One- and Two-Family Dwelling Code and the Model Energy Code.*

The National Fire Protection Association (NFPA), Batterymarch Park, Quincy, MA 02269, also issues codes and standards vital to the housing industry. NFPA publishes and maintains the National Electric Code and the One- and Two-Family Dwelling Electrical Code. Both codes are recognized and referenced by the model code organizations in their code documents.

### *Inspections*

After the building permit has been issued and construction begins, inspections are required at several stages of completion, usually at the completion of footings, framing, electrical work, plumbing, and mechanical features, and finally of the whole building. You need to schedule inspections, as follows, during building.

**Footings.** These inspections are conducted on the open trenches and/or formwork prior to pouring concrete. Steel reinforcement, if required, is inspected at the same time. The depth of the footings below grade is checked to insure proper level and footing size, and soil conditions are checked to insure that the footings provide proper bearing.

**Framing.** This must be inspected for grade, size, and placement prior to being covered with finish materials.

**Electrical and plumbing lines.** These are roughed in while the framing is open. Insulation and vapor barriers, as required, are placed in the walls and ceiling and coordinated with the electrical, plumbing, and mechanical installations.

**Ductwork and mechanical equipment.** These are installed and then inspected. Before any work is enclosed, they must be inspected and receive approvals for compliance with building, electrical, plumbing, and mechanical codes.

Once these inspections are completed and approvals obtained, the interior of the house is ready to receive finish materials.

**Final inspection.** This is required after all necessary electrical and plumbing fixtures, duct registers, and/or baseboard units, roofing material, and doors and windows are installed. The final inspection includes approval of numerous other details necessary to finish the house. In many jurisdictions a certificate of occupancy is issued after all final approvals are secured.

### Financial Planning

Financial planning should occur early in the preconstruction process. It is good procedure to visit the loan officer of a lending institution to discuss your plans. Be prepared to discuss preliminary house plans, the approximate size and location of the building lot, your income and other financial resources, and, in general, how the construction will be accomplished. If you are planning to do some of the construction yourself, be prepared to describe your experience and training in order to assure the loan officer that you are capable of performing the tasks.

An experienced loan officer is able to estimate the approximate costs you can expect to incur based on a knowledge of the local building industry. In addition to estimating the cost, the loan officer can estimate the amount of money that you could expect to qualify to borrow.

It is recommended that you contact more than one lending institution. Often considerable variation is found from

lender to lender regarding types of loans, loan amounts, interest rates, and down payments.

Once you select a lender, the loan office is likely to provide guidance regarding professional assistance. They may recommend that you seek a professional architect or builder to assist in such matters as the final house design, plan preparation, detailed estimating of labor and materials, and subcontractor selection.

Some lenders require two loan agreements. One loan is a short-term construction loan and the other is the long-term mortgage. The construction loan is designed to provide the builder with the financial resources necessary to pay for the construction of the house as it progresses. A typical schedule for disbursing the construction loan money, commonly referred to as a “draw schedule,” is as follows:

Draw	Amount	Requirements
1	15%	Land survey completed Building permit issued Foundation walls or slab completed Floor joists and subfloor in place Insurance policy in place
2	15%	All exterior walls framed and sheathed Roof complete Well dug, if applicable
3	10%	All interior framing in place Heating, plumbing, and electrical lines roughed in Bathtub set
4	20%	All exterior walls complete All windows set All exterior doors hung Interior wall covering complete
5	15%	All trim work complete Basement floor poured, if applicable Heating plant in place and connected Septic system completed, if applicable
6	15%	Interior and exterior painting complete Cabinets installed All tile work complete Plumbing, heating, and electrical fixtures operating

7	10%	All appliances operating
		Air-conditioning operating, if applicable
		Driveways, walkways, and walls complete
		Finish grading complete
		Sodding or grass seeding and shrubbery planted

The interest rate associated with the construction loan may be higher than that for the mortgage. This higher rate, however, is paid only on the amount of money disbursed and only during the term of the construction.

Once the house is complete and ready for occupancy, the amount of the construction loan may be transferred to the mortgage at lower interest for the longer term.

### Site Selection

Selecting a lot on which to build a new house requires an investigation not only of the legal history and future plans for the land and surrounding areas but also of the physical characteristics of the soils and underlying geology. In some cases the investigation is best performed by a qualified land planner or engineer. In other cases the staff of local government offices can be of assistance.

Investigation of the legal history of the property, commonly called a title search, is usually performed by an attorney or title search company, who check that there are no outstanding liens against the property and confirm the correctness of previous transfers.

Investigation of the current zoning status of the property and surrounding areas, and of the status of the area in the master plan for the local municipality, is also important. This includes an examination of plans for the expansion of the transportation network and how these plans may affect the location of the house.

The physical characteristics of the lot include a boundary description or survey. The land recording procedures often require an official survey, which must be performed by a licensed surveyor.

Local offices of the U.S. Department of Agriculture Soil Conservation Service are an excellent source of data describing soil conditions and the geology of the area. This information is important if a well is to be drilled or a septic system to be installed. It may also affect the choice of foundation system to be built, particularly in areas with unstable soils.

For information regarding availability of electricity or natural gas service, water, storm sewer, sanitary sewer,

and telephone service, contact the organizations, public or private, that provide the services.

### House Design

A good way to begin designing a house is to visit model homes and collect ideas. Professional and trade magazines frequently offer floor plan files that contain many ideas. You may wish to secure the services of a professional architect to develop the final plans.

In general, a simple plan and an uncomplicated roof offer important advantages. Their construction is more rapid and involves less waste than more complex designs.

Two factors to consider in choosing a design are the relative ease of future expansion of the house, and its ultimate resalability. For example, an expandable design may use a more steeply pitched roof to provide space for future rooms in the attic area or may include second-floor dormers in the original design, so that additional rooms can be provided at a future date at a much lower cost than by adding to the side or rear of the house. Professional advice may be of value when considering expandability of the design and ultimate resale of the house. Other features of design that can affect costs are described below.

The width and length of the house can be chosen to use standard-length joists and rafters and standard spacings to avoid waste of material. An architect or builder has this information. Dimensions can also permit use of standard-width sheets of sheathing materials on both interior and exterior. In contrast, dimensions that require waste or ripping add to labor and material costs.

Rooms can be arranged so that plumbing and heating lines are short and risers can serve more than one room. In constructing an expandable design, roughing in plumbing and heating lines to the second floor does not add appreciably to the original construction costs but would reduce costs later if the second floor were to be completed.

Whereas a rectangular plan is the most economical from many standpoints, economy should not always govern final design. A rectangular plan for the house proper, with a full basement, can be made more desirable by a garage or porch wing of a different size or alignment. Such attachments require only shallow footings, without the excavation necessary for basement areas.

The type of foundation affects costs. Selection of slab, crawl space, or basement should be based on climatic conditions and on the needs of the family for storage, hobby, or recreation space. While space is not so desirable in the basement as in areas above grade, its cost per cubic foot is a great deal lower. The design of a house on

slab usually includes some space for heating, laundry, and storage; this extra area often costs as much as a full basement. Many multilevel houses include habitable rooms over concrete slabs as well as a full basement.

Many contemporary house designs include a flat or low-pitched roof that allows a light truss to serve as both ceiling joists and rafters. This generally costs less than a pitched roof in materials and labor. However, not all house styles are adaptable to such a roof. Cost savings can often be realized by using preassembled roof trusses for pitched roofs. Dealers who handle large quantities of lumber are usually equipped to furnish trusses of this type.

Pitched roofs are of gable or hip design, while the gambrel roof has features of both designs. The hip roof is somewhat more difficult to frame than the gable roof, but usually requires less trim and siding. Painting is much simpler in the hip roof because the wall area is reduced by elimination of the gable, and because of accessibility. In the gambrel roof, which is adapted to two-story houses, roof shingles serve also as siding over the steep-pitched portions. A roof of this type provides a greater amount of headroom than the more common gable.

### Selecting Materials

A great variety of grades and types of material can be used in a house and the choice of materials affects the cost.

With regard to grade, it is poor practice to use a low-grade or inferior material that could later result in excessive maintenance costs. It is equally uneconomical to use materials of a higher grade than required for strength or appearance.

As for types of material, for foundation walls, concrete blocks can be used in place of poured concrete. A good water-resistant surface is less costly to provide on a poured wall than on a block wall, but a common hollow concrete block has better insulating properties than a poured concrete wall of equal thickness. Costs often vary in different areas. A third alternative for foundations is pressure-treated wood, which may cost even less than concrete.

**(Caution: Wood preservatives used in pressure treating wood may present certain hazards. Refer to the precautionary information given in chapter 8.)**

For chimneys, precast blocks may be considered, if available. These blocks are made to take flue linings of varied sizes and are laid up more rapidly than brick. Concrete blocks can also be used instead of bricks in laying up the base for a first-floor fireplace. Prefabricated lightweight chimneys that require no masonry may also save money.

The cost of dimension lumber for framing varies somewhat with species, grade, and size. Use the better grades for joists and rafters and the lower grades for studs. Do not use better grades of lumber than are actually needed. Proper moisture content is an important factor and is discussed separately in a later section.

Cost can be saved by use of conventional items such as cabinets, moldings, windows, and other millwork that are carried as stock or can be easily obtained. Many manufacturers have a good variety of millwork components to choose from. Any nonstandard materials that require extra machine setups will be much more expensive.

For wall covering and for floor covering, the use of a single material can provide substantial saving. A combination subfloor/underlayment of 5/8-inch or 3/4-inch tongue-and-groove plywood will serve as subfloor and as a base either for resilient tile or similar material or for carpeting. Panel siding consisting of 4-foot-wide full-height sheets of plywood or similar material may serve both as sheathing and as a finish siding. For example, exterior flakeboard with a painted finish can be used as corner bracing on the stud wall and may also qualify as a panel siding. Plywood may be obtained with a paper overlay or with rough-sawn, striated, reverse board-and-batten, brushed, and other finishes.

Costs of exterior siding and other finish materials often vary substantially. Many factory-primed sidings are available that require only finish coats after they are applied. A rough-sawn, low-grade cedar or similar species in board-and-batten pattern with a stained finish often results in a lower overall cost of exterior coverings. Many species and textures of plywood are available for the exterior.

Corrosion-resistant nails add slightly to the initial cost but save many dollars in reduced maintenance costs. Use of galvanized or other rust-resistant nails for applying exterior siding and trim reduces the need for frequent treatment or refinishing. Stainless steel or aluminum nails are a must on siding having a natural finish.

The choice of material for flooring, trim, and other interior finish presents many cost-related considerations. Areas that are to be fully carpeted do not require a floor finish, but it may cost substantially less to finish the floor during the original construction than to replace carpet later.

Species of woods used for trim, jambs, and other interior moldings vary from softwoods to the more expensive hardwoods such as oak or birch. Softwoods are ordinarily painted, while hardwoods are given a natural finish or are lightly stained. The softwoods cost less but are less resistant to damage from blows and impacts.

Panel and flush doors are available in several types and species. For interior use, hollow-core flush doors are satisfactory, but for exterior use flush doors should have a solid core to resist warping. Flush doors can be obtained in a number of wood species and grades. For example, unselected gum wood may be painted, whereas more costly woods are best finished with a varnish or sealer. The standard exterior panel door harmonizes with many styles of architecture.

### **Labor-Saving Techniques**

Some labor-saving techniques involving equipment or procedure should be included in the planning stage. Power equipment, such as a radial-arm saw, circular saw, or an automatic nailer, helps to reduce the time required for framing and is used by most progressive contractors. Such equipment not only reduces assembly time for floor, wall, and roof framing and sheathing but is helpful in applying siding and exterior and interior trim. For example, a radial-arm saw facilitates the making of square cuts and lengths that result in better nailing and more rigid joints.

When gypsum wallboard drywall finish is used, many contractors employ the horizontal method of application. This brings the taped joint below eye level and, because wallboard comes in lengths up to 16 feet, longer sheets may be used. Vertical joints may be made at window or door openings. This reduces the number of joints to be treated and results in a better looking wall.

It may be possible to reduce costs of staining and painting the exterior and interior surfaces and trim. One study of interior painting indicated that costs were substantially reduced by prestaining before fitting the jambs, stops, casing, and other trim normally stained or sealed after being fitted and nailed.

### **Materials Delivery**

The care of materials and the conditions to which they are exposed at the site are important to most of the materials used in house construction. Problems of storage on site are reduced if loads of material are delivered when they are needed at different stages of construction. The first load, delivered after the foundation has been completed, may include all materials required for the wood floor system. A second load, at a later date, can provide the materials for framing and sheathing the walls. A third load can be for roof and ceiling framing and roof sheathing.

Materials for factory-built or preassembled houses can be delivered in one large truckload because a crew erects the house in a matter of hours. This virtually eliminates the need for protecting the materials at the site.

The builder of a single house may not be able to arrange staged delivery to coincide with construction needs, and such millwork items as window and door frames, doors, and moldings may therefore require some type of on-site protection. Finished cabinets, floor underlayment, flooring, and other critical items should be delivered only after the house is enclosed, so that they have complete protection from the weather. During fall, winter, and spring months, the house should be heated to 60 °F so that finished wood materials are not affected by weather conditions. When such materials as flooring are exposed to damp and cold, problems are caused by changes in their dimensions.

### **Efficient Use of Materials**

Materials used in wood-frame house construction are produced in a limited number of standard dimensions. Framing lumber is produced in lengths of 8 feet and up by 2-foot increments to 18 feet. Wood, metal, and plastic siding as well as wood trim are produced in lengths of 8 feet or more. Wood siding and trim is available by 2-foot increments up to 16 feet. Panel products such as plywood, structural flakeboard, fiberboard, and gypsum wallboard are commonly produced in 4-foot by 8-foot dimensions, although some siding panels may be produced in 9-foot and longer lengths. Gypsum wallboard is also produced in 4-foot widths with lengths in 2-foot increments between 8 and 16 feet.

As has already been noted, a house costs less per square foot if it has been laid out with a view to maximal use of materials in their standard dimensions. Because most building materials are produced in some multiple of 2 feet, a house plan laid out in multiples of 2 feet uses materials for floor construction, exterior walls, and roof most efficiently. Before designing the house it is good practice to determine the dimensions of building materials stocked by local suppliers.

Value engineering is the practice of comparing alternative materials and methods to determine the least costly combination that will result in an acceptable product. A publication titled *Reducing Home Building Costs with Optimum Value Engineered Design and Construction* (NAHB Research Foundation 1977), cited in the selected bibliography, presents a discussion of value engineering in the context of home building. The discussion covers the entire sequence of planning, engineering, and construction techniques that work together to produce a house with efficient utilization of material and labor. Value engineering concepts and practices have been incorporated at many places in this book.

### **Energy Conservation**

Numerous modifications of house design and construction save energy. Some, such as reducing the area of glass,

may actually reduce the cost of the house. Others, such as adding insulation, increase the cost in one respect (material and installation) but allow cost savings in other respects (smaller air conditioners, smaller heating systems, smaller flues, and lower service entrance wiring costs).

Calculating the savings associated with energy-conserving features is complex and varies with climate, house type, type and cost of fuel or energy, cost of labor and materials, and type and efficiency of the heating and cooling system. An expert should be consulted to perform the calculation. The decision whether to incorporate specific energy-conserving features in the design and construction of the house should be based on a comparison of costs with estimated savings.

Design items of particular concern in the planning stage are shape of house, ceiling height, wall thickness, type of sheathing, and size and placement of windows. In the section on energy conservation in chapter 8, brief discussions are presented of a variety of design and construction features that are likely to be cost-effective in energy conservation as long as the price of energy remains high. Many of these features are discussed in more detail in *Insulation Manual: Homes and Apartments* (NAHB Research Foundation 1979) cited in the selected bibliography.

### Protection of Materials

In normal construction procedures, after excavation is complete, some dimension lumber and sheathing materials are delivered to the building site. It is the builder's responsibility, after delivery, to protect these materials against wetting and other damage. Rapid use of structural and framing materials minimizes storage problems. Structural and framing materials in place in a house before it is enclosed may become wet during a storm, but, in contrast to materials stacked for storage, their exposed surfaces can dry out quickly in subsequent dry weather without damage.

Lumber should not be stored in tightly stacked piles nor without some type of protection. If lumber is not to be used for several days or a week, it should be unloaded onto skids with a 6-inch clearance above the soil. The pile should then be covered with waterproof paper, canvas, or polyethylene so that it sheds water. However, the cover should allow air to circulate and not enclose the pile to the groundline. In a tight enclosure, moisture from the ground may affect the moisture content of lumber. The use of a polyethylene cover over the ground before lumber is piled will reduce the rise of moisture. The same type of protection should be given to sheathing grade plywood. Trusses delivered to the site for roof or floor assemblies should be stored on a level surface and protected similar to lumber and plywood as described above.

When the framing and the application of wall and roof sheathing have been completed, the exterior roof trim, such as cornice and rake finish, is installed. During this period, the shingles may have been delivered. Asphalt shingles should be stored so that bundles lie flat without bending; curved or buckled shingles often result in an unsightly roof. Wood shingles can be stored with only moderate protection from rain.

Window and exterior door frames should not be delivered until they can be installed. In normal construction procedures, the frames are installed after the roof is completed and roofing installed. Generally, window units are ready for installation, with sash and weatherstrip in place and all wood protected by a dip treatment with a water-repellent preservative. Such units, even though so treated, should be protected against moisture or mechanical damage. If it is not possible to install frames when they arrive, place them on a dry base in an upright position and cover them.

Siding materials can be protected by storing them temporarily in the house or garage. Place them so they will not be stepped on and split. Wood bevel siding is usually bundled with the pieces face to face to protect the surfaces from mechanical damage and soiling. Some manufacturers treat their siding with a water repellent and pack it in bundles with an outer protective wrap. All siding materials that cannot be installed immediately should be protected against exposure to conditions that could appreciably change moisture content.

Insulation materials should be stored inside the house. They are generally not installed until the electrical, heating, and plumbing trades have completed the roughing-in phases of their work.

Millwork, floor underlayment, flooring, and interior trim manufactured by reputable companies are normally shipped at a moisture content satisfactory for immediate use. However, if storage conditions at the lumber company or in an unheated house during an inclement season are not satisfactory, wood parts pick up moisture. The results may not be apparent immediately. If material is installed at too high a moisture content, openings will appear during the following heating season between flooring strips and at poorly matched joints in the trim because members have dried out and shrunk.

In flooring, for instance, the recommended moisture content at installation varies from 10 percent in the damp southern states to 6 or 7 percent for other localities. In examining wood floors with cracks between the boards, it has been found that in most cases the material had picked up moisture after manufacture and before it was installed. As such material redries during the heating season, it

shrinks and the boards separate. Some of the moisture pickup may occur before the flooring is delivered to the building, but often such pickup occurs after delivery and before installation.

In an unheated building under construction, the average relative humidity is much higher than in an occupied house. Thus, the flooring and finish tend to absorb moisture. To prevent moisture pickup at the building and to dry out any excess moisture picked up between time of manufacture and delivery, the humidity must be reduced below that considered normal in an unheated house. This may be accomplished by maintaining a temperature above the outdoor temperature even during the warmer seasons.

Before any floor underlayment, flooring, or interior finish is delivered, the outside doors and windows should be hung and the heating plant installed to supply heat. For warm-weather control, when the workers leave at night, the thermostat should be set to maintain a temperature 15 °F above the average outdoor temperature. In the morning when the workers return, the thermostat can be set back so that the burner does not operate. During the fall, winter, and spring, the temperature should be kept at about 60 °F.

Several days before flooring is to be laid, bundles should be opened and the boards spread about so that their surfaces can dry out evenly. This permits the drying of moisture picked up before delivery. Wood wall paneling and floor underlayment should also be exposed to the heated conditions of the house so the material approaches the moisture content it will reach in service.

Actually, it is good practice to expose all interior finish to this period of moisture adjustment. Supplying some heat to the house in damp weather, even during the summer months, will be justified by improved appearance and owner satisfaction.

### **Subcontracting**

Nearly all house construction requires the use of subcontractors to perform particular tasks. Subcontractors possess special knowledge and skills, and access to special equipment. It is not uncommon for professional house builders to function as general contractors hiring subcontractors for the entire construction process.

Labor time on site has a substantial impact on construction costs. The size of the operation generally governs the method of construction. A contractor may use two carpenter crews, one for framing and one for interior finishing. Close cooperation with subcontractors such as plumbers, plasterers, and electricians can avoid waste of time. Delivery of items when needed obviates storage and so reduces erection time on site.

Subcontractors fall into two general categories: those supplying only labor and those supplying both labor and materials. Subcontractors for masonry, framing, and roofing and others who provide only labor expect the materials to be available at the building site for the task they are to perform. Subcontractors for excavation, plumbing, electrical work, heating, and air-conditioning supply both labor and materials.

Agreements with subcontractors should take the form of written contracts. The first step is to prepare a detailed written list of the work to be performed and to obtain bids from at least three possible subcontractors. Local professional builders can provide information on the performance history of subcontractors from whom bids are received.

The specifications that form the basis for the subcontractor's bid should include a clear statement of local licensing and bonding requirements, responsibility for obtaining permits and inspections, and responsibility for liability insurance.

When the work is completed, the subcontractor should sign a release indicating that he has received full payment for his services.

### **Schedule of Activity**

A work schedule should be prepared describing each major task to be performed and giving an estimate of how long each task will take. This schedule can be used for such purposes as arranging for material deliveries, scheduling the work of subcontractors, and coordinating the timing of inspections of the work in process.

Developing a work schedule requires a thorough knowledge of the sequence of tasks to be performed and the time ordinarily taken to accomplish each task. Local architects or builders can assist in the preparation of such a schedule.

A typical work schedule (fig. 1) calls for the completion of construction in approximately 75 days from start. It must be understood that construction can start only after financing has been arranged and after appropriate permits have been obtained. Such preconstruction activities can take as long as or longer than the actual construction.

In this schedule, the first week is devoted to preparing the site, excavating the foundation, and installing temporary utility service.

During the second week, foundation footings are prepared and water and sewer lines are installed below ground. A footing inspection takes place and the footings and foundations are completed during this week.

The third week is devoted to erecting the framing of the floors, walls, and roof; applying the cornice trim to the roof line; and installing windows and exterior doors. Plumbing is also roughed in, sheathing and decking are applied, and electrical wiring can be roughed in.

The cornice trim work probably extends into the fifth week. When it is complete, the roof covering material can be installed and the exterior paint applied. During exterior painting, the heating, ventilating, and air-conditioning (HVAC) equipment can be roughed in or installed.

At this point a series of open framing inspections normally occur. In addition to an inspection of the structural integrity of the framing, an inspection of the roughed-in plumbing, electrical, and HVAC work usually takes place.

During the sixth week, insulation and vapor retarders may be installed, followed by the application of interior wall finish such as gypsum wallboard. If the exterior covering is to be brick, the brick is installed during the sixth week.

Installing interior wall finish and exterior brick work, if applicable, probably extends into the seventh week. During the latter part of the seventh week the interior trim, interior doors, and cabinetry can be installed.

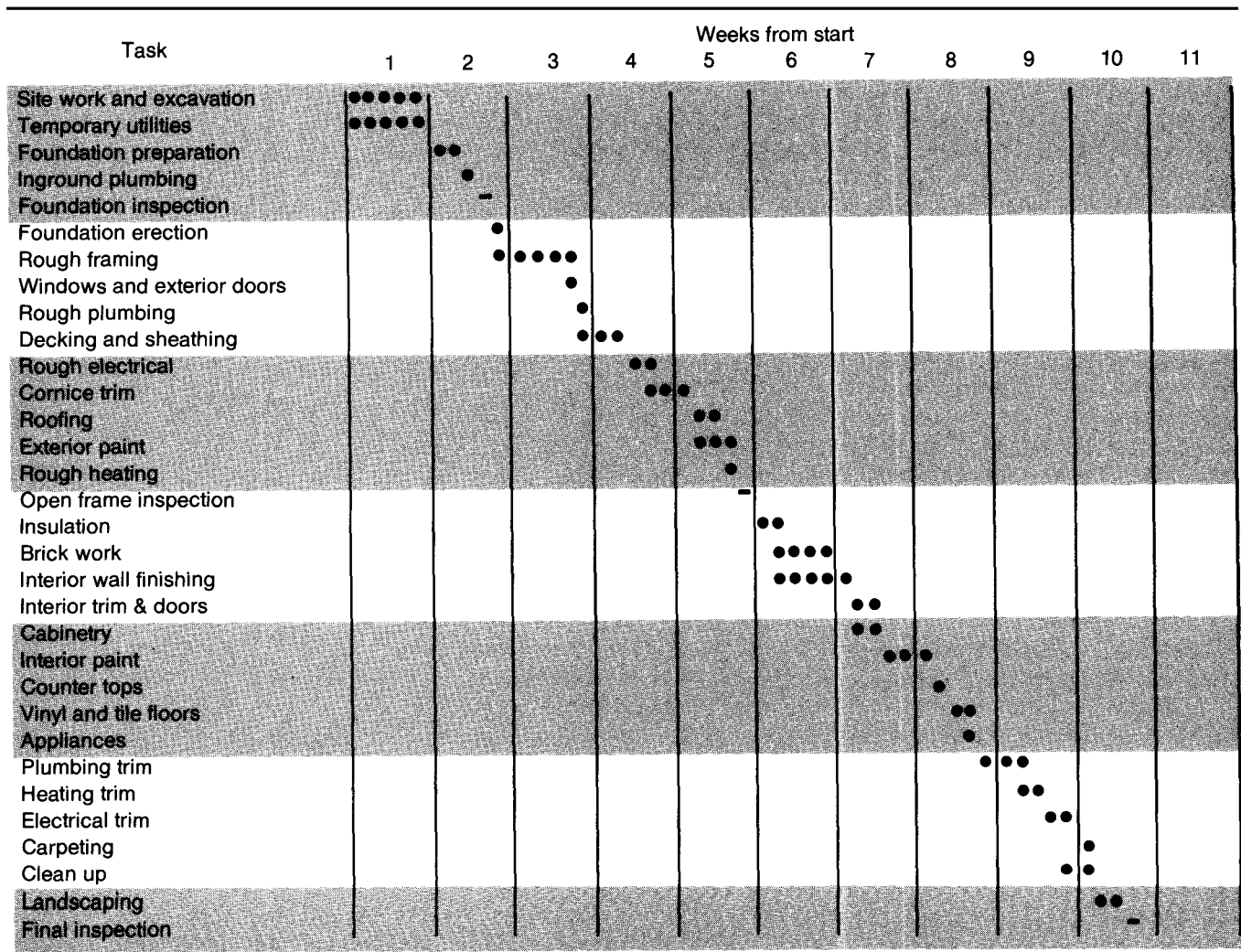
Interior work, continuing during the eighth week, includes painting, counter-top installation, and laying of vinyl or tile floors.

During the ninth week, major appliances are installed and the plumbing, electrical, and heating work finish is applied.

During the 10th week, carpeting is installed and the house is cleaned to prepare for occupancy. The final landscaping is also done.

Final inspection of the completed house takes place during the 11th week. When this inspection is completed and the work is certified as acceptable, the house is ready for occupancy.

Figure 1—Typical construction work schedule.





## Chapter 2

# LAYING THE GROUNDWORK



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## Laying the Groundwork

Tasks related to site preparation and construction of footings and foundations, including a retaining wall, are discussed in this chapter.

### **Site Preparation**

Before excavation for a new house is begun, the subsoil conditions must be determined by test borings and/or by checking existing houses constructed near the site. It is good practice to examine the type of foundations used in neighboring houses because the findings may influence design of the new house. For example, if a rock ledge were encountered at the chosen site, its removal would be costly. A high water table may require change of design from a full basement to a crawl space or concrete slab construction. If the area has been filled, the footings should always extend through to undisturbed soil. Any variation from standard construction practices increases the cost of the foundation and footings.

### *Site access and services*

Before construction begins, provision must be made for equipment and delivery trucks to have access to the site; for sources of basic power, telephone, and water during construction; and for storing large quantities of a variety of materials throughout the construction process.

In providing access to the building lot for such heavy vehicles as cement trucks and loaded delivery trucks, the major factors to be considered are the season of the year, the soil conditions, and the slope of the building site. It may be necessary to excavate an access road and to provide some form of temporary road surface such as crushed stone.

Electric power and water are needed for many tasks in the building process. To provide electric power, the utility company may have to install a temporary electric service entrance. To provide water, a well may have to be drilled or temporary water service be installed at a nearby fire hydrant. Desirable support services at the building site include a telephone and toilet facilities.

Plans must be made for storage of materials at the site in such a fashion that they do not interfere with building activities. Plan the location of building materials delivered to the site to give easy access for delivery trucks and convenience for construction activity. Trees and other vegetation removed in clearing the site should be piled away from the construction area and out of the path of

trenches, wells, or septic tanks. Top soil that has been removed can be saved for landscaping. Subsoil removed during the excavation for a basement foundation can be saved and used for backfill. Erosion control may be important and adequate control can often be provided temporarily by well-placed straw bales.

### *Placement of the house*

A preliminary plot plan is submitted for approval with the request for a building permit. A final plot plan is prepared after surveying the site and determining house placement. Zoning regulations usually specify such matters as minimum setback and side-yard requirements, and the house must be placed on the lot to conform to those regulations.

When the plot of land is surveyed, the corners are marked by the surveyor. The surveyor should also mark the corners of the area within the lot in which the house may be built to comply with local regulations.

In preparation for establishing the exact placement of the house corners, stakes should be driven in the ground to mark the approximate location of the driveway and house. This approximate positioning should take the terrain into account, avoiding rock outcroppings and preserving trees that are to remain. Space should be reserved for a septic field and/or a water well, if applicable. The positioning of the water well with respect to the septic field is frequently controlled by health department regulations. Locating the water well should also recognize the need to provide access for a drilling rig. For energy efficiency, the side of the house with the most windows should face to the south.

All trees should then be removed from the areas to be driveway, within the house foundation, or within 15 to 20 feet of the house foundation. Clearing this area provides space for excavation and for a bulldozer to backfill around the house without getting too close to the foundation wall. It may be desirable to retain trees elsewhere on the lot. Deciduous trees may be left standing to shade the south side of the house in the summer while admitting the sun in the winter. Evergreen trees may serve as a wind break on the north side of the house and should be retained on the east and west sides of the house to shade it from low-angle morning and evening sunlight in the summer.

The next step is to locate the exact corners of the house. This must be done accurately and must establish

squareness because all subsequent construction is based on this determination. In order to facilitate the process, the exact length of the diagonal of each rectangular section of the house outline should be calculated. (See the technical note on square corners.) Use three steel tape measures to lay out two adjoining sides of the house and the associated diagonal. The measuring tapes should be held level and plumb bobs used to establish the corner points on the ground. Stakes should be driven at each of the three corners and a nail driven in the top of each stake should be used to mark the exact location of the plumb bob. The fourth corner should be established by using two of the steel tape measures to measure the exact lengths of the two remaining sides. The fourth corner stake should be driven into the ground and a nail driven into the top of the stake under the tip of the plumb bob to indicate the exact corner location.

An alternative approach to establishing the exact corners of the house outline is to measure and stake the two corners for one side. Starting from one end, measure the length of an adjoining side. Using the "3-4-5" rule for a perfect 90° corner, measure along one of the sides some number of 3-foot units (3, 6, 9, or 12 ft). Measure along the other side a like number of 4-foot units (4, 8, 12, or 16 ft). If the corner is exactly 90°, the length of the diagonal (the hypotenuse of the triangle formed by the two measured sides) will be a like number of 5-foot units (5, 10, 15, or 20 ft). Adjust the position of the added side and stake the third corner. Proceed around the outline of the house measuring the lengths of the sides and adjusting to ensure that all corners are exactly 90°.

When the location of the house has been exactly established, the next step is to set the batter boards (fig. 2) to retain the exact outline of the house during construction of the foundation. The height of these boards is sometimes used to establish the height of the footings and foundation wall.

Drive three 2- by 4-inch or larger stakes of suitable length at 4 feet (minimum) beyond the lines of the foundation at each corner. Use a surveyor's level to establish level marks on the stakes. At each corner, nail 1- by 6-inch or 1- by 8-inch batter boards horizontally so the tops are all at the same level at all corners. Stout string is next held across the top of boards facing each other at two corners and adjusted so that it is exactly over the nails in the tops of the corner stakes at either end; a plumb bob is handy for setting the lines. A sawkerf or nail is placed at the outside edge of the board where the lines cross so that the string may be replaced if broken or disturbed. After similar cuts or nails have been located in all eight batter boards, the lines of the house will have been established. Check the diagonals again to make sure that the corners are square and adjust as necessary.

A precise plot plan may be prepared after the exact house location has been established and should then be filed with the original plot plan and building permit. The final plot plan should show the lot outline as established by the surveyor and the outline of the house foundation and driveway. If applicable, the plot plan should also show the location of the septic system and water well.

### **Excavation and Footings**

Various types of earth-moving equipment are employed for basement excavation. Top soil is often stripped and stockpiled with a bulldozer or front-end loader for future use. The excavation can be done with a front-end loader, power shovel, or similar equipment. Backhoes are used to excavate for the walls of houses built on a slab or a crawl space, if soil is stable enough to prevent caving. This eliminates the need for forming below grade if footings are not required.

Excavation is carried down, preferably only to the level of the top of the footings or the bottom of the basement floor, because some soils become soft upon exposure to air or water. Unless formboards are to be used, it is not advisable to make the final excavation for footings until it is nearly time to pour the concrete.

The excavation must be wide enough to provide space to work when constructing and waterproofing the foundation wall, and for laying draisintile, if necessary (fig. 3). The steepness of the back slope of the excavation is determined by the subsoil encountered. With clay or other stable soil, the back slope can be nearly vertical but, with sand, an inclined slope is required to prevent caving.

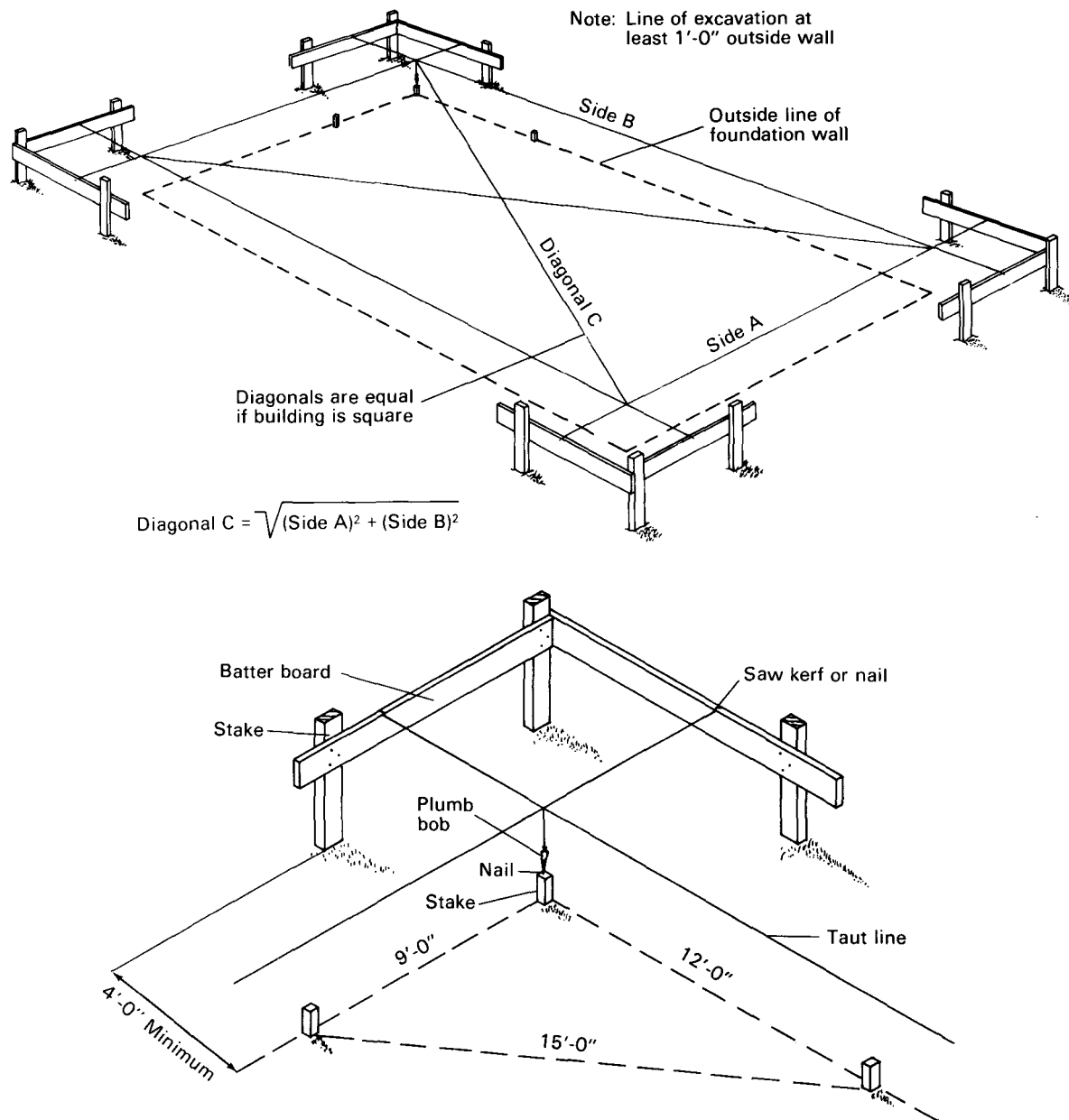
Some contractors only rough-stake the perimeter of the building for the removal of the soil. When the proper floor elevation has been reached, the footing layout is made and the soil removed to form the footing. After the concrete for the footings is poured and set, the foundation wall outline is established on the footings and marked for the placement of the formwork or concrete block wall.

### **Footings**

Footings act as the base of foundation wall and transmit the superimposed load to the soil. The type and size of footings should be suitable for the soil condition, and in cold climates the footings should be far enough below finished grade level to be protected from frost. Local codes usually establish this depth, which is often 4 feet or more in northern sections of the United States and in Canada.

Poured concrete is generally used for footings, although developments in treated wood foundation systems permit all-weather construction and provide reliable foundations as well. Gravel, being less expensive than concrete or

Figure 2—Staking and laying out the house.



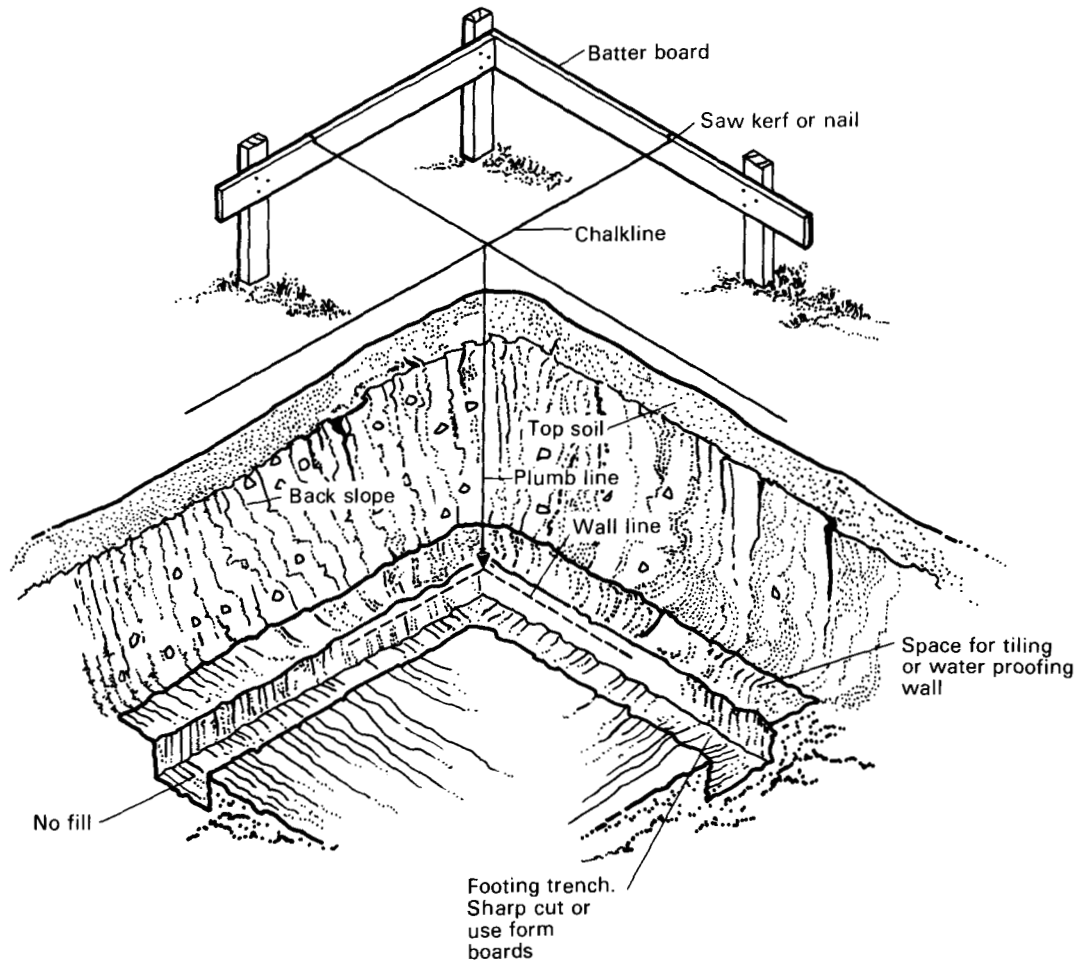
wood, is recommended as footings for foundation walls of pressure-treated wood (see the section on foundation walls).

Where fill has been used to raise the level of the house, the footings must extend below the fill to undisturbed earth. In areas having fine clay soil, which expands when it becomes wet and shrinks when it dries, irregular settlement of the foundation system and building may occur. A professional engineer should be consulted when building a house on this expansive clay soil.

Wall footings. Well-designed foundation wall footings are important in preventing settling or cracks in founda-

tion walls. To determine the size of footings, one method often used with normal soils is based on the proposed wall thickness. As a general rule, the footing depth should be equal to the wall thickness (fig. 4A), and the footings should project beyond each side of the wall one-half the wall thickness. The footing bearing area, however, should be designed on the basis of the load of the structure and the bearing capacity of the soil (see table 1). If soil is of low load-bearing capacity, wider footings with steel reinforcement may be required. Local regulations often specify dimensions for wall footings and also for column and fireplace footings.

Figure 3—Establishing corners for excavation and footing.



**Table 1**—Foundation wall footing widths for typical single-family dwelling loads for various allowable soil bearing capacities

Total design load (lb) per linear foot of footing	Footing widths (in)			
	1,500 lb/ft <sup>2</sup>	2,000 lb/ft <sup>2</sup>	2,500 lb/ft <sup>2</sup>	3,000 lb/ft <sup>2</sup>
1,000	8	6	4.8	4
1,500	12	9	7.2	6
2,000	16	12	9.6	8
2,500	20	15	12	10

Source: NAHB Research Foundation (1977). *Reducing Home Building Costs with OVE Design and Construction*.

The following are a few rules for footing design and construction:

1. Footings should be at least 6 inches thick.
2. If footing excavation is too deep, fill with concrete—never replace soil.
3. Use formboards for footings where soil conditions prevent sharply cut trenches.

4. Place bottom of footings below the frost line.
5. Reinforce footings with steel rods where they cross pipe trenches.
6. In freezing weather, heat the footings or cover with straw.

**Pier, post, and column footings.** Footings for piers, posts, or columns (fig. 4B) should be square and should include a pedestal on which a load-bearing member will rest. A 4-inch or 6-inch solid-concrete cap block laid flat on the footing can serve as a pedestal. More esthetically pleasing pedestals may be installed, but they require the construction of a form and the pouring of concrete. The finished pedestal height must be at least equal to the thickness of the concrete floor slab; its sides may be vertical or may slope outward; and its top dimensions must equal or exceed the dimensions of the base of the pier, post, or column it will support. Bolts for the bottom bearing plate of steel posts and for the metal post bases for wood posts are usually set when the pedestal is poured. At other times, steel posts are set directly on the footing and the concrete floor poured around them. Concrete is

never poured around wooden posts. Concrete blocks are sometimes used as pedestals, especially in crawl space construction.

Footings vary in size depending on the superimposed load, the allowable soil bearing capacity, and the spacing of the piers, posts, or columns. Common sizes are 24 by 24 by 12 inches and 30 by 30 by 12 inches (see table 2).

**Table 2 – Column footing sizes for typical single-family dwelling loads for various allowable soil bearing capacities**

Total design load (lb)	Footing sizes (in)			
	1,500 lb/ft <sup>2</sup>	2,000 lb/ft <sup>2</sup>	2,500 lb/ft <sup>2</sup>	3,000 lb/ft <sup>2</sup>
5,000	22 × 22	19 × 19	17 × 17	16 × 16
10,000	31 × 31	27 × 27	24 × 24	22 × 22
15,000		33 × 33	30 × 30	27 × 27
20,000			34 × 34	31 × 31

Source: NAHB Research Foundation (1977). *Reducing Home Building Costs with OVE Design and Construction*.

Footings for fireplaces, furnaces, and chimneys should ordinarily be poured at the same time as other footings.

**Stepped footings.** Stepped footings are often used where the lot slopes to the front or rear and the garage or living areas are at basement level. The vertical part of the step is poured as part of the footing. The bottom of the footing is always placed on undisturbed soil and located below the frost line. Each run of the footing should be horizontal.

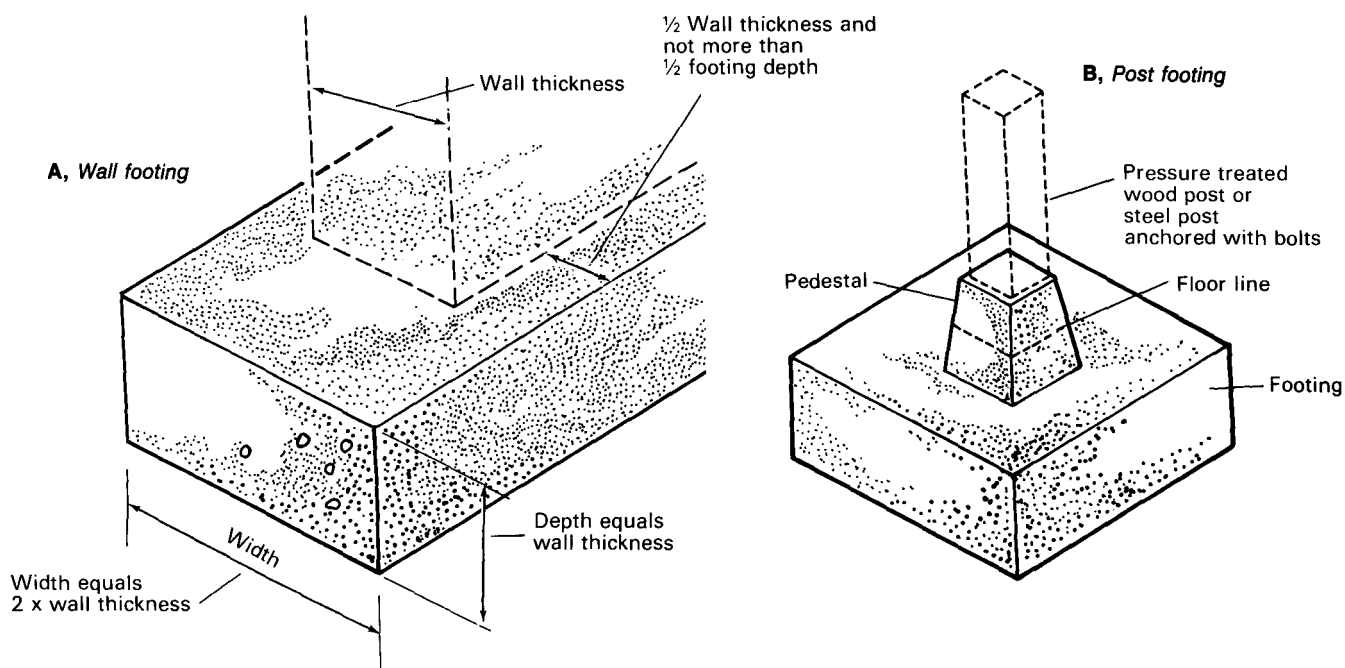
The vertical step between footings should be at least 6 inches thick and the same width as the footings (fig. 5). The height of the step should not be more than three-fourths of the adjacent horizontal footing width nor exceed 2 feet. On steep slopes, more than one step may be required. On very steep slopes, special footings may be required. For example, two separate footings may be required. The lower footing is poured and the lower wall is constructed up to the level of the upper footing. Forms for the upper footing are then built to extend the upper footing over the top of the lower wall. The extended portion of the upper footing is reinforced and tied to the lower wall with steel reinforcing rods. Alternatively, reinforced concrete lintels can be used to bridge from the upper footing to the lower wall. Because of the complexity of these designs, an engineer should be consulted.

### Ordering concrete

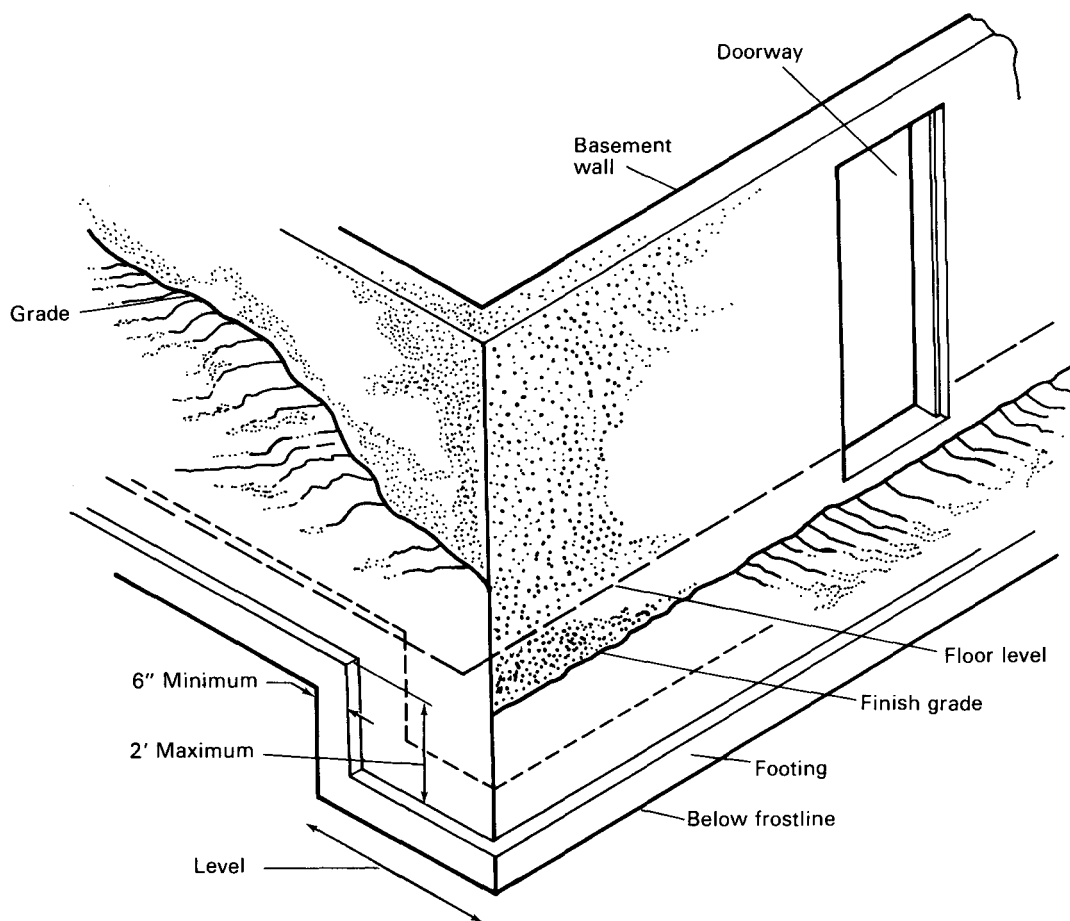
Concrete and masonry units such as concrete block serve various purposes in most house designs, including houses on concrete slab and crawl space houses with poured concrete or concrete block foundation walls.

For small jobs, instructions for do-it-yourself mixing are usually available on the bag of Portland cement. The mixture generally includes one part air-entrained Portland cement, two parts sand, and four parts 1½-inch crushed rock. These are mixed together and water is then added, little by little, until the mixture is completely wet but can still be piled. Too much water weakens the concrete.

**Figure 4 – Footings.**



**Figure 5 – Stepped footing.**



A great amount of concrete is supplied by ready-mix plants, even in rural areas. Concrete in this form is normally ordered by the number of bags per cubic yard and the maximum size of the gravel or crushed rock. A five-bag mix is considered adequate for most residential work. A six-bag mix is commonly specified where high strength or reinforcing is required.

The size of gravel or crushed rock that can be obtained varies in different locations, and for the smaller gravel sizes it may be necessary to change the cement ratio from that normally recommended. Generally speaking, it is good practice to use more cement when the maximum gravel size is smaller than 1½ inches. When maximum gravel size is 1 inch, add one-quarter bag of cement to the five-bag mix; when maximum size is ¾ inch, add one-half bag; and when maximum size is ⅜ inch, add one full bag.

#### ***Pouring concrete***

Concrete should be poured (or placed) continuously and kept practically level throughout the area being poured.

The concrete should be rodded or vibrated to remove air pockets and force the concrete into all parts of the forms.

In hot weather, protect concrete from rapid drying. It should be kept moist for several days after pouring. Rapid drying significantly lowers its strength and may result in early destruction of the exposed surfaces of sidewalks and drives.

In very cold weather, keep the temperature of the concrete above freezing until it has set. The rate at which concrete sets is affected by temperature, being much slower at or below 40 °F than at higher temperatures. In cold weather, it is good practice to use heated water and aggregate during mixing. In severely cold weather, insulation or heat should be used until the concrete has set. Further discussion of working with concrete under various weather conditions is presented in the section on all-weather construction in chapter 8. A technical note on concrete presents a discussion of various characteristics of concrete that can be altered by various additives to meet specific needs.

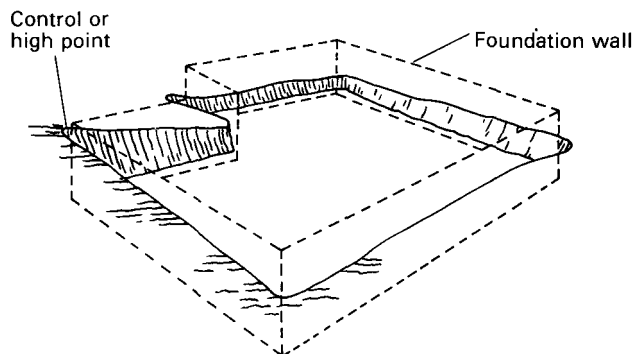
## Foundation

Foundation walls form an enclosure for basements or crawl spaces and carry wall, floor, roof, and other building loads. The two types of walls used most commonly are concrete cast in place (poured) and concrete block. Pressure-treated wood foundation walls are being increasingly used and are accepted by most codes. Preservative-treated posts and poles offer many possibilities for low-cost foundation systems and can also serve as a structural framework for the walls and roof.

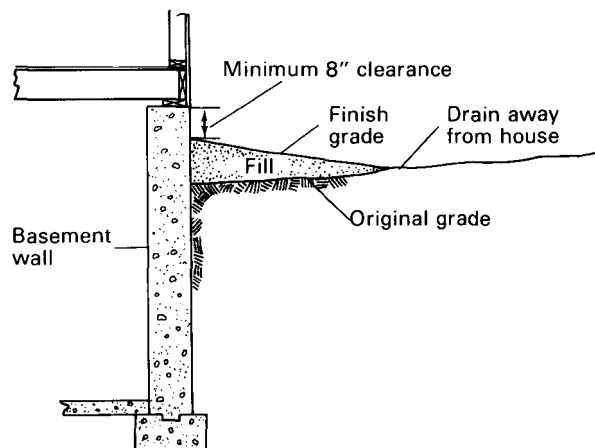
### *Height of foundation walls*

It is common practice to establish the depth of the excavation and consequently the height of the foundation, by using the highest elevation of the excavation's perimeter as the control point (fig. 6). This method insures good drainage if a sufficient height of foundation is allowed for the sloping of the final grade (fig. 7). Foundation walls at least 7 feet 4 inches high are desirable for full basements; walls 8 feet high are common.

**Figure 6—Establishing depth of excavation.**



**Figure 7—Finished grade sloped for drainage.**



Foundation walls should be extended at least 8 inches above the finished grade around the outside of the house. This helps protect the wood finish and framing members from soil moisture. Also, wooden building materials should start well above the grass level so that, in termite-infested areas, there will be an opportunity to observe any termite tubes between the soil and the wood and to take protective measures before damage develops. Enough height should be provided in crawl spaces to permit periodic inspection for termites and for installation of soil covers to minimize the effects of ground moisture on framing members.

To enhance drainage away from the foundation, the finished grade at the building line should be 4 to 12 inches or more above the original ground level, having the higher values in this range in sloping lots (fig. 7). In very steeply sloped lots, a retaining wall is often necessary.

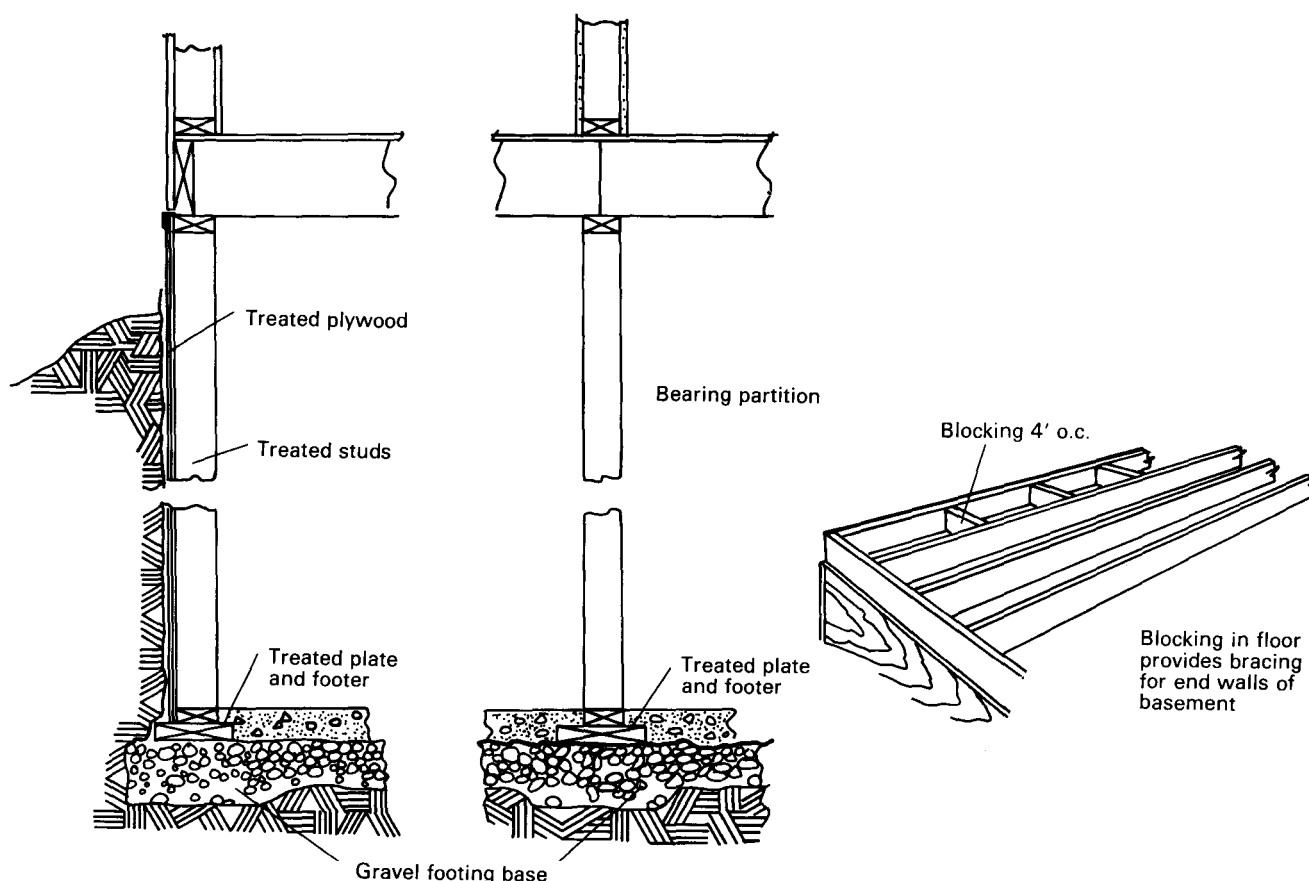
For houses having a crawl space, the distance between the ground level and underside of the joists should be at least 18 inches. Where the interior ground level is excavated or otherwise below the outside finish grade, 4-inch foundation drains covered with draining gravel and 15-pound roofing felt should be installed around the interior base of the wall and extended to the finished grade outside the foundation.

### *Basement foundation walls of treated wood*

Basements constructed of pressure-treated lumber and plywood have achieved substantial acceptance in many areas of the United States and Canada. (See chapter 8 for precautionary information on pressure-treated wood.) Thousands of homes have been built by this method, which offers unique advantages. With basement walls of treated wood, electrical wiring is readily installed, insulation may be installed between the studs, and standard interior wall finish materials are easily nailed over the studs. Other advantages include suitability for construction in cold weather and the potential for prefabrication. Typical wall panels, including footing plates (fig. 8), can be fabricated from pressure-treated wood. The panels may be erected rapidly on site, reducing construction time and avoiding delays caused by weather. Because carpenters erect the panels, there are fewer trades to coordinate. Where basement walls extend above grade, they are easily painted or covered with the same siding materials as the house walls.

Preservative treatment for residential all-weather wood foundations is prescribed in American Wood Preservers Bureau Standard FDN. Each piece of lumber that has been treated in accordance with this standard bears the AWPB stamp. Lumber and plywood treated in accordance with this standard is extremely durable (see chapter 8). Only treated lumber and plywood bearing an AWPB FDN stamp should be used.

**Figure 8 – Pressure-treated wood basement footing and foundation wall.**



Construction of a pressure-treated wood basement begins with excavation to the required level in the usual manner. Plumbing lines to be located below the basement floor area are installed as necessary. The entire basement area is then covered with a layer of crushed stone or gravel a minimum of 4 inches thick, extending approximately 6 inches beyond the footing line. The stone or gravel bed is carefully leveled. The gravel or crushed stone serves to distribute footing loads 4 inches or more on each side of the footing plate. Wall panels are then installed on top of the footing plate, fastened together and braced in place. Joints are caulked, and the entire exterior of the foundation wall that is below grade is draped with a continuous sheet of 6-mil polyethylene.

The stone or gravel bed is covered with 6-mil polyethylene over which a standard concrete slab floor is poured. A sump and pump may be desirable to assure a dry basement. The first-story floor must be securely fastened to the top of the wood basement walls to resist the inward force of backfill. Where soil pressure is substantial, it may be necessary to use framing angles at this point. Solid blocking should be installed 48 inches on center in the joist space at end walls to transmit foundation wall loads to the floor. The wood foundation wall

should not be backfilled until the basement floor and the first-story floor are in place.

Standard engineering procedures can be used in designing basement walls of treated wood. As with other basement wall designs, the controlling factors are the height of backfill and the soil conditions. Table 3 summarizes typical framing requirements for different heights of fill, and typical sizes of footing plate for one- and two-story houses up to 28 feet wide. Pressure-treated 1/2-inch-thick standard C-D grade (exterior glue) plywood should be installed with the face grain across studs. Blocking at horizontal plywood joints is not required if joints are at least 4 feet above the bottom plate. These specifications are based on a soil condition with 30 pounds per cubic foot equivalent fluid weight.

#### ***Poured concrete basement foundation walls***

Thicknesses and types of wall construction are ordinarily controlled by local building regulations. Thicknesses of poured or cast-in-place concrete basement walls vary from 8 to 10 inches and concrete block walls from 8 to 12 inches, depending on height of story and length of unsupported walls.

**Table 3 – Framing requirements for pressure-treated wood basement walls**

No. of stories	Height of fill (in.)	Nominal stud size <sup>a</sup>	Minimum required "f"-value <sup>b</sup>	Minimum required "E"-value <sup>b</sup>	Nominal footing plate size
1	24	2 × 4	1,130	1,400,000	2 × 8
	48	2 × 4	1,435	1,600,000	2 × 8
	72	2 × 6	1,260	1,600,000	2 × 8
	86	2 × 6	1,520	1,800,000	2 × 8
2	24	2 × 4	1,435	1,600,000	2 × 10
	48	2 × 6	1,000	1,400,000	2 × 10
	72	2 × 6	1,260	1,600,000	2 × 10
	86	2 × 6	1,520	1,800,000	2 × 10

Source: NAHB Research Foundation (1977). *Reducing Home Building Costs with OVE Design and Construction*.

<sup>a</sup>Assumes studs spacing of 12 inches and 30 pounds per cubic foot equivalent fluid weight of soil.

<sup>b</sup>See technical note on design values for common species and grades of lumber.

Clear wall height should be no less than 7 feet from the top of the finished basement floor to the bottom of the joists; greater clearance is usually desirable to provide adequate headroom under girders, pipes, and ducts. Above the footings, many contractors pour 8-foot-high concrete walls which provide a clearance of 7 feet 8 inches from the top of the finished concrete floor to the bottom of the joists. Concrete block walls, 11 courses above the footings with 4-inch solid cap block, produce a height of about 7 feet 4 inches from the basement floor to the joists.

Crawl space foundation wall heights are determined by the depth of frost level and by the height needed to maintain adequate under-floor access. They are usually 18 to 24 inches from the ground to the bottom of the floor framing members.

Poured concrete walls (fig. 9) require forming that must be tight, well-braced, and tied to withstand the forces of the pouring operation and the fluid concrete.

Poured concrete walls should be double-formed (with formwork constructed for each wall face). Reusable forms are used in the majority of poured walls. Panels can consist of wood framing with plywood facings and are fastened together with clips or other ties (fig. 9). Wood sheathing boards and studs with horizontal members and braces are sometimes used in the construction of forms. As with reusable forms, formwork should be plumb, straight, and sufficiently braced to withstand pouring. Frames for basement windows, doors, and other openings are set in place as the forming is erected, along with forms for the beam pockets that are located to support the ends of the floor beam.

Reusable forms usually require little bracing other than horizontal members and sufficient blocking and bracing to

keep them in place during pouring. Forms constructed with vertical studs and waterproof plywood or lumber sheathing require horizontal walers and bracing.

Level marks of some type, such as nails along the form, should be used to assure a level foundation top. This provides a level sill plate and floor framing.

The concrete should be poured continuously, and constantly rodded or vibrated to remove air pockets and to work the material under window frames and other blocking. Care should be taken to avoid excessive vibrating because this may cause the gravel or crushed rock in the concrete to settle to the bottom and weaken the wall. If wood spacer blocks are used, they should be removed and not permitted to become buried in the concrete. Anchor bolts for the sill plate, spaced 8 feet on center, should be placed while the concrete is still plastic. Concrete should always be protected when outside temperatures are below freezing.

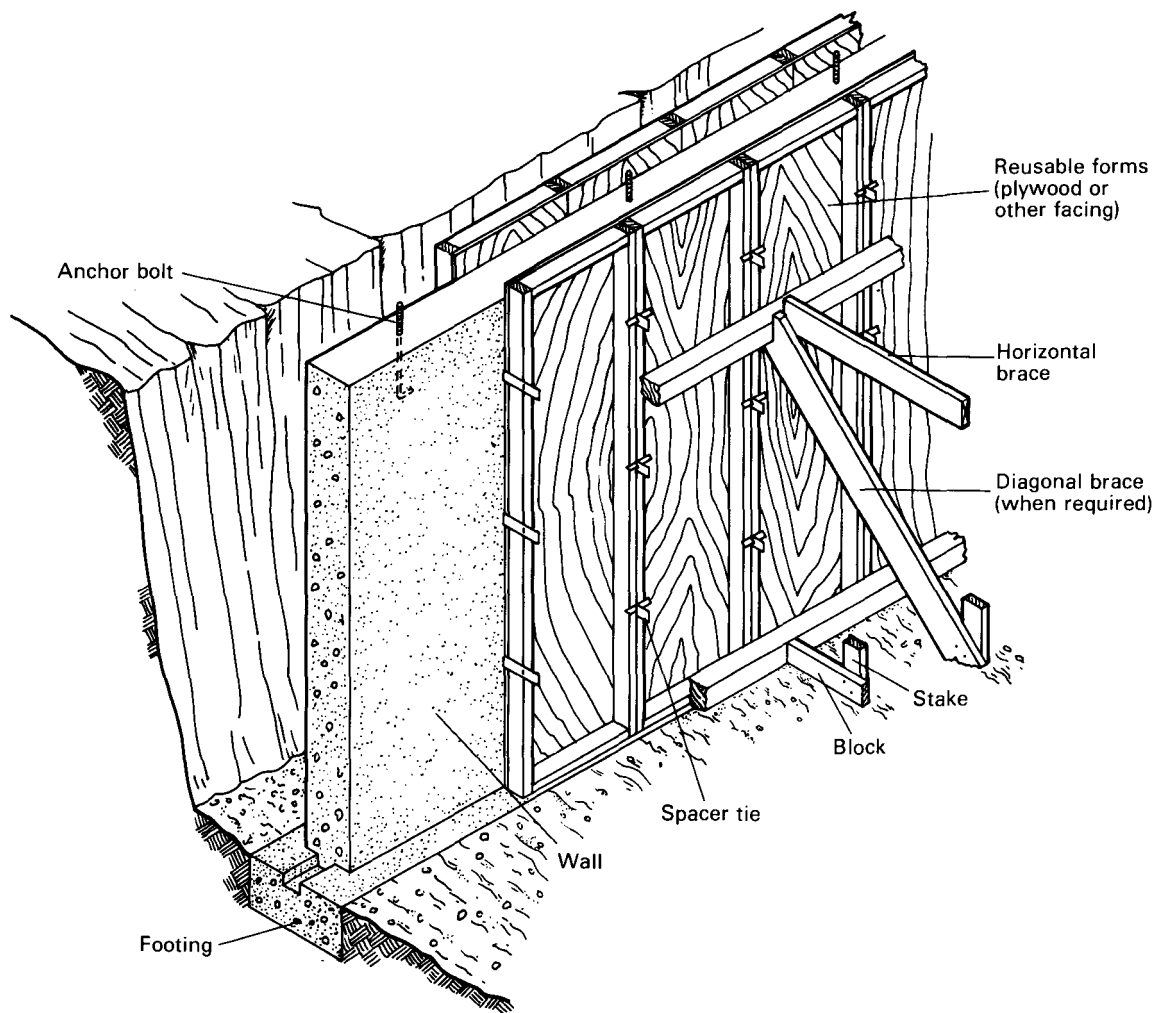
Forms should not be removed until the concrete has hardened and acquired sufficient strength to support loads imposed during early stages of construction. At least 2 days, and preferably longer, are required when temperatures are well above freezing, and perhaps a week when outside temperatures are below freezing. Never backfill until both the floor framing and basement slab are in place.

Poured concrete walls can be dampproofed with a heavy cold coat or hot coat of tar or asphalt. This coat should be applied to the outside from the footings to the finish gradeline, when the surface of the concrete has dried enough to assure good adhesion. Such coatings are usually sufficient to make a wall watertight against ordinary seepage such as may occur after a rainstorm. In addition, the backfill around the outside of the wall may consist of gravel. The objective of a gravel backfill is to prevent soil from holding water against the foundation wall and to allow the water to flow quickly down to the drain tiles at the base of the wall. Instead of gravel backfill, a drainboard composed of plastic fibers or polystyrene beads can be installed against the foundation wall. The material serves the same function as the gravel backfill. In poorly drained soils, a membrane may be necessary as described in the section on masonry basement foundations.

### ***Masonry basement foundations***

Concrete blocks are available in various sizes and forms, but the blocks most commonly used are 8, 10, or 12 inches wide. Modular blocks that allow for the thickness and width of the mortar joint are usually about 7<sup>5</sup>/<sub>8</sub> inches high and 15<sup>5</sup>/<sub>8</sub> inches long. Such blocks form a wall with mortar joints spaced 8 inches from centerline to centerline vertically and 16 inches from centerline to centerline horizontally.

**Figure 9** – *Forming for cast-in-place concrete foundation walls.*



Block courses start at the footing and are laid up with mortar joints of about  $\frac{3}{8}$  inch, usually in a common bond (staggered vertical joints). Joints should be tooled smooth to resist water seepage. Full bedding of mortar should be used on all contact surfaces of the block. When pilasters (column-like projections) are used to carry the concentrated loads at the ends of a beam or girder, they are placed on the interior side of the wall and terminated at the bottom of the beam or girder they support. Pilasters can be formed by laying up wider blocks than are used in the rest of the wall, from the footing to the bottom of the supported beam.

Basement door and window frames should be set with keys for rigidity and to prevent air leakage (fig. 10).

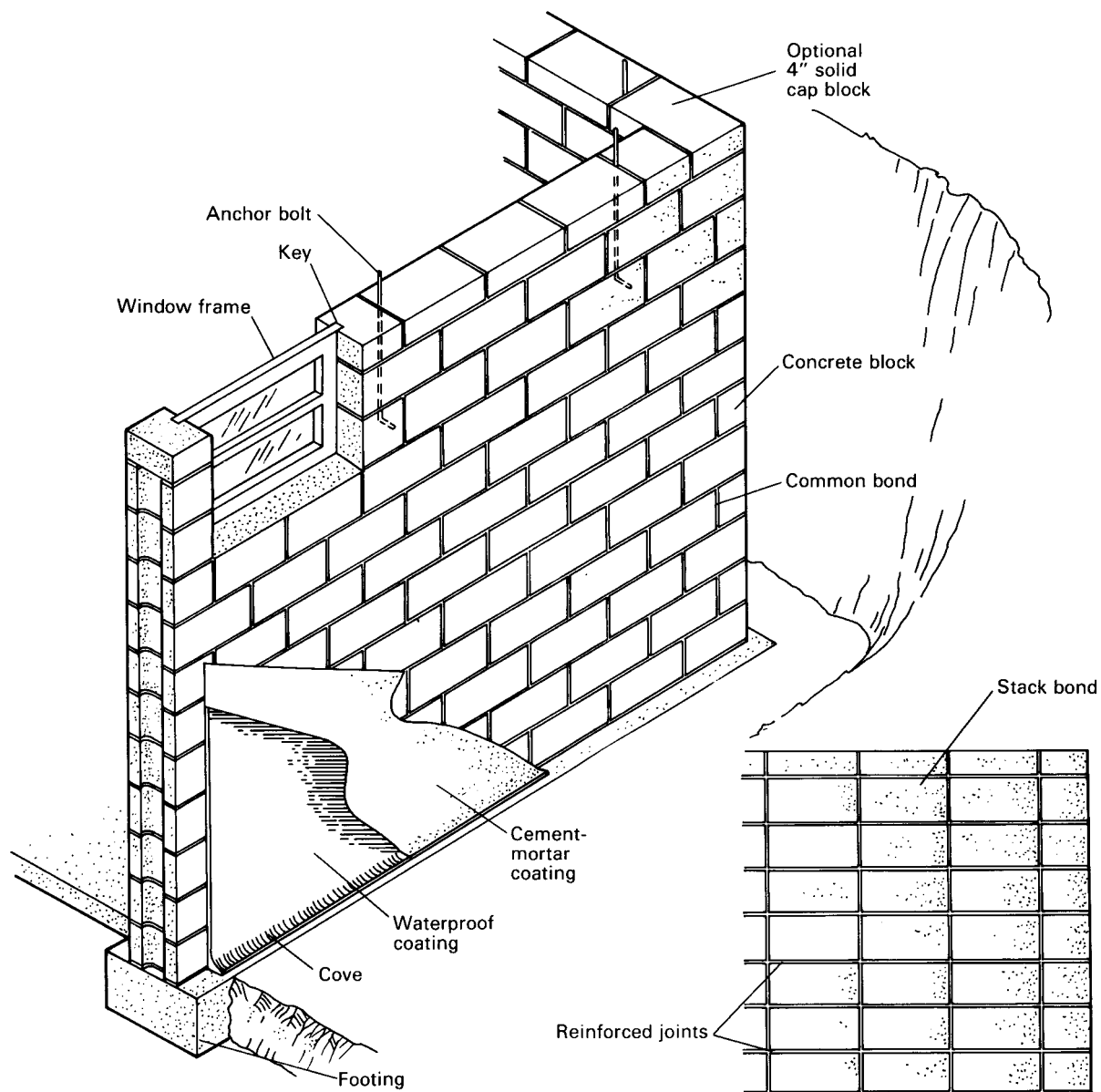
Anchor bolts for sills are usually placed through the top two rows of blocks (fig. 10). The bent bottom end of the anchor bolt should be positioned under the lower block and the block openings should be filled solidly with mortar or concrete.

When an exposed block foundation is used as a finished wall for basement rooms, the stack bond pattern may be employed for a pleasing effect. This consists of placing blocks one above the other, resulting in continuous vertical mortar joints. However, when this system is used, it is necessary to incorporate joint reinforcing in every second course. Reinforcement usually consists of small-diameter steel trusses 6, 8, or 10 inches wide and 16 feet long that are laid flat on the bed of mortar between block courses. To gain additional strength, reinforcing rods can be installed vertically in some of the block cores which are then filled with concrete.

Freshly laid block walls should be protected when temperatures are below freezing. Freezing of the mortar before it has set often results in low adhesion, low strength, and joint failure.

The wall may be waterproofed by applying a coating of cement-mortar over the block with a cove formed at the

Figure 10—Concrete block foundation wall.



juncture with the footing (fig. 10). When the mortar is dry, a coating of asphalt or other waterproofing will normally assure a dry basement. Other methods include the application of a 6-mil polyethylene film over the asphalt to provide a water barrier or the installation of the drain-board against the asphalt coating before backfilling, as described previously.

### Basement Floor and Crawl Space

#### Drain tile

Foundation or footing drains must often be placed (a) around foundations enclosing basements or habitable

spaces below the outside finish grade (fig. 11), (b) in sloping or low areas, or (c) any location where it is necessary to drain away subsurface water as a precaution against damp basements and wet floors.

Drains are installed at or below the level of the area to be protected. They should drain toward a ditch or into a sump where the water can be pumped to a storm sewer. Perforated plastic drain pipe, 4 inches in diameter, is ordinarily placed at the bottom of the footing level on top of a 2-inch gravel bed (fig. 11). Another 6 to 8 inches of gravel is used over the pipe. In some cases, 12-inch-long tile is used to form the drain. Tiles are spaced about  $\frac{1}{8}$  inch apart and joints are covered with a strip of asphalt

felt. Drainage is toward the out-fall or ditch. Dry wells for drainage water are used only when the soil conditions are favorable for this method of disposal. Local building regulations vary and should be consulted before construction of the drainage system.

### ***Basement floors***

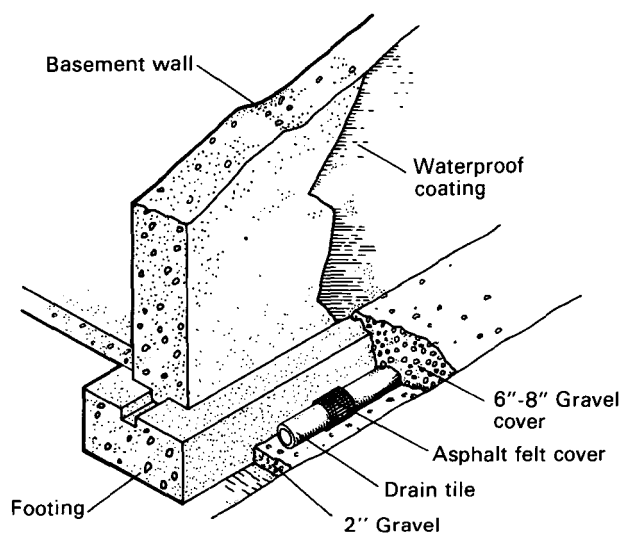
Basements are normally finished with a concrete floor whether or not the area is to contain habitable rooms. Structurally, the floor keeps the soil pressure from pushing in the bottom of the foundation wall. Concrete floors are cast in place after all improvements such as sewer and water lines have been connected. Concrete slabs should not be poured on recently filled areas unless such areas have been thoroughly compacted.

At least one floor drain should be installed in a basement floor, usually near the laundry area. Large basements may require two or more floor drains. Positioning and installation of the drain and piping should precede the pouring of the concrete floor.

Four inches of compacted gravel should be installed as a base for the concrete. The purpose of the gravel base is to break the capillary action between the soil and the concrete. This helps to make a drier floor. The gravel also serves temporarily to store ground water that may seep beneath the slab. Instead of being forced to the floor surface through cracks in the slab, the water is able to migrate to floor drains beneath the slab.

A 6-mil polyethylene film should also be used on top of the gravel base to keep moisture from migrating through the slab into the basement.

**Figure 11** – Drain tile for soil drainage at outer foundation walls.



Basement floor slabs should be either level or sloped toward floor drains. Before the concrete is poured, lengths of 2- by 4-inch lumber (called 2 by 4's, though actually 3½ inches wide) are installed on edge on the basement floor at 8-foot intervals. The top edges of the 2 by 4's are used to set the depth of the concrete for the floor slab and to determine the level or slope of the surface. The elevation of the tops of the 2 by 4's should be decided with a surveyor's level. A less precise alternative is to measure down from the bottom edge of the floor joists installed overhead.

The concrete is then poured. A straight 10-foot length of 2 by 4 is used as a screed spanning the 2 by 4 forms installed on the floor at 8-foot intervals. The screed is worked back and forth to bring the concrete to the level of the top edges of the 2 by 4 forms. Concrete should be added to low spots beneath the screed.

The 2 by 4 forms should be removed as soon as the screeding process is completed. The disturbed concrete should then be leveled, adding concrete as needed.

### ***Crawl spaces***

In some areas of the country, houses are often built over crawl space rather than over a basement or on a concrete slab. It is possible to construct a satisfactory house over crawl space by using (a) a good soil cover, (b) a small amount of ventilation, and (c) sufficient insulation to reduce heat loss.

Houses cost less to build over crawl space than over a full basement. Little or no excavation or grading is required except for footings and walls. In mild climates, footings are located only slightly below the finish grade. However, in the northern states and in Canada where frost penetrates deeply, the footing is often located 4 or more feet below the finish grade. In this case, full basement or raised entry construction may offer much more space at little additional cost. The footings should always be poured over undisturbed soil and never over fill unless special piers and grade beams are used.

**Treated wood crawl spaces.** Crawl space foundation walls can be constructed of FDN-stamped pressure-treated lumber and plywood, as described in the section on treated wood basement foundations. The use of wood offers opportunities for prefabrication not possible with concrete or masonry foundations.

Panels are assembled in the same manner as pressure-treated wood basement foundation walls using pressure-treated studs, plates, and plywood facing. However, because a crawl space requires no more than 24 inches of headroom, the ½-inch-thick plywood facing needs to extend only 2 feet down from the top plate to the level of

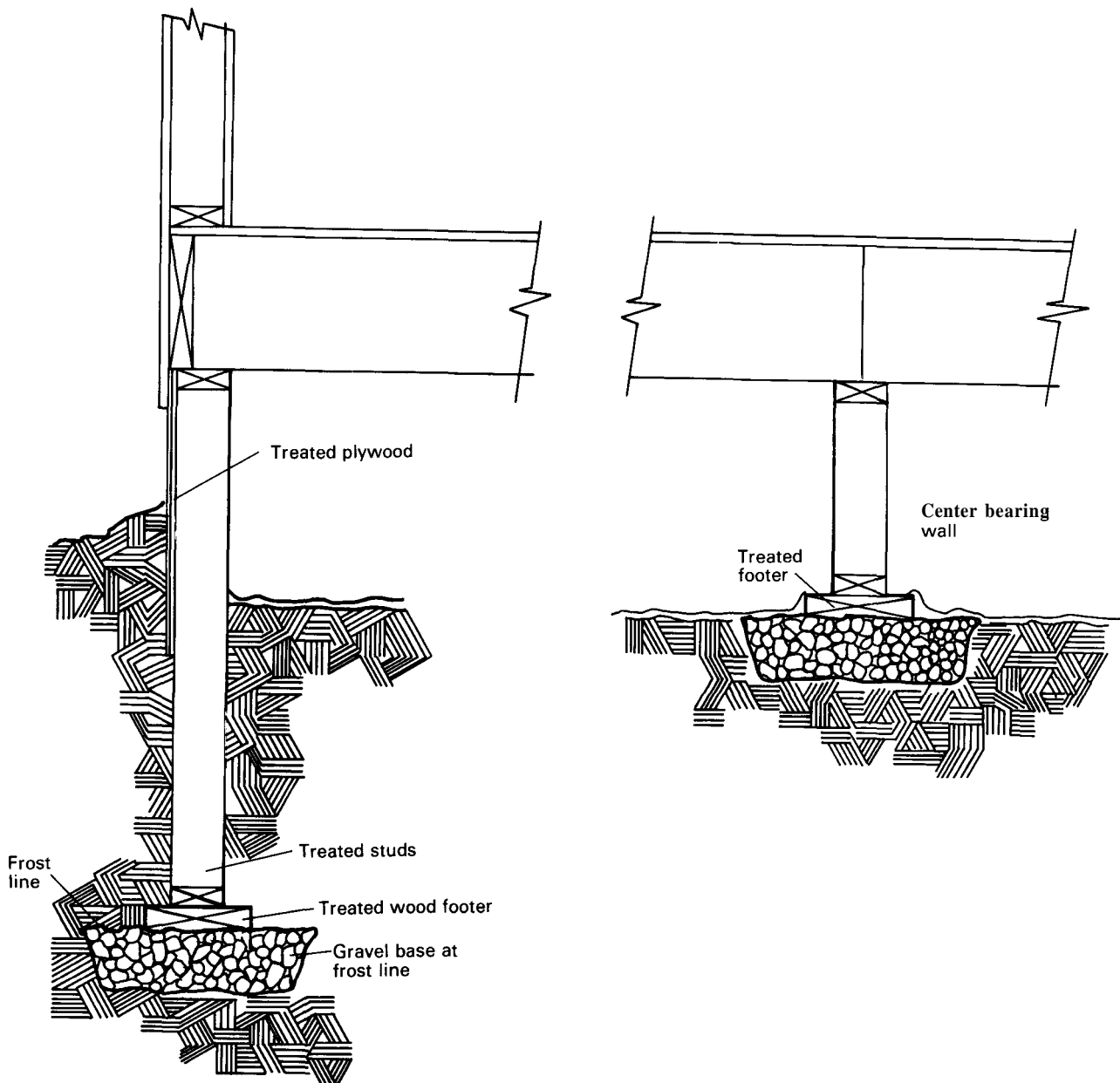
the crawl space floor, while the unfaced studs continue down to the frost line (fig. 12). Pressure-treated 2- by 4-inch studs may be spaced at 24 inches on center for single-story construction. For two stories, a spacing of 12 inches on center is necessary.

Construction begins with excavation to the level of the crawl space floor. If local frost conditions require greater depth, a trench of appropriate width is dug around the perimeter, allowing the wall to extend down to the required depth. A layer of crushed stone or gravel with a minimum depth of 4 inches is then deposited at the bottom of the trench and carefully leveled. Wall panels are

installed over footers placed on the gravel and braced in place, plywood joints are caulked, and the wall is covered with 6-mil polyethylene below grade on the exterior.

A wood-frame center-bearing wall may also be used. Such a wall should be assembled from 2- by 4-inch studs spaced at 24 inches on center. A plywood facing is not required. The walls may be supported on a stone or gravel bed in a shallow trench (fig. 12). As an alternative, center support may be provided by a conventional beam supported on columns or piers.

**Figure 12** – *Pressure-treated-wood crawl-space footing and foundation wall.*



**Masonry crawl spaces.** Construction of a masonry wall for a crawl space is much the same as for a full basement, except that no excavation is required within the walls. Waterproofing and drain tile are normally not required for this type of construction. Masonry piers replace the wood or steel posts used to support the center beam of the basement house. Footing size and wall thicknesses vary with location and soil conditions. A common minimum thickness for walls in single-story frame houses is 8 inches for hollow concrete block and 6 inches for poured concrete. Minimum footing thickness is 6 inches; width is 12 inches for concrete block and 10 inches for poured concrete.

Poured concrete or concrete block piers are often used to support floor beams in crawl-space houses. They should extend at least 12 inches above the groundline. Minimum size for a concrete block pier should be 8 by 16 inches with a 16- by 24-inch concrete footing that is 8 inches thick. A solid cap block is used as a top course. Poured concrete piers should be at least 10 by 10 inches in size with a 20- by 20-inch footing that is 8 inches thick.

Unreinforced concrete piers should be no greater in height than 10 times their least cross-sectional dimension.

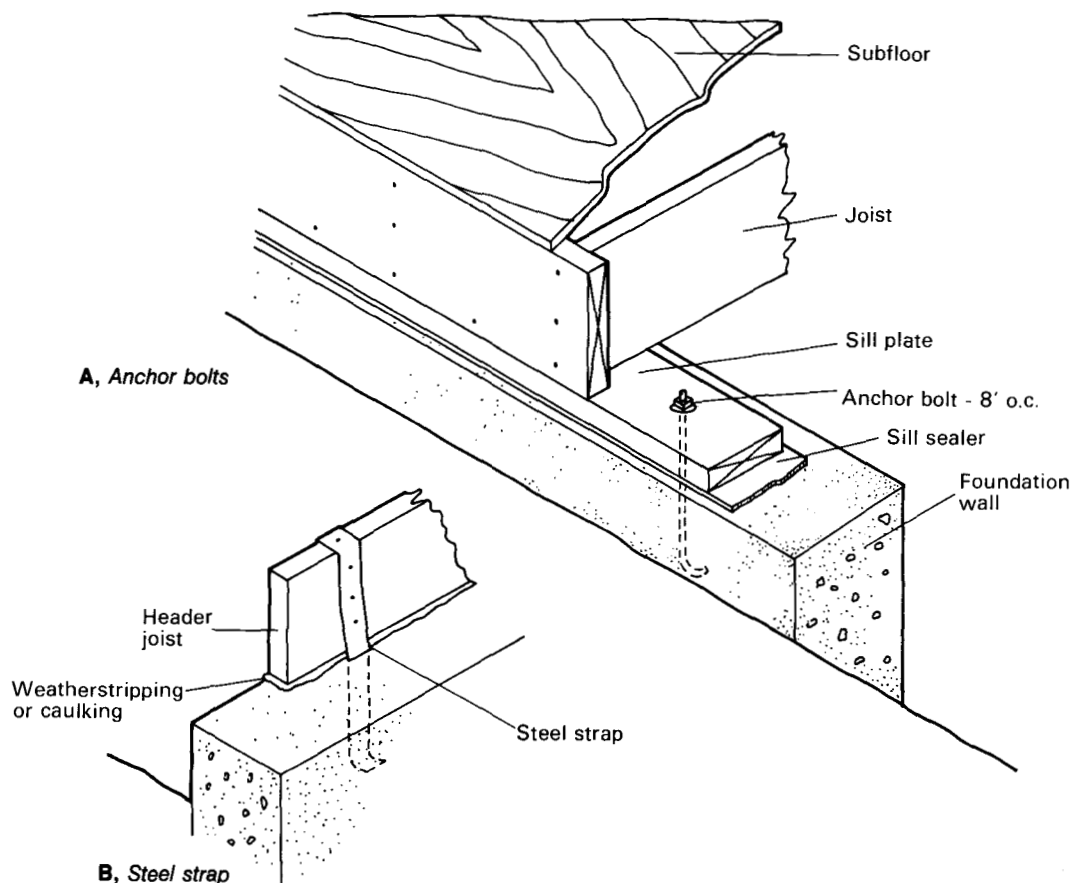
Concrete block piers should be no higher than four times the least cross-sectional dimension. Spacing of piers should not exceed 8 feet on center under exterior wall beams and interior girders set at right angles to the floor joists and should not exceed 12 feet on center under exterior wall beams set parallel to the floor joists. Exterior wall piers should not extend above grade more than four times their least dimension unless supported laterally by masonry or concrete walls. The size of the pier for wall footing should be based on the load and the bearing capacity of the soil.

## Other Features

### *Sill plate anchors*

In wood-frame construction, the sill plate should be anchored to the foundation wall with  $\frac{1}{4}$ -inch bolts spaced about 8 feet apart (fig. 13A). In some areas, sill plates are fastened with masonry nails or power-actuated nails, but such nails do not have the uplift resistance of bolts. In areas of high wind and storm, well-anchored plates are very important.

**Figure 13** – Anchoring floor system to foundation wall:



A sill sealer is often used under the sill plate on cast-in-place walls to fill any irregularities between the plate and the wall. Anchor bolts should be embedded 8 inches or more in poured concrete walls and 16 inches or more in block walls with concrete-filled cores. The bent end of the anchor bolt should be hooked under a block and the core filled with concrete. If termite shields are used, they should be installed under the plate and sill sealer.

Some contractors construct wood-frame houses without using a sill plate. The floor system must then be anchored with steel strapping, which is placed during the pouring of concrete or in the joints between precast blocks. The strap is bent over and nailed to the floor joist or header joist (fig. 13B). The use of concrete or mortar beam fill provides resistance to entry by air and insects.

### ***Reinforcing poured walls***

Poured concrete walls normally do not require steel reinforcing except over window or door openings located below the top of the wall. Construction of such openings, however, requires that a properly designed steel or reinforced concrete lintel be built over the frame (fig. 14A). Rods are set in place about 1 inch above the opening while the concrete is being poured. Frames should be prime painted or treated before installation. For concrete block walls, a similar lintel is commonly used of reinforced, poured, or precast concrete.

Where concrete work includes a connecting porch or garage wall not poured with the main basement wall, it is necessary to provide reinforcing rod ties (fig. 14B). The rods are placed during pouring of the main wall. Depending on the size and depth, at least three ½-inch reinforcing rods should be used at the intersection of each wall. Keyways may also be used to resist lateral movement. Such connecting walls should extend below normal frost line and be supported by undisturbed ground. Porch walls require footings if they extend more than 3 feet from the main wall or if the porch walls are to carry a roof load. Wall extensions in concrete block walls are also built of block and are constructed at the same time as the main walls over a footing placed below frost line.

### ***Masonry veneer over frame walls***

If brick or masonry veneer is used for the outside finish over wood-frame walls, the foundation must include a supporting ledge or offset about 5 inches wide (fig. 15). This results in a “finger space” of about 1 inch between the veneer and the sheathing for ease in laying the brick.

When a block foundation is constructed, the supporting ledge for the brick veneer can be provided by using two different block sizes. For example, 12-inch block can be installed from the footing to the level where the brick

veneer is to begin; 8-inch block can be used from that point upward to support the house framing. A combination of 10-inch and 6-inch block can also be used. The resulting 4-inch ledge requires that the brick veneer be installed with a ½-inch overhang to provide “finger space” for laying the brick.

Providing a brick veneer ledge for a house with pressure-treated wood foundation may be accomplished by building a wall of pressure-treated 2- by 4-inch framing outside the primary foundation wall. This requires the primary wall to have a 2- by 12-inch bottom plate which also supports the outer 2- by 4-inch wall. No sheathing is applied to the outer wall.

A base flashing or 6-mil polyethylene film is used at the brick course below the bottom of the sheathing and framing to collect condensation that may run down the wall behind the brick. The vertical leg of the flashing should be behind the sheathing paper. Weep holes, to provide drainage, are located on 4-foot centers at this course. They are formed by omitting the mortar in a vertical joint between bricks. Galvanized steel brick ties, spaced about 32 inches apart horizontally and 16 inches vertically, should be used to bond the brick veneer to the framework. Where sheathing other than wood is used, the ties should be secured to the studs.

Brick should be laid in a full bed of mortar. Mortar should not be dropped into the space between the brick veneer and the sheathing. Outside joints should be tooled to a smooth finish to achieve maximum resistance to water penetration.

Masonry laid during cold weather should be protected from freezing until after the mortar has set.

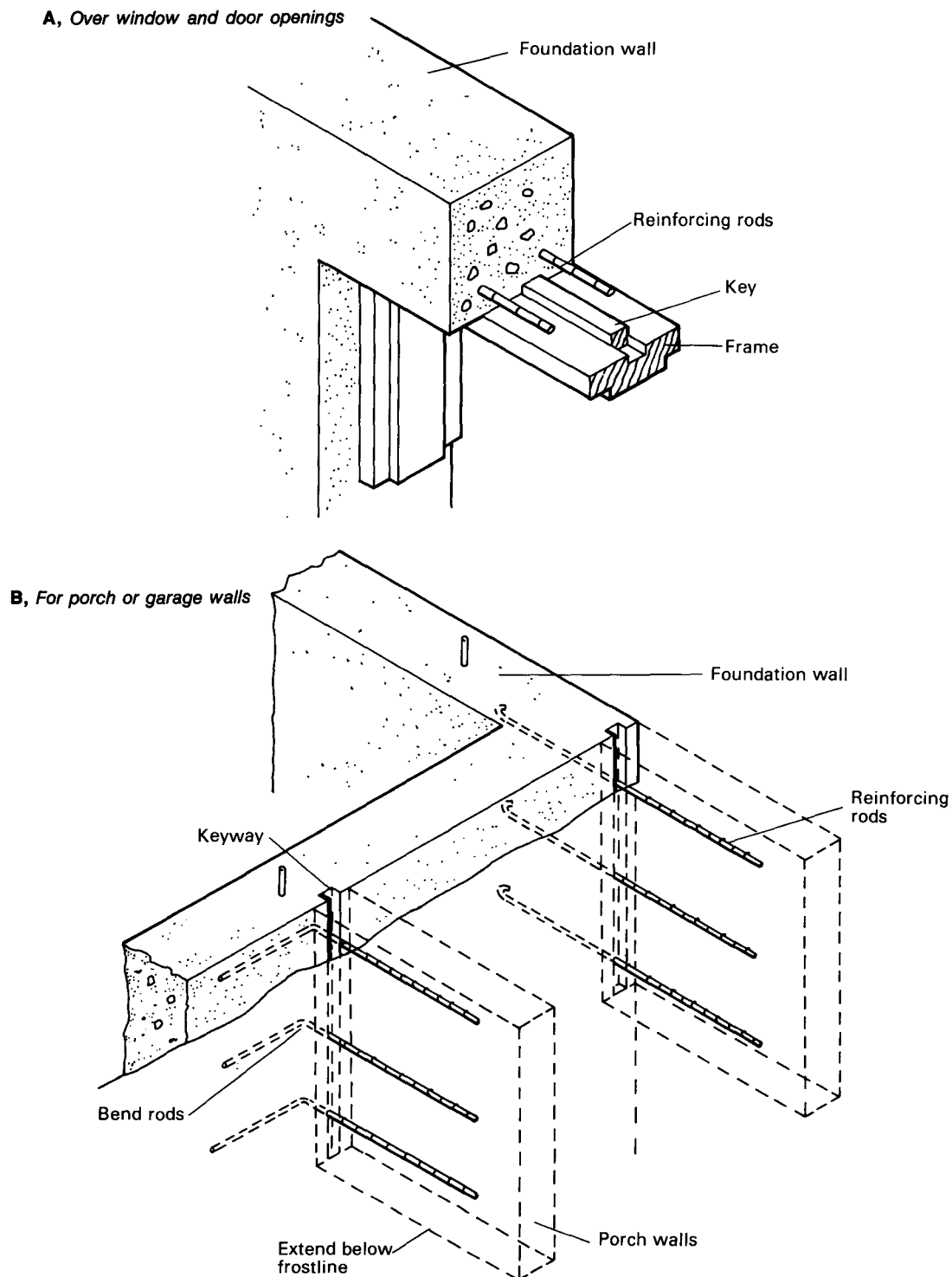
### ***Notch for wood beams***

When basement beams or girders are wood, the wall notch or pocket for such members should be large enough to allow a ½-inch clearance, at least, for ventilation at the sides and ends of the beam (fig. 16). Unless pressure-treated wood is used, there is risk of decay where beams and girders are so tightly set in wall notches that moisture cannot readily escape.

### ***Protection against termites***

Certain areas of the country are infested with wood-destroying termites. This is true, in particular, along the Atlantic Coast, in the Gulf States, the Mississippi and Ohio Valleys, and southern California. In such areas, wood construction over a masonry foundation should be protected by one or more of the following:

**Figure 14 – Steel reinforcing rods in concrete foundation walls:**



1. Poured or precast concrete foundation walls.
2. Masonry unit foundation walls capped with reinforced concrete.
3. Metal shields made of rust-resistant material. Metal shields are effective only if they extend beyond the masonry walls and are continuous, with no gaps or loose joints.
4. Preservative treatment of wood. This protects only the members treated.
5. Treatment of soil with insecticide. This is one of the most common and most effective protective measures.

For more information, see the section on termite protection in chapter 8.

### ***Crawl-space ventilation and soil cover***

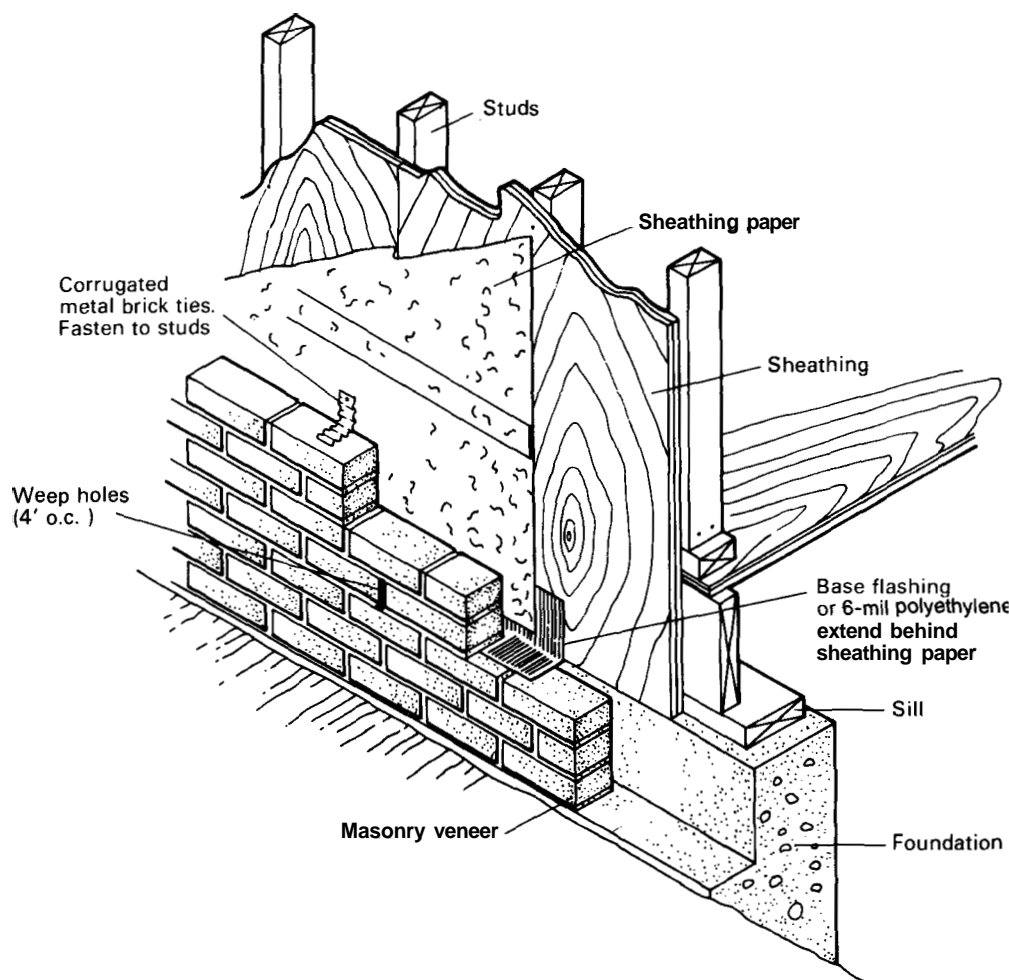
Crawl spaces below the floor of basementless houses and under porches should be ventilated and protected from ground moisture by a soil or ground cover (fig. 17). A soil cover, preferably 6-mil polyethylene, is normally recommended under all conditions to protect wood framing members from ground moisture. Using a soil cover permits the use of smaller, inconspicuous vents.

Such protection minimizes the effect of ground moisture on wood framing members. High soil moisture content and humidity may cause the moisture content in the wood to rise high enough to permit staining and decay to develop in untreated members.

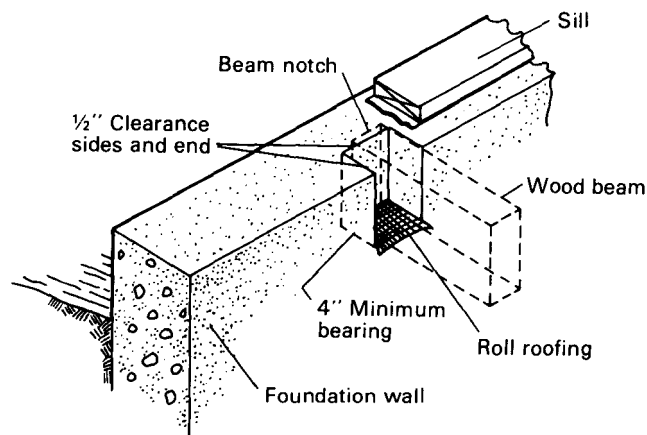
Where there is a partial basement that has an operable window and is open to the crawl space area, no wall vents are required. Use of a soil cover in the crawl space area is nevertheless recommended.

For crawl spaces with no adjoining basement, the net ventilating area required with a soil cover is  $1/1,600$  of the ground area. For a ground area of 1,200 square feet ( $\text{ft}^2$ ), the required ventilating area is  $0.75 \text{ ft}^2$ . This should be divided between two small vents located on opposite sides of the crawl space. Vents should be covered with a corrosion-resistant screen of No. 8 mesh (fig. 17). It should be noted that the total free (net) area of the vents is somewhat less than the total area of opening, because of the presence of the vent frames, and the screening and louvers. The net free area is indicated on vents purchased from a building supplier.

**Figure 15** – Foundation ledge for masonry veneer.



**Figure 16** – Foundation wall notch for wood beams.

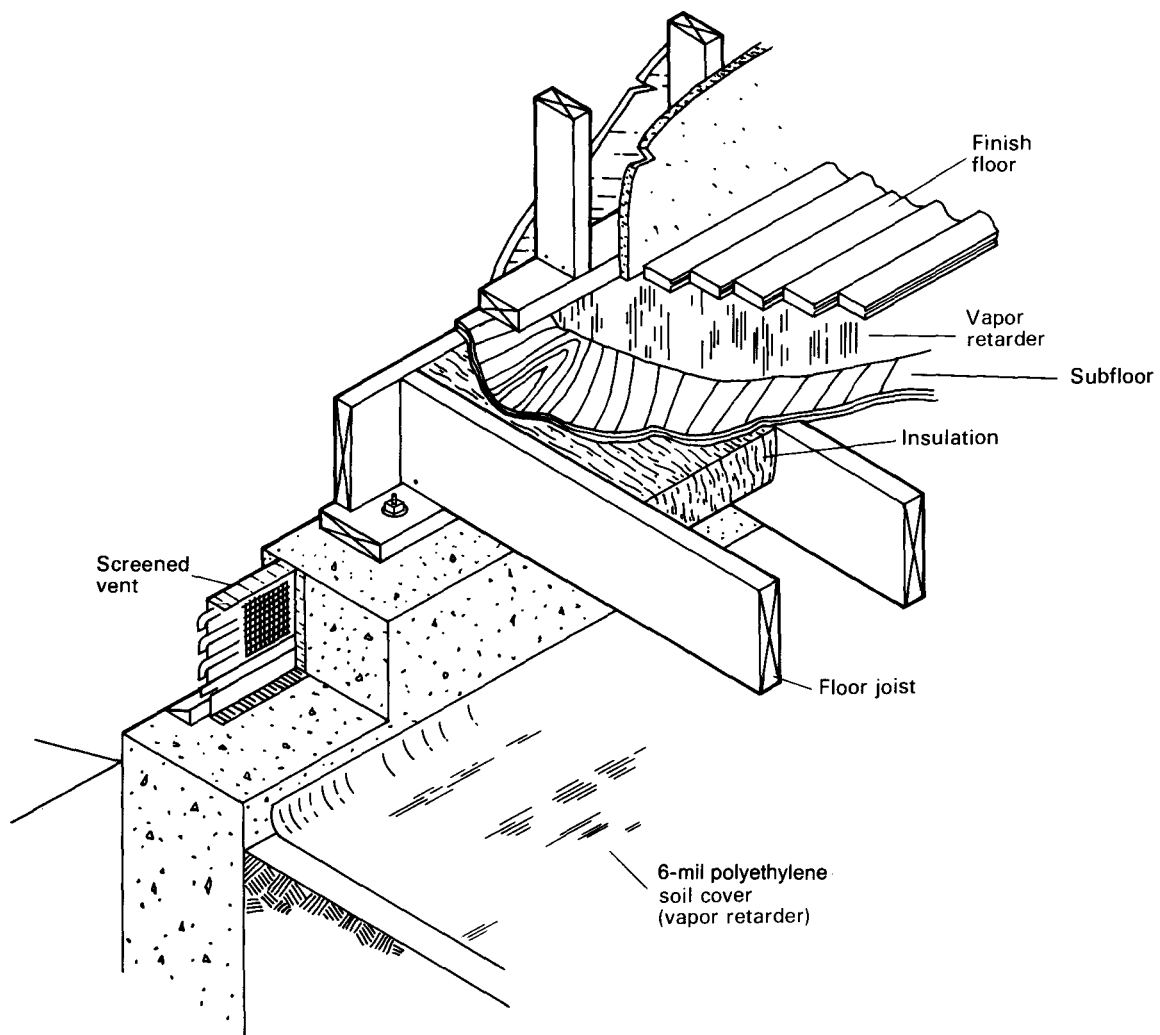


Where no ground cover is used, the total free (net) area of the vents should equal 1/160 of the ground area. For a ground area of 1,200 ft<sup>2</sup> a total net ventilating area of about 8 ft<sup>2</sup> is required. This can be provided by installing four vents, each with 2 ft<sup>2</sup> of free ventilating area. A larger number of vents of smaller size, providing the same net ratio, can be used. The vents that are installed should be the type that can be closed during cold weather to reduce heat loss and the possibility of frozen pipes.

### Concrete Floor Slabs on Ground

The number of new one-story houses with full basements has declined in recent years, particularly in the warmer parts of the United States. As previously noted, this results in part from the lower construction costs for houses without basements. It also reflects a decrease in need for basement space.

**Figure 17** – Crawl-space ventilator and soil cover.



Traditionally, basements provided space for a central heating plant, for storage and handling of bulk fuel and ashes, and for laundry and utility equipment. Increased use of electricity, oil, and natural gas for heating has virtually eliminated the need for large coal furnaces and for storage for coal and ashes. Space on the ground floor level can be provided for a compact arrangement of modern heating plant, laundry, and utilities, and the need for a basement often disappears.

A common type of floor construction for houses without basements is a concrete slab. Sloping ground or low areas are usually not ideal for slab-on-grade construction because structural and drainage problems can add to costs. However, split-level houses often have a portion of the foundation designed for a grade slab. In such instances, the slope of the lot is taken into account and can become an advantage.

#### ***Basic requirements for floor slabs***

Basic requirements for construction of concrete floor slabs include the following:

1. Finished floor level should be above natural ground level high enough for finished grade around the house to be sloped away for good drainage. The top of the slab should be no less than 8 inches above ground.
2. Top soil should be removed and sewer and water lines installed, then covered with 4 to 6 inches of gravel, crushed rock, or clean sand, well tamped in place.
3. A vapor retarder consisting of a heavy plastic film, such as 6-mil polyethylene, should be used under the concrete slab. Joints should be lapped at least 4 inches. The vapor retarder should not be punctured during placing of the concrete. Certain types of rigid foam insulation such as extruded polystyrene can serve as a vapor retarder beneath the slab if the joints are taped.
4. A permanent, waterproof, nonabsorbent type of rigid insulation should be installed around the perimeter of the slab. Insulation may extend down on the inside or outside of the slab vertically and under the slab edge horizontally a total distance of 24 inches.
5. Concrete slabs should be at least 3½ inches thick.
6. After leveling and screeding, the surface should be finished with wood or metal floats while concrete is still plastic. If a smooth, dense surface is needed for the installation of wood or resilient tile with adhesives, the surface should be steel troweled.

#### ***Combined slab and foundation***

A combined slab and foundation, sometimes referred to as a thickened-edge or monolithic slab, is a useful choice in warm climates where frost penetration is not a problem and soil conditions are especially favorable. It consists of

a shallow footing, reinforced at the perimeter and poured with the slab over a vapor retarder (fig. 18). The bottom of the footing should be at least 1 foot below the natural gradeline and should be supported on solid, unfilled, well-drained ground.

#### ***Independent concrete slab and foundation walls***

In climates where the ground freezes to any appreciable depth during the winter, the walls of the house must be supported by foundations or piers that extend below the frost line to solid bearing on unfilled soil. When the walls have such support, the concrete slab and the foundation wall are usually separate. Two typical systems meet these conditions (figs. 19 and 20).

Reinforced grade beams separate from the concrete slab are used in many parts of the country (fig. 19). When the soil has inadequate bearing capacity, reinforced concrete piers can be installed beneath the grade beam. These piers carry the load of the house down to rock or stronger soil. The piers are also effective in counteracting frost heave under the grade beam in moderately cold climates.

In more severe climates the foundation wall is typically built as shown in figure 20, using concrete block or poured concrete resting on spread footings. The base of the footings must be below the frost line and their width is determined by the bearing capacity of the soil and the load of the structure.

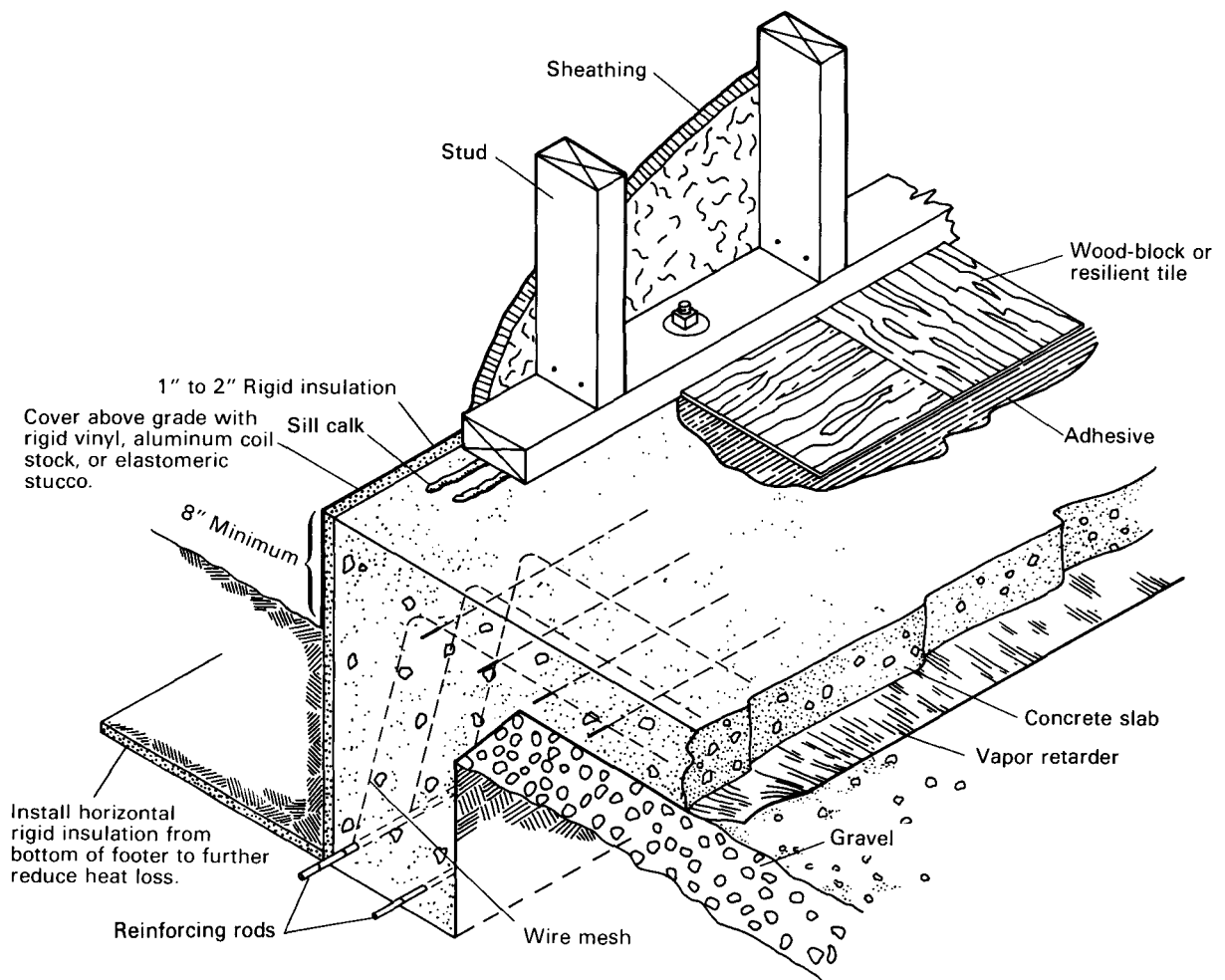
#### ***Insulation requirements for concrete floor slabs on ground***

Except in warm climates, perimeter insulation for slabs is necessary to reduce heat loss and to provide warmer floors during the heating season. Proper locations for this insulation under several conditions are shown in figures 18, 19, and 20.

Thickness of the insulation depends on the climate and on the materials used. Some insulations have more than twice the insulating value of others. The resistance (R) per inch of thickness, as well as the heating design temperature, govern the amount required. Two general rules are:

1. For average winter low temperatures of 0 °F and higher (moderate climates), the total R should be about 10.0 and the insulation should extend vertically along the side of the slab (fig. 18) or horizontally under the slab (fig. 20) for not less than 2 feet.
2. For average winter low temperatures of -20°F and lower (cold climates), the total R should be about 10.0 without floor heating and insulation should extend vertically along the side of the slab (fig. 18) or horizontally under the slab (fig. 20) for not less than 4 feet.

**Figure 18** – Combined floor slab and footing foundation system.



**Figure 19** – Reinforced grade beam for concrete slab giving moderate resistance to frost heave when piers are used.

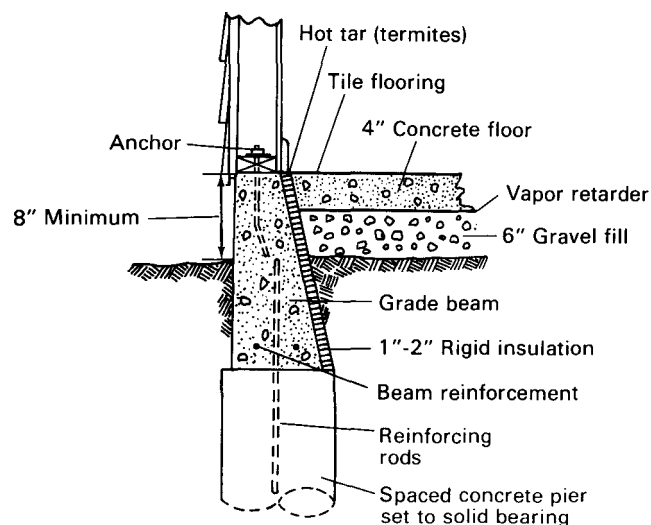


Table 4 shows these factors in more detail. The values shown are minimal; increased insulation results in lower heat losses.

### *Protection against termites*

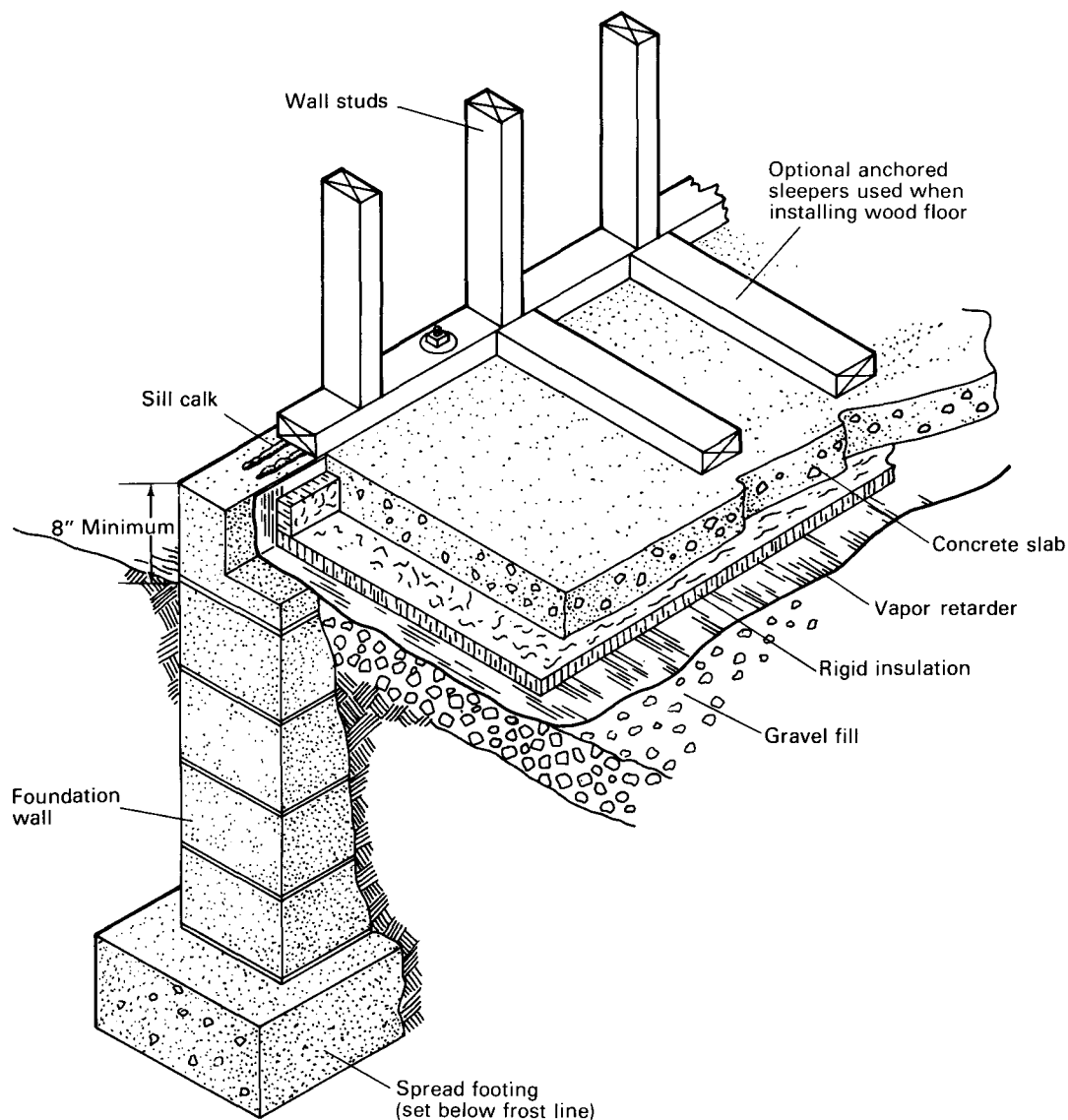
In areas where termites are a problem, soil should be chemically treated around the perimeter of the slab and around pipe or other penetrations through the slab.

### *Insulation*

Properties desired in insulation for floor slabs include:

1. Resistance to heat transmission.
2. Resistance to absorption or retention of moisture.
3. Durability when exposed to dampness and frost.
4. Resistance to crushing by floor loads, weight of slab, and/or expansion forces.
5. Resistance to fungus and insect attack.

Figure 20 – Independent concrete slab and foundation wall system for climates with deep frost line.



Moisture that may affect insulating materials can come from vapor inside the house and dampness in the soil. Vapor retarders and coatings may retard but not entirely prevent the penetration of moisture into the insulation. Dampness may reduce the strength of insulation against crushing, which in turn may permit the edge of the slab to settle. Compression of the insulation reduces its efficiency. However, 4 inches of drained gravel placed between the soil and the insulation breaks the capillary movement of water into the insulation and a 6-mil polyethylene film over the insulation blocks the movement of vapor.

Commonly used insulation materials are extruded polystyrene or expanded polystyrene with a density of 2 pounds per cubic foot (ft<sup>3</sup>).

Table 4 – Resistance values used in determining minimum amount of edge insulation for concrete floors slabs on ground for various design temperatures

Low temperatures (°F)	Depth insulation extends below grade(ft)	Resistance (R) factor	
		No floor heating	Floor heating
-20	4	10.0	10.0
-10	4	10.0	10.0
0	4	10.0	10.0
+10	2	7.5	10.0
+20	2	5.0	7.5

### Retaining Walls

Retaining walls are used to alter topography or to provide improved storm-water management. In some local

jurisdictions a special permit is required to erect a retaining wall in excess of a given height such as 36 inches.

Materials used in constructing retaining wall include pressure-treated wood, masonry, and poured concrete.

Pressure-treated rectangular wood timbers or railroad ties may be used to construct retaining walls (fig. 21). The timbers are stacked so that the butted ends of the members in one course are offset from the butted ends of the members in the courses above and below. The bottom course should be placed at the base of a level trench. In well-drained sandy soil there is no need for preparation or materials for special footing. In less well-drained soils, 12 to 24 inches of gravel backfill behind the wall and a 6-inch-deep gravel footing are desirable. Each course of timbers should be nailed to the course below using galvanized spikes with lengths 1% times the thickness of the timbers. Every second course of timbers should include members inserted perpendicularly to the face of the wall and nailed with spikes to the lower course. These perpendicular tieback members should extend horizontally into the soil behind the wall for a distance equal to their distance above the base of the wall. The end of the tieback member should be nailed to a deadman timber 24 inches in length that has been buried horizontally in the soil and

aligned parallel to the timbers in the wall. These tiebacks and deadmen should be installed every 4 to 6 feet along the retaining wall. The tiebacks and deadmen in a course should be located midway between those in the second course below. The objective of the deadmen and tiebacks is to prevent the finished wall from tipping over because of the pressure from the soil behind the wall.

An alternative retaining wall design is shown in figure 22. Pressure-treated rectangular timbers or railroad ties are set in holes spaced 4 feet apart. Rough-sawn pressure-treated 2-inch lumber is then placed behind vertical members. The 2-inch cross-pieces are held in place by backfilling as they are placed. In poorly drained soils, the backfill should consist of 12 to 24 inches of gravel. In this design the vertical members should be set in post holes to a depth of 4 feet or to frost line depth, whichever is greater, in order to resist tipping from the pressure of the retained soil.

The third retaining wall design involves the use of pressure-treated plywood and pressure-treated 4-inch round or rectangular posts (fig. 23). The posts are set at 24-inch intervals in holes to the depth of the frost line. Pressure-treated  $\frac{3}{4}$ -inch plywood is then placed behind the posts and held in place by the backfill. Holes are drilled

**Figure 21** – Pressure-treated timber retaining wall.

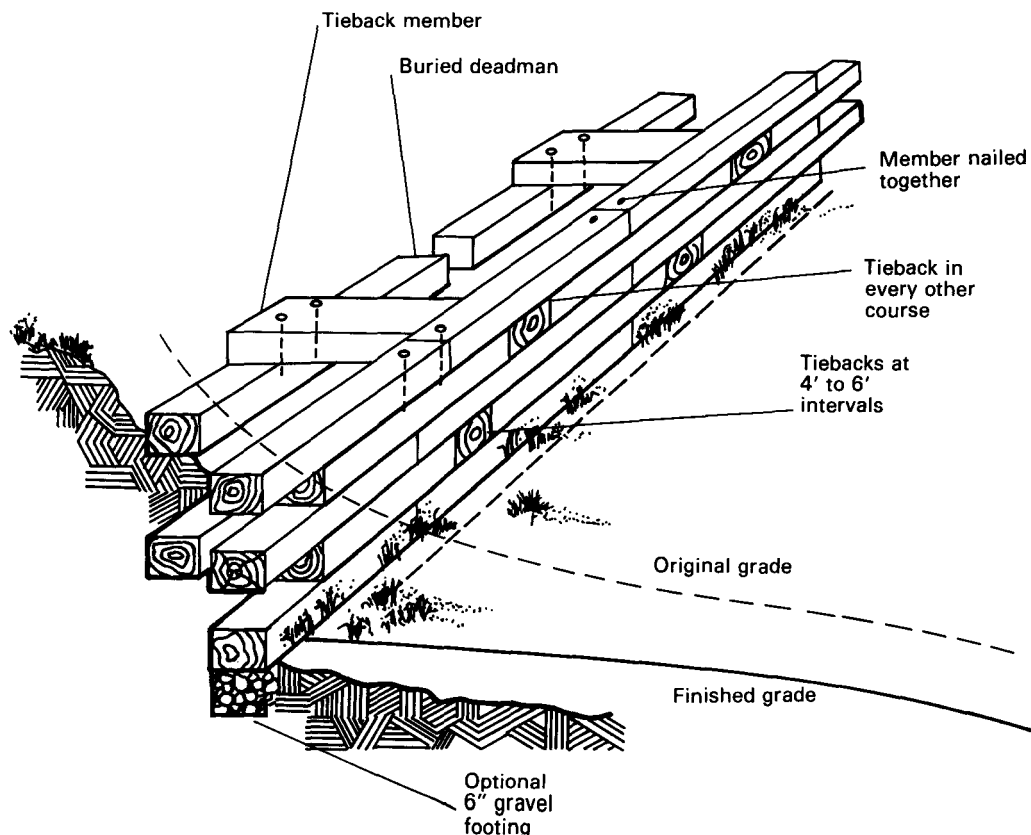


Figure 22 – Pressure-treated timber and rough-sawn dimension lumber retaining wall.

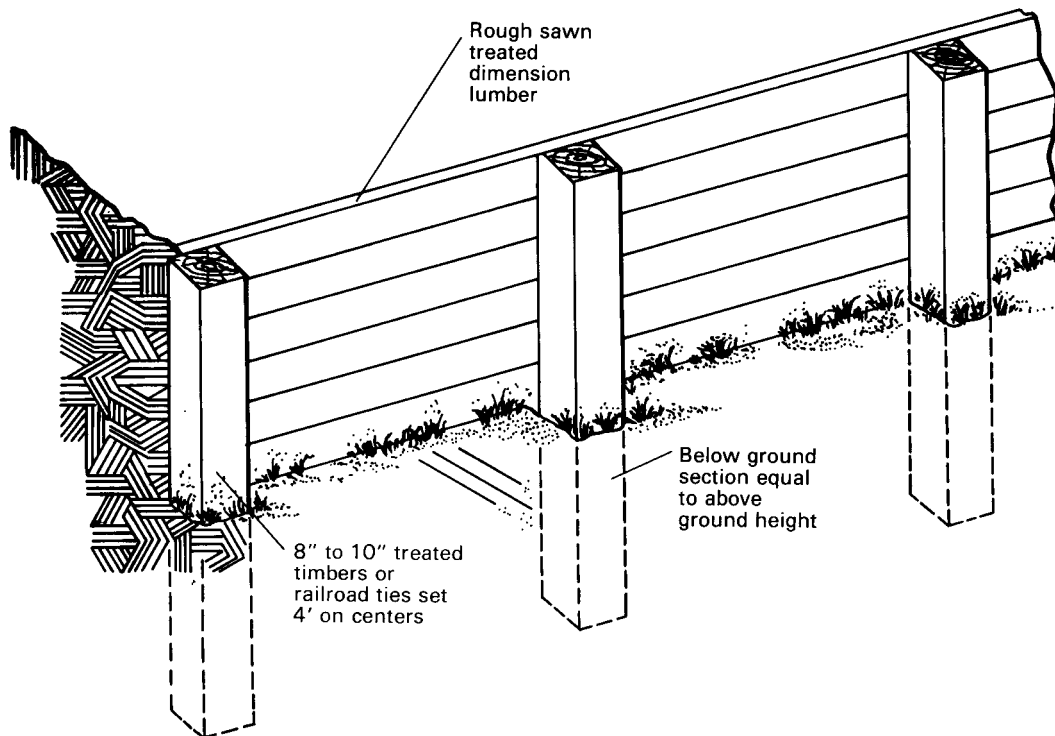
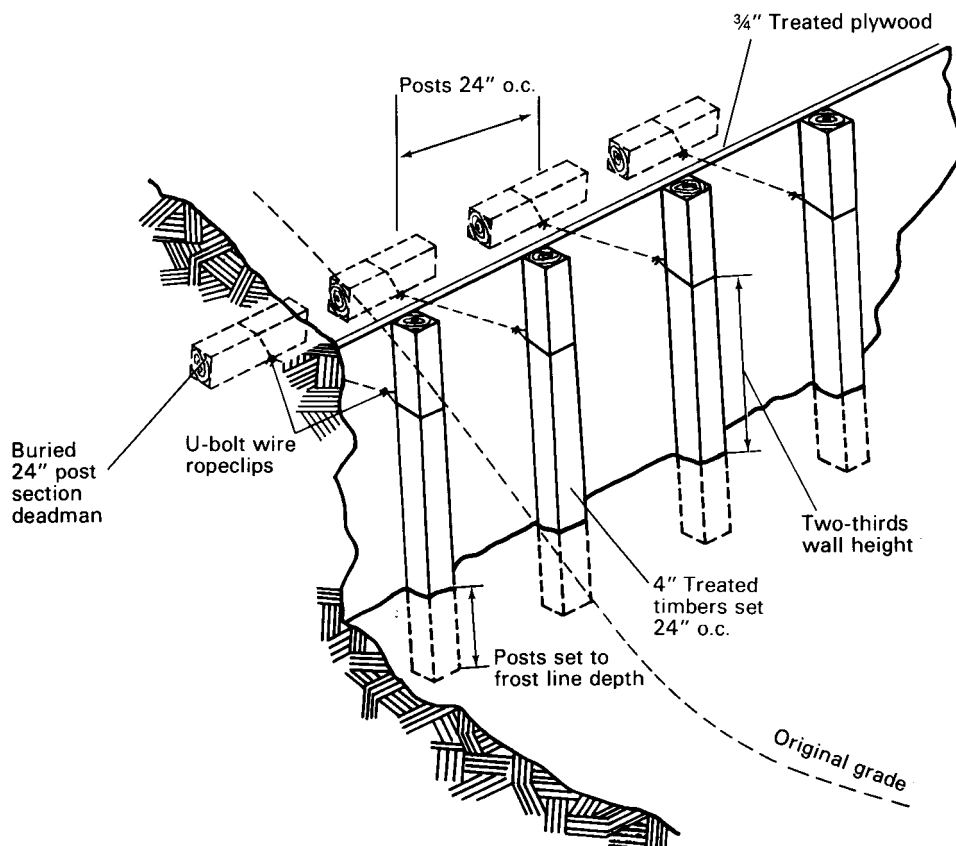


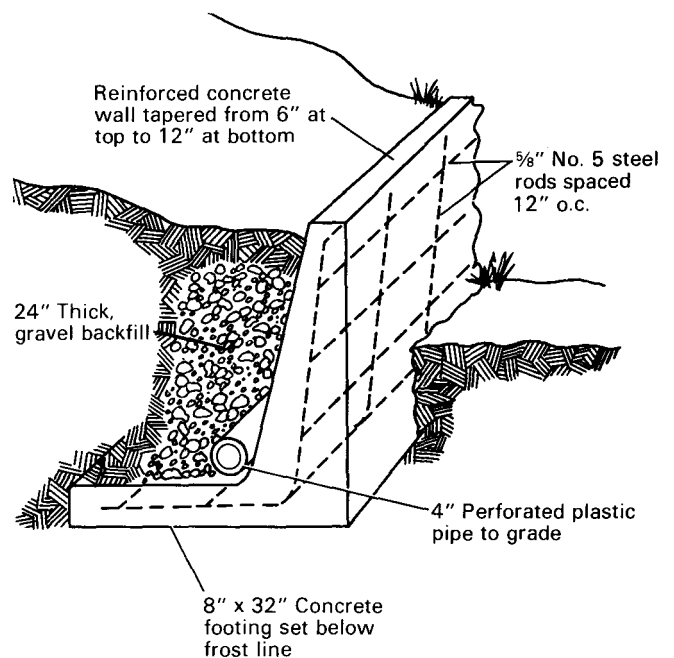
Figure 23 – Pressure-treated post and plywood retaining wall.



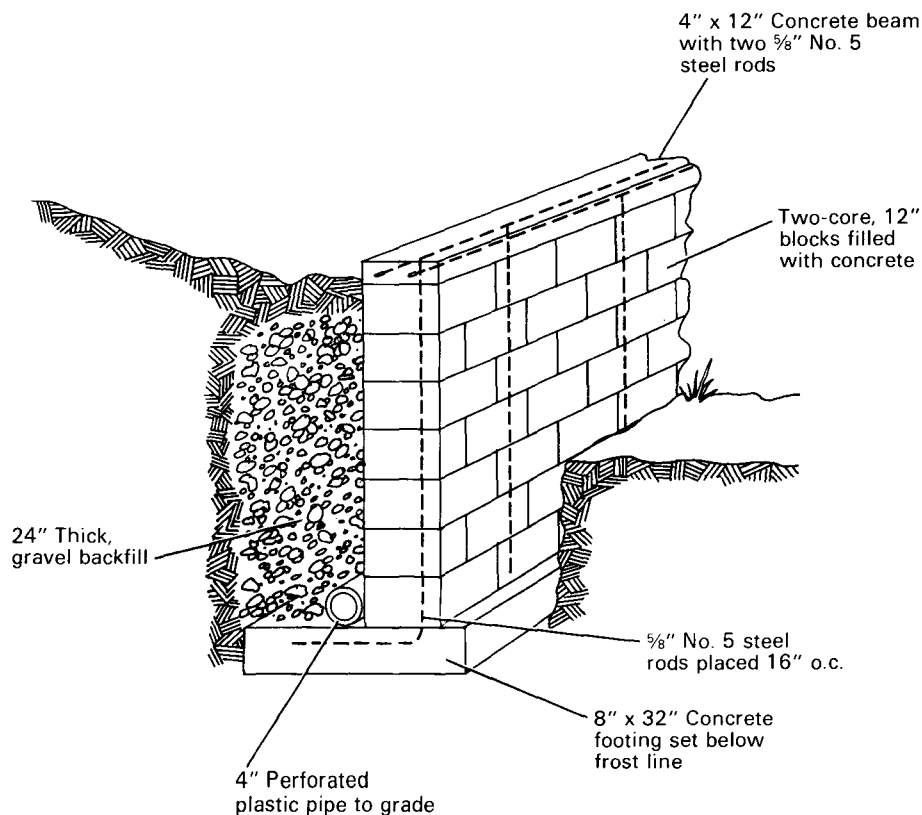
through the plywood on each side of the posts at two-thirds the height of the wall. Plastic-coated galvanized wire rope is then installed through the holes and around each of the posts and fixed in place by a U-bolt wire rope clip behind the plywood. A 24-inch section of the treated post material is buried in the soil to the depth of the wire rope that is attached to the vertical posts. These deadmen should be buried behind the wall a distance not less than their height above the base of the wall. The free end of each of the wire ropes is then wrapped around the buried post sections and fixed in place by a U-bolt wire rope clip. The wire rope in this retaining wall design serves to tie the vertical posts to the buried deadmen and therefore carries the load of the soil retained by the wall. In order to carry this load the wire rope should have a breaking strength of not less than 1,000 pounds. All cut ends and drilled holes in the pressure-treated wood and plywood should be brushed with a liberal treatment of preservative chemical. As with other retaining wall designs, 12 to 24 inches of gravel backfill behind the wall is recommended in poorly drained soils.

A reinforced concrete block retaining wall is shown in figure 24. An extra wide footing is dug to a depth below the frost line. Before concrete is poured, steel reinforcing rods with  $\frac{5}{8}$ -inch-diameter and a 90° bend are installed. These rods, placed on 16-inch centers, extend from the

**Figure 25** – Reinforced concrete retaining wall (4 feet high above grade).



**Figure 24** – Reinforced concrete block retaining wall (maximum 4 feet high above grade).



back to the front of the footing and then turn upward to the height of the wall. The location of the vertical portion of the rod should be close to the soil side of the concrete block core voids. After the footing concrete has hardened, 2-core, 12-inch concrete blocks are laid so that the upturned reinforcing rods pass through the open cores of the block. After the block mortar has set, a wooden form is constructed on top of the blocks to form the mold for a 4-inch reinforced concrete beam. Two straight  $\frac{5}{8}$ -inch steel reinforcing rods spaced 4 inches apart are laid on the beam form and wired to the vertical reinforcing rods. Concrete is then poured into the beam form and rodded into the open block cores. After the concrete has set, 12 to 24 inches of gravel should be used as backfill behind the wall to provide drainage and to minimize the pressure from behind the wall caused by freezing.

The retaining wall can be constructed solely of poured concrete instead of concrete block (fig. 25). The footing for the wall is dug to a depth below the frost line. A form is then built in which to pour the concrete for the footing and wall as a single unit. The form for the face of the wall should be vertical but the back of the wall should be built at an angle to provide a wall that is thicker at the base. Reinforcing rods  $\frac{5}{8}$  inch in diameter should be placed in the form and wired together to form a lattice with the rods spaced on 12-inch centers. Concrete is poured in the form to the depth of the footing and allowed partially to set before the concrete is poured for the vertical portion of the wall. Backfilling the wall with 12 to 24 inches of gravel is recommended.



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## Framing and Closing In

The sections contained in this chapter address the tasks related to erecting the structural framing for the house and creating an enclosure that provides some degree of protection from the elements.

### Recommended Nailing Practices

Wood members are most commonly joined together with nails, but on occasion metal straps, lag screws, bolts, staples, and adhesive can be used. Proper fastening of frame members and covering materials provides rigidity and strength. For example, proper fastening of intersecting walls usually reduces cracking of plaster at the inside comers.

The recommended number and size of nails, shown in the technical note on nailing schedule, is based on good nailing practices for the framing and sheathing of a well-constructed wood-frame house. Sizes of common wire nails are shown in figure 26.

Houses that are located in hurricane areas should be provided with supplemental fasteners called hurricane straps or tiedowns to anchor the floor, walls, and roof to the foundation. Wind, snow, and seismic loads are one of the special topics discussed in chapter 8.

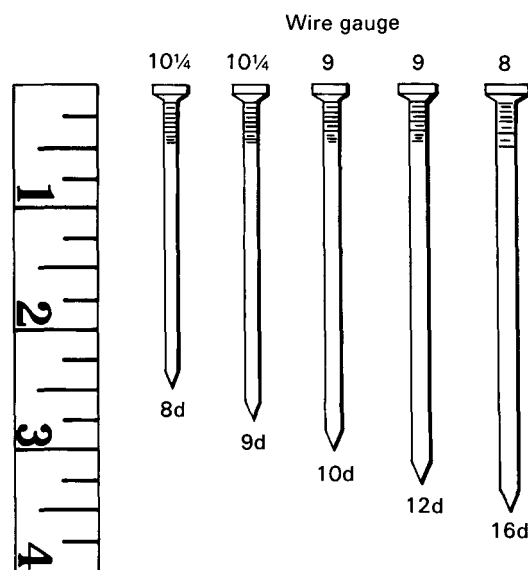
### Floor Framing

Floor framing consists of columns or posts, beams, sill plates, joists, and subfloor. Assembled on a foundation, they form a level anchored platform for the rest of the house and a strong diaphragm to keep the lateral earth pressure from pushing in the top of the foundation wall. The columns or posts and beams of wood or steel that support the joists over a basement are sometimes replaced by frame or masonry walls when the basement area is divided into rooms. Floors of the second story are generally supported on load-bearing walls in the first story. Wood-frame houses may also be constructed over a crawl space with floor framing similar to that used over a basement or on a concrete slab as shown in the section on foundations.

### Factors in design

An important consideration in the design of a wood floor system is wood shrinkage. When wood with a high moisture content is used, subsequent shrinkage can result in cracks, doors that stick, and other problems. This is particularly important where wood beams are used,

Figure 26 —Common nails.



because wood beams may shrink and foundation walls will not. In beams and joists used in floor framing, moisture content should not exceed 19 percent; about 15 percent is a much more desirable maximum. Dimension material can be obtained at either of these moisture contents, when specified.

Grades of dimension lumber vary considerably with wood species. For the specific uses described in this publication, material is divided into five categories. The first category is the highest quality, the second is better than average, the third average, and the fourth and fifth for more economical construction. Joists and beams are usually of a species of second category material, while sills and posts are usually of third or fourth category. (See technical note on lumber grades.)

Stairways and other openings that penetrate the floor structure should be located so as to interrupt as few members as possible. Stairways should be oriented parallel to floor joists so that only one joist need be interrupted with 24-inch on-center joist spacing. Wherever possible, the stair opening should be coordinated with a normal joist location on at least one side. Stairways should never interrupt a structural beam or bearing wall when it can be avoided.

The stairway design should be completed before floor framing begins, because the stairwell opening must be

framed at the time the floor is constructed. The rough-framed opening for a stairwell should be 1 inch wider than the desired finished stairway width. The length of the opening must be accommodated to tread run and stair rise, which in turn are governed by total rise.

Other openings such as those for clothes chutes and flue hole should also be located to avoid interrupting framing members. Two-foot on-center spacing of joists generally provides ample clearance for such openings.

### *Sill plate*

A wood-frame floor system should be anchored to the foundation to resist wind forces acting on the structure. This is usually done with a 2- by 6-inch sill plate attached to the foundation by ½-inch anchor bolts at 8-foot intervals. Floor joists are toenailed to the sill plate (fig. 27A). The sill plate may also be attached with anchor straps that are embedded in the foundation in the same manner and at the same spacing as anchor bolts. These devices do not require holes in the sill plate; metal straps are simply bent up around the plate and nailed. Anchor straps are less exacting and do not interfere with other framing as conventional bolts often do.

Sill plates may be entirely eliminated where the top of a foundation of poured concrete (fig. 27B) or concrete block (fig. 28B) is sufficiently level and accurate. Joists may bear directly on a solid concrete wall or on a top course of solid concrete block. They may also bear directly on cross webs of hollow core block or on cores that have been filled with mortar. Where the sill plate is omitted, anchorage of the floor system may be provided by anchor strap devices, as described above. The straps should be spaced to coincide with joist locations so that each may be nailed directly to the side of a joist (fig. 28).

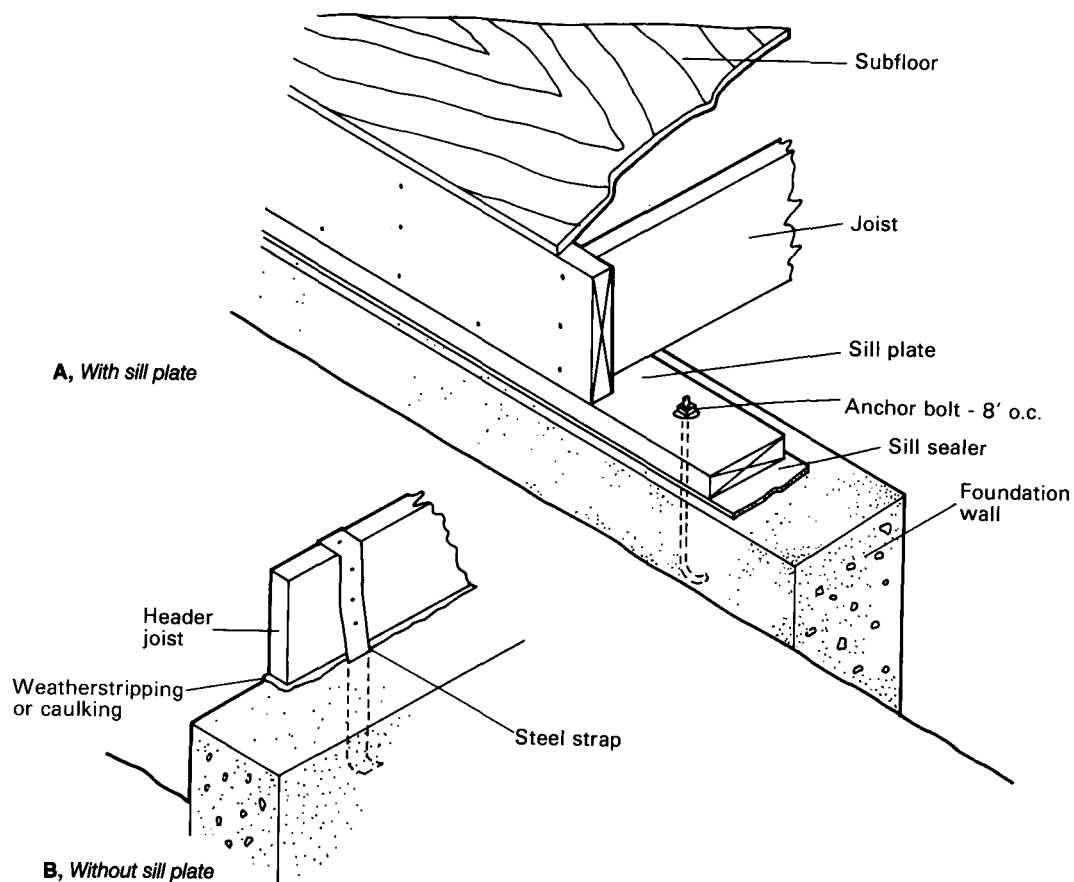
As noted previously, a foundation of pressure-treated wood does not require a sill plate or special anchor devices. Floor joists bear directly on the top foundation wall plate and are toenailed to provide anchorage.

### *Posts and girders*

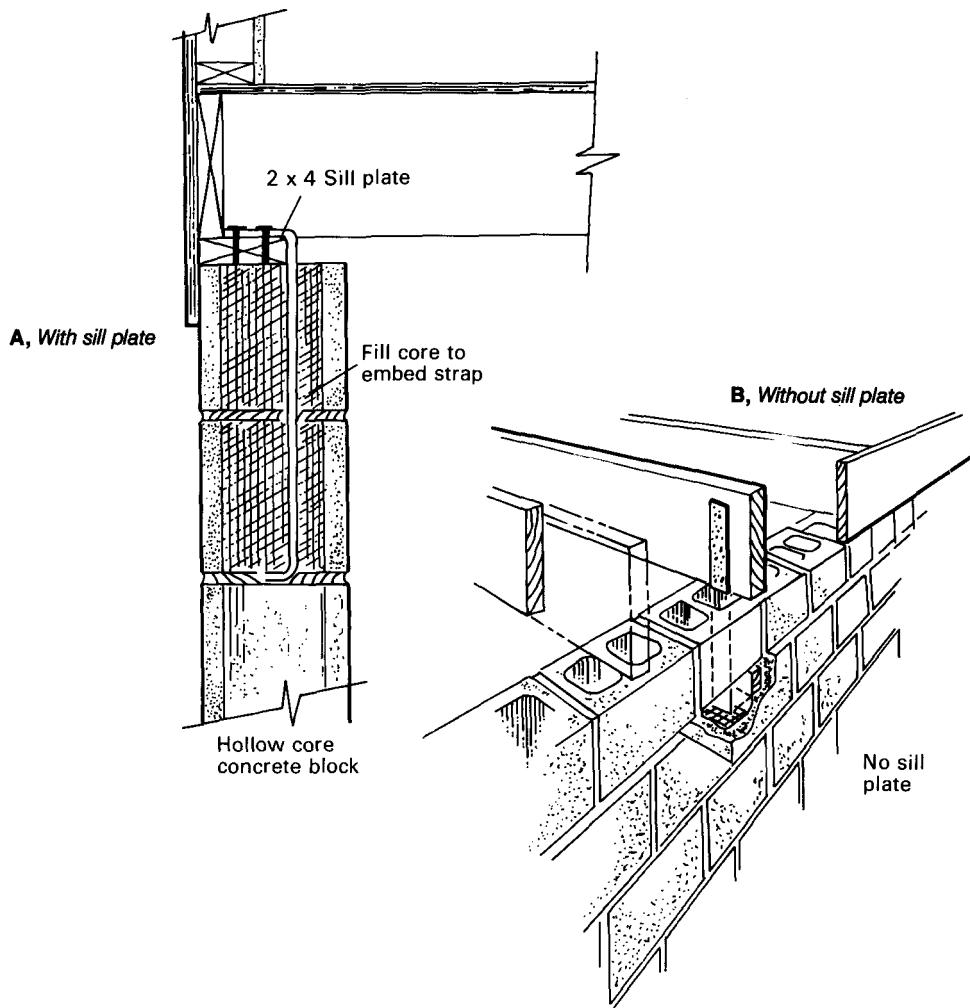
Wood posts or steel columns are generally used in the basement to support wood or steel beams. Masonry piers or wood posts are commonly employed in crawl-space houses.

Steel pipe columns can be used to support either wood or steel beams. They are normally supplied with a steel

**Figure 27** – Anchoring floor system to poured concrete foundation wall:



**Figure 28** – Anchoring floor system to concrete block foundation wall:



bearing plate at each end. Secure anchoring to the beam is important (fig. 29).

Wood posts should be solid, pressure-treated, and not less than 6 by 6 inches in size for freestanding use in a basement. When combined with a framed wall, they may be 4 by 6 inches to conform to the width of the studs. Wood posts should be squared at both ends and securely fastened to the beam (fig. 30). The bottom of the post should rest on and be pinned to a masonry pedestal 2 to 3 inches above the finish floor.

#### ***Center beams***

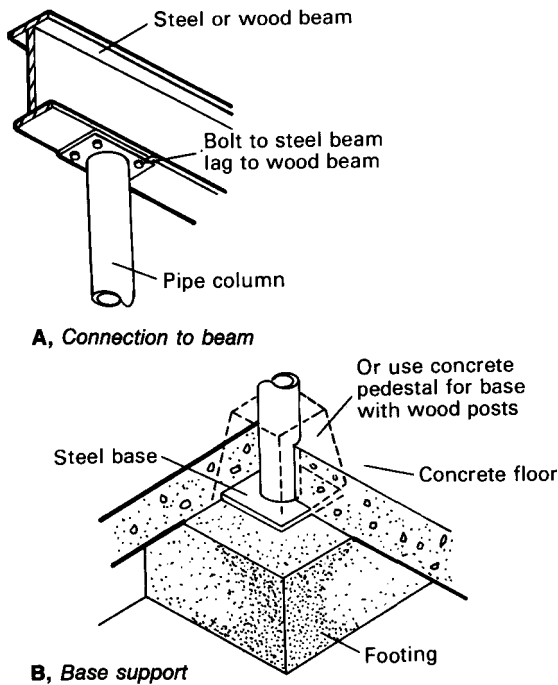
Wood-frame floor construction typically employs a beam or girder to provide intermediate support for the first floor. In two-story construction, the beam generally supports the second floor as well via a load-bearing wall extending along the center of the first story.

For maximum benefit in reducing joist spans, beams and bearing walls should be located along the centerline of the structure. In some cases it may be desirable to offset the center support 1 foot from the centerline to provide for even-length joists; for example, in a 30-foot-deep floor system, displace the centerline to 14 and 16 feet from the two sides instead of 15 feet from both. However, as discussed later, this is not necessary if off-center spliced joists are used.

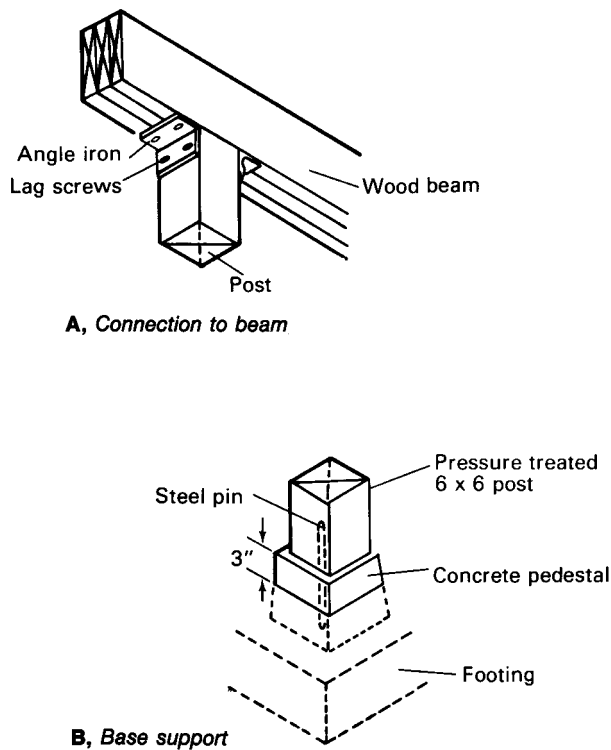
The center beam usually bears on the foundation at each end and is supported along its length by columns or piers. The spacing of columns or piers is adjusted to the spanning capability of the beam for a particular design load.

Two basic types of center beams—wood and steel—are commonly used. The decision on which to use should be based on a comparison of the total installed cost of each, including intermediate support columns or piers, and footings. Other considerations include delivery, scheduling, and ease of construction.

**Figure 29** – Steel post support for wood or steel beam:



**Figure 30** – wood post support for wood beam:



Wood center beams are of two types, solid or built-up. The built-up beam is preferable because it can be made up from dimension material that is drier and more stable.

For equal widths, the built-up beam is stronger than the solid beam.

### ***Built-up wood beams***

Built-up beams are constructed by nailing three or four layers of dimension lumber together. The built-up beam may be made longer than any of the individual members by butting the ends of the members together. These butt joints must be staggered between adjacent layers so that they are separated by 16 inches. In addition, the built-up beam must be supported by a column or pier positioned within 12 inches of the butt joints (fig. 31).

Typical allowable spans for built-up wood beams are shown in table 5. Dry lumber should always be used to avoid settlement problems caused by shrinkage of the built-up beam and the joists it supports. It is not necessary to use a wood plate over wood beams, because floor joists can be nailed directly to the beam.

Ends of wood beams should bear at least 4 inches on the masonry walls or pilasters. When wood is untreated, a ½-inch air space should be provided at each end and side of wood beams framing into masonry (fig. 31). The top of the beam should be level with the top of the sill plates on the foundation walls.

### ***Steel I-beams***

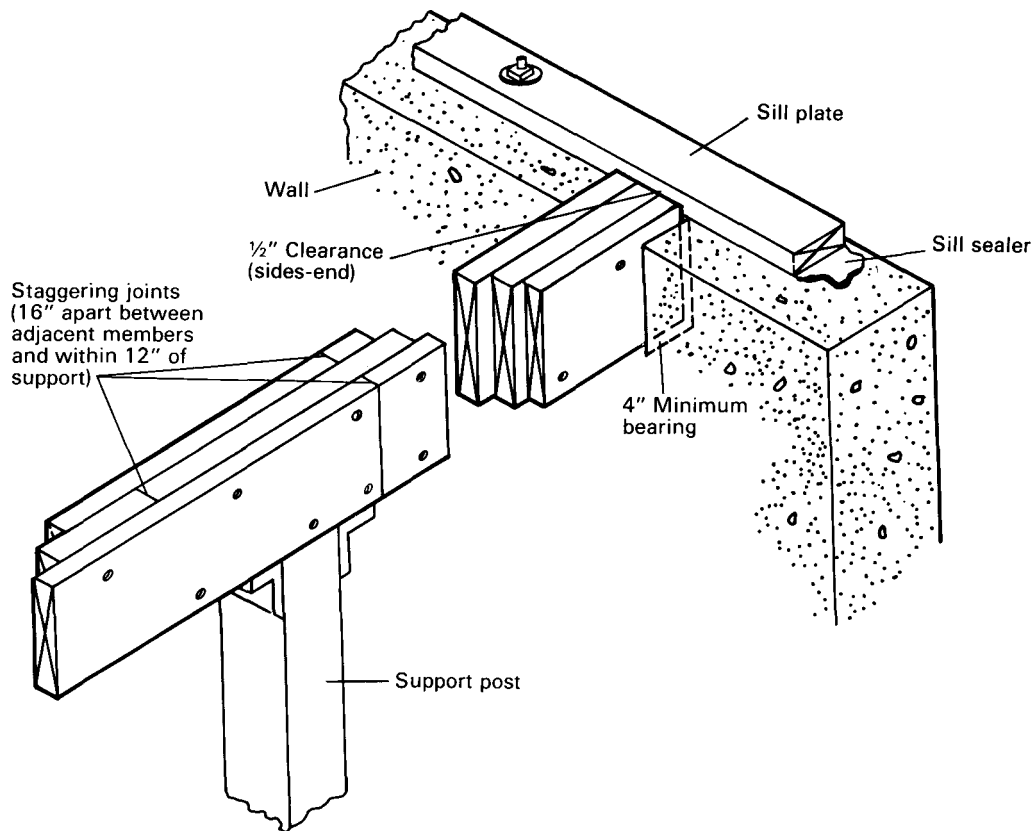
Steel I-beams are often used because they have greater strength and stiffness than wood beams, which enables them to carry a given load over a given span with a beam of lesser depth and thus provides greater headroom or reduces the requirement for additional supporting posts. Allowable spans for steel I-beams are shown in table 6. However, steel beams require an additional supplier, which can complicate delivery schedules. They are also heavier and more difficult to handle in the field. The total cost of a steel beam, including columns or piers, is generally greater than that of a wood beam.

Where steel beams are used, a wood plate 2 by 4 or 2 by 6 inches across is usually attached to the top surface by bolting or by driving nails part way into the sides of the plate and bending the protruding nail shanks over the edges of the beam flange. Floor joists are then toenailed to the beam plate to anchor to the floor and to provide lateral bracing for the beam. A beam plate is not required if the floor joists are secured by other means.

### ***Beam-joist installation***

In the simplest method of floor framing, the joists bear directly on top of the wood or steel beam. The top of the beam coincides with the top of the foundation or anchored sill, if the latter is used (fig. 31). This method assumes

**Figure 31** —Typical built-up wood beam installation.



that basement wall heights provide adequate headroom below the girder. When a forced-air heating system is to be installed, this arrangement of beam and joists provides space for the main duct to be run parallel to the beam and for the laterals to be run between the joists above the level of the beam.

As previously noted, beams and joists should be constructed of dry lumber to reduce problems caused by settlement resulting from shrinkage. This is of particular concern when wood joists bear directly on top of the wood beam at the center of the house while bearing on the concrete foundation wall at the outer ends. In order to equalize the depth of wood at the beam and at the outer wall—and thereby equalize shrinkage potential—joists should be attached to the side of the wood beam using joist hangers or supporting ledger strips (fig. 32). The simplest method is to use steel joist hangers (fig. 32A). Where ledgers are used, joists must always bear on the ledgers (fig. 32B). It is important that a small space be allowed above the beam to provide for shrinkage of the joists.

Joists may be butted to a steel beam in the same general way as is illustrated for a wood beam, with joists resting on a wood ledger that is bolted to the web (fig. 33).

### *Floor joists*

Floor joists are selected primarily to meet strength and stiffness requirements. Strength requirements depend on the load to be carried. Stiffness requirements place an arbitrary control on deflection under load. Stiffness is also important in limiting vibrations from moving loads—often a cause of annoyance to occupants.

Wood floor joists have generally nominal thickness of 2 inches and nominal depth of 8, 10, or 12 inches. The size required depends upon the loading, length of span, spacing between joists, and species and grade of lumber used.

After the sill plates have been anchored to the foundation walls and the center beam installed, the joists are laid out according to the house design. The center-to-center spacings most commonly used are 24 inches or 16 inches.

Span tables for floor joists, provided by the National Forest Products Association or in local building codes, can be used as guidelines. Table 7 is a simplified version for joists spaced 24 inches on center and table 8 for 16 inches on center. The sizes shown in the table are minimal; it is sometimes desirable to use the next larger lumber size than that listed in the table.

**Table 5 – Allowable spans for built-up wood center beams**

Beam composition	Width of structure (ft)	Length of maximum clear span			
		Minimum required bending stress (9 of 1,000 psi <sup>a</sup> )		Minimum required bending stress (9 of 1,500 psi <sup>b</sup> )	
		One-story	Two-story	One-story	Two-story
3 2x8	24	6' 7"	—	8' 1"	4' 7"
	26	6' 4"	—	7' 9"	4' 3"
	28	6' 2"	—	7' 5"	—
	32	5' 5"	—	6' 6"	—
4 2x8	24	7' 8"	5' 2"	9' 4"	6' 2"
	26	7' 4"	4' 9"	9' 0"	5' 8"
	28	7' 1"	4' 5"	8' 8"	5' 4"
	32	6' 7"	—	8' 1"	4' 8"
3 2x10	24	8' 5"	4' 11"	10' 4"	7' 6"
	26	8' 1"	4' 7"	9' 11"	5' 6"
	28	7' 10"	4' 3"	9' 6"	5' 1"
	32	6' 11"	—	8' 4"	4' 6"
4 2x10	24	9' 9"	5' 7"	11' 11"	7' 10"
	26	9' 4"	6' 1"	11' 6"	7' 3"
	28	9' 0"	5' 8"	11' 1"	6' 9"
	32	8' 5"	5' 0"	10' 4"	6' 0"
3 2 x 12	24	10' 3"	6' 0"	12' 7"	7' 2"
	26	9' 10"	5' 6"	12' 1"	6' 8"
	28	9' 6"	5' 2"	11' 7"	6' 2"
	32	8' 5"	4' 6"	10' 2"	5' 2"
4 2 x 12	24	11' 10"	8' 0"	14' 6"	9' 7"
	26	11' 5"	7' 5"	13' 11"	8' 10"
	28	11' 0"	6' 10"	13' 5"	8' 3"
	32	10' 3"	6' 0"	12' 7"	7' 3"

Source: NAHB Research Foundation (1971). *Manual of Lumber- and Plywood-Saving Techniques for Residential Light-Frame Construction*.

<sup>a</sup>The bending stress (f) measures the strength and varies with the species and grade of lumber as shown in the technical note on design values.

<sup>b</sup>The allowable spans shown assume a clear-span trussed roof construction. In two-story construction, a load-bearing center partition has been assumed. The built-up wood center beam and/or the load-bearing partition in two-story construction may be offset from the centerline of the house by up to 1 foot.

Joists should be inspected for straightness visually, as they are being placed. Any joists having a slight crook edgewise should be placed with the crown on top. A crowned joist tends to straighten out when subfloor and normal floor loads are applied. Those joists that are not crowned should be inspected for the presence of knots along the edge. The largest edge knots should be placed on top, because knots on the upper side of a joist are placed in compression and have less effect on strength.

The header joist is fastened by nailing through it into the end of each joist with three 12d or 16d nails. In addition, the header joist and the stringer joists parallel to the exterior wall in platform construction (fig. 34) are toenailed to the sill with 10d or 12d nails spaced 16 inches on center. Each joist should be toenailed to the sill and

**Table 6 – Allowable spans between columns or piers supporting steel center beams<sup>a</sup>**

Steel beam designation <sup>b</sup> & total house width (ft)	Length of maximum clear span	
	For 1-story house	For 2-story house
8B10.0		
24	13' 9"	10' 0"
26	13' 3"	9' 8"
28	12' 9"	9' 4"
32	11' 11"	8' 9"
10B11.5		
24	16' 0"	11' 8"
26	15' 5"	11' 3"
28	14' 10"	10' 10"
32	13' 10"	10' 2"
8W17.0		
24	19' 4"	14' 1"
26	18' 7"	13' 7"
28	17' 11"	13' 1"
32	16' 9"	12' 4"
10017.0		
24	20' 9"	15' 2"
26	20' 0"	14' 7"
28	19' 3"	14' 1"
32	18' 0"	13' 2"
10W21.0		
24	23' 2"	17' 5"
26	22' 8"	16' 9"
28	22' 2"	16' 9"
32	20' 9"	15' 2"

Source: United States Steel Corporation (1980). *Steel beam stress & deflection estimator for use in calculating sizes of laterally supported beams for residential and light construction*.

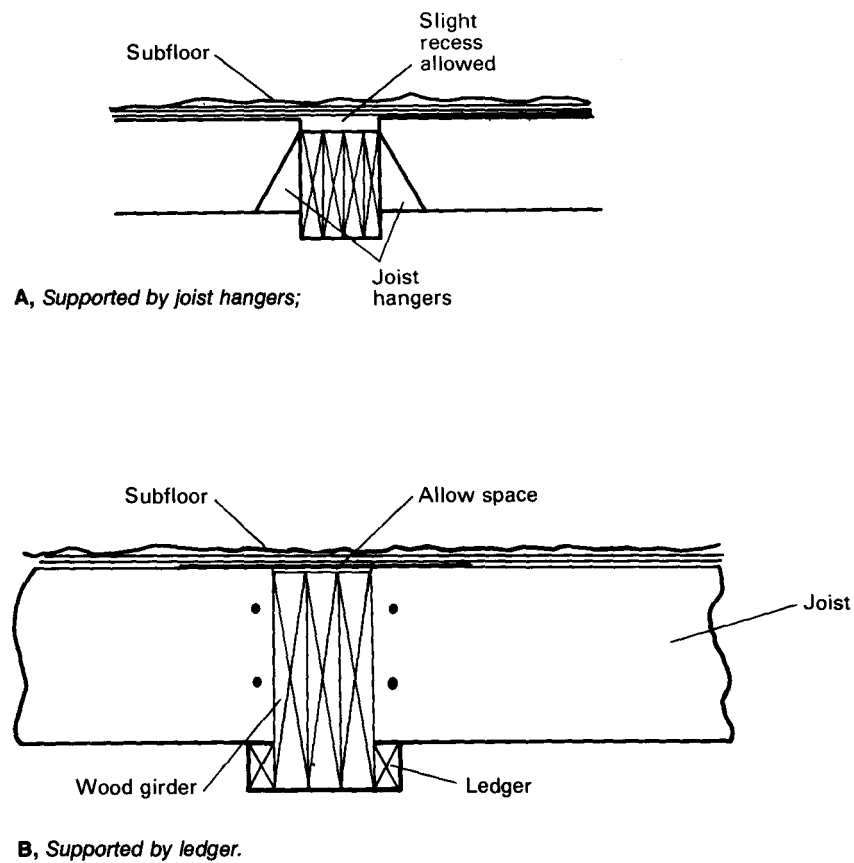
<sup>a</sup>Based on a continuous beam over two equal spans with a maximum of ½-inch deflection at design load and assuming a clear span trussed roof.

<sup>b</sup>The steel beam designations presented are those most commonly available at building material suppliers. The designation gives the height of the beam in inches, a letter designating the type of I-beam, and the weight of the beam in pounds per linear foot. (An "8B10.0" I-beam is an I-beam that weighs 10.0 pounds per linear foot.)

center beam with two 10d or three 8d nails, then nailed to other joists with three 12d nails where they lap over the center beam. If joists are butted over the center beam they should be joined with a nominal 2-inch scab nailed to each joist with three 12d nails.

An off-center splice may be used in framing floor joists. This system often allows the use of one smaller joist size when center supports are present. In off-center splicing, long joists are cantilevered over the center support and spliced to short joists (fig. 35). The locations of the splices over the center beam are alternated. Depending on the span, species, and joist size, the overhang varies between about 2 feet and 3 feet. Metal splice plates are used on each side of the joints. Selecting the proper plate size and installing the plate must be done by a truss fabricator.

**Figure 32**—Joists butted to side of wood beam:



**Table 7** – Allowable spans for simple floor joists spaced 24 inches on center for wood with modulus of elasticity values of  $1.0$  to  $2.0 \times 10^6$  pounds per square inch.

	Length of maximum clear span										
	1.0 x 10 <sup>6</sup> psi	1.1 x 10 <sup>6</sup> psi	1.2 x 10 <sup>6</sup> psi	1.3 x 10 <sup>6</sup> psi	1.4 x 10 <sup>6</sup> psi	1.5 x 10 <sup>6</sup> psi	1.6 x 10 <sup>6</sup> psi	1.7 x 10 <sup>6</sup> psi	1.8 x 10 <sup>6</sup> psi	1.9 x 10 <sup>6</sup> psi	2.0 x 10 <sup>6</sup> psi
<b>Living areas (40 lb/ft<sup>2</sup> live load)</b>											
Minimum required bending stress (lb/in <sup>2</sup> )	1,050	1,120	1,190	1,250	1,310	1,380	1,440	1,500	1,550	1,610	1,670
Joist size											
2 x 6	7' 3"	7' 6"	7' 9"	7' 11"	8' 2"	8' 4"	8' 6"	8' 8"	8' 10"	9' 0"	9' 2"
2 x 8	9' 7"	9' 11"	10' 2"	10' 6"	10' 9"	11' 0"	11' 3"	11' 5"	11' 8"	11' 11"	12' 1"
2 x 10	12' 3"	12' 8"	13' 0"	13' 4"	13' 8"	14' 0"	14' 4"	14' 7"	14' 11"	15' 2"	15' 5"
2 x 12	14' 11"	15' 4"	15' 10"	16' 3"	16' 8"	17' 0"	17' 5"	17' 9"	18' 1"	18' 5"	18' 9"
<b>Sleeping areas (30 lb/ft<sup>2</sup> live load)</b>											
Minimum required bending stress (lb/in <sup>2</sup> )	1,020	1,080	1,150	1,210	1,270	1,330	1,390	1,450	1,510	1,560	1,620
Joist size											
2 x 6	8' 0"	8' 3"	8' 6"	8' 9"	8' 11"	9' 2"	9' 4"	9' 7"	9' 9"	9' 11"	10' 1"
2 x 8	10' 7"	10' 11"	11' 3"	11' 6"	11' 10"	12' 1"	12' 4"	12' 7"	12' 10"	13' 1"	13' 4"
2 x 10	13' 6"	13' 11"	14' 4"	14' 8"	15' 1"	15' 5"	15' 9"	16' 1"	16' 5"	16' 8"	17' 0"
2 x 12	16' 5"	16' 11"	17' 5"	17' 11"	18' 4"	18' 9"	19' 2"	19' 7"	19' 11"	20' 3"	20' 8"

Source: National Forest Products Association (1977). *Span Tables for Joists & Rafters*.

Note: Use table 8 for joists spaced 16 inches on center.

The modulus of elasticity (E) measures stiffness and varies with the species and grade of lumber as shown in the technical note on design values. The bending stress (f) measures strength and varies with the species and grade of lumber as shown in the technical note on design values.

**Table 8** – Allowable spans for simple floor joists spaced 16 inches on center for wood with modulus of elasticity values of 1.0 to 2.0 x 10<sup>6</sup> pounds per square inch

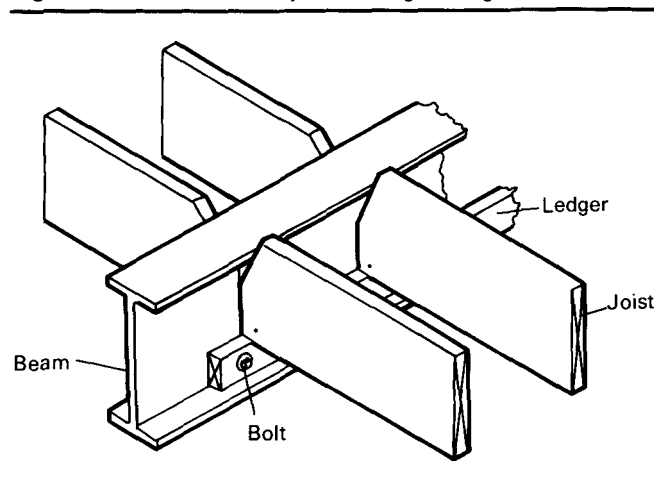
	Length of maximum clear span										
	1.0 x 10 <sup>6</sup> psi	1.1 x 10 <sup>6</sup> psi	1.2 x 10 <sup>6</sup> psi	1.3 x 10 <sup>6</sup> psi	1.4 x 10 <sup>6</sup> psi	1.5 x 10 <sup>6</sup> psi	1.6 x 10 <sup>6</sup> psi	1.7 x 10 <sup>6</sup> psi	1.8 x 10 <sup>6</sup> psi	1.9 x 10 <sup>6</sup> psi	2.0 x 10 <sup>6</sup> psi
<b>Living areas (40 lb/ft<sup>2</sup> live load)</b>											
Minimum required bending stress (lb/in <sup>2</sup> )	920	980	1,040	1,090	1,150	1,200	1,250	1,310	1,360	1,410	1,460
Joist size											
2 x 6	8' 4"	8' 7"	8' 10"	9' 1"	9' 4"	9' 6"	9' 9"	9' 11"	10' 2"	10' 4"	10' 6"
2 x 8	11' 0"	11' 4"	11' 8"	12' 0"	12' 3"	12' 7"	12' 10"	13' 1"	13' 4"	13' 7"	13' 10"
2 x 10	14' 0"	14' 6"	14' 11"	15' 3"	15' 8"	16' 0"	16' 5"	16' 9"	17' 0"	17' 4"	17' 8"
2 x 12	17' 0"	17' 7"	18' 1"	18' 7"	19' 1"	19' 6"	19' 11"	20' 4"	21' 9"	21' 1"	21' 6"
<b>Sleeping areas (30 lb/ft<sup>2</sup> live load)</b>											
Minimum required bending stress (lb/in <sup>2</sup> )	890	950	1,000	1,060	1,110	1,160	1,220	1,270	1,320	1,410	1,360
Joist size											
2 x 6	9' 2"	9' 6"	9' 9"	10' 0"	10' 3"	10' 6"	10' 9"	10' 11"	11' 2"	11' 4"	11' 7"
2 x 8	12' 1"	12' 6"	12' 10"	13' 2"	13' 6"	13' 10"	14' 2"	14' 5"	14' 8"	15' 0"	15' 3"
2 x 10	15' 5"	15' 11"	16' 5"	16' 10"	17' 3"	17' 8"	18' 0"	18' 5"	18' 9"	19' 1"	19' 5"
2 x 12	18' 9"	19' 4"	19' 11"	20' 6"	21' 0"	21' 6"	21' 11"	22' 5"	22' 10"	23' 3"	23' 7"

Source: National Forest Products Association (1977). Span Tables for Joists & Rafters.

Note: Other tables should be used for other joist spacings.

The modulus of elasticity (E) measures stiffness and varies with the species and grade of lumber as shown in the technical note on design values. The bending stress (f) measures strength and varies with the species and grade of lumber as shown in the technical note on design values.

**Figure 33** – Steel beam with joists bearing on ledger.



Joists should be at least doubled under parallel load-bearing partition walls. Solid bridging should be used in place of doubled joists when access from below is needed for installing heating ducts in the load-bearing partition (fig. 34). It is not necessary, however, to double joists under parallel partitions not bearing load. In fact, it is not necessary to locate a partition not bearing load over a floor joist; the floor sheathing is normally adequate to support the partition between joists (fig. 36).

### Header joists

The header joist, or band joist, used across the ends of floor joists, has traditionally been the same size as floor joists. One function of a header joist is to brace floor joists temporarily in position prior to application of the subfloor. The header joist also helps to support stud loads in conventional construction, where wall studs do not necessarily align with floor joists.

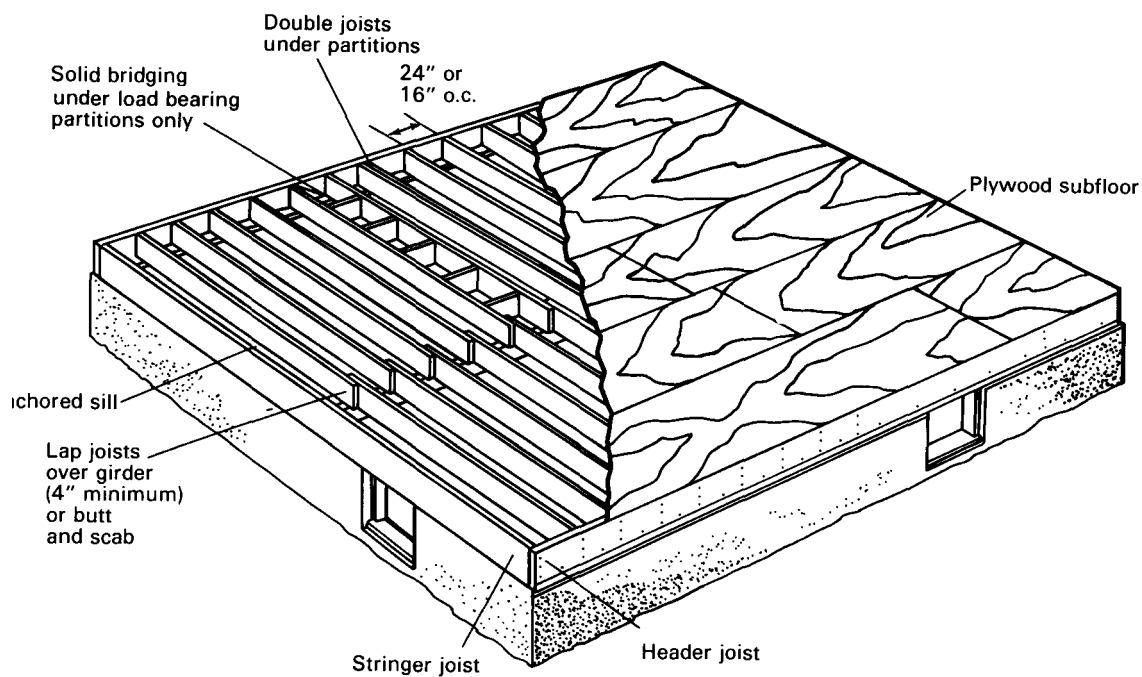
With modular planning, however, each wall stud should bear directly over a floor joist. A header joist nominally 1 inch thick may therefore be used in place of the traditional 2-inch header. A header joist of lumber nominally 1 inch thick uses less material and is easier to install with 8d nails.

### Glued floor design

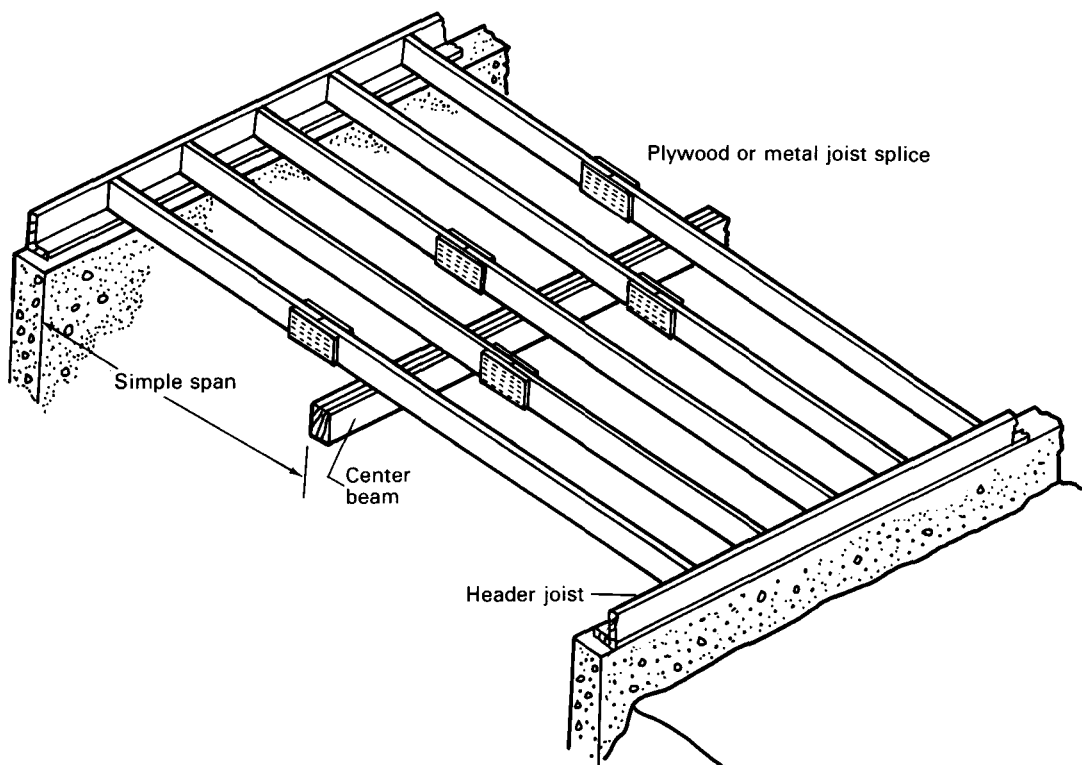
When a plywood subfloor is properly glued to floor joists with a construction adhesive, the subfloor and floor joists tend to act together as a single structural member. The composite T-beam thus formed can span a greater distance than a floor that is fastened only with nails.

Glue-nailing of the plywood subfloor is recommended as a cost-effective method of increasing the stiffness and/or allowable space of a floor, as shown in table 9. Glue-nailing is also highly effective in reducing the floor squeaks and loose nails that may otherwise develop later as a result of shrinkage of joists.

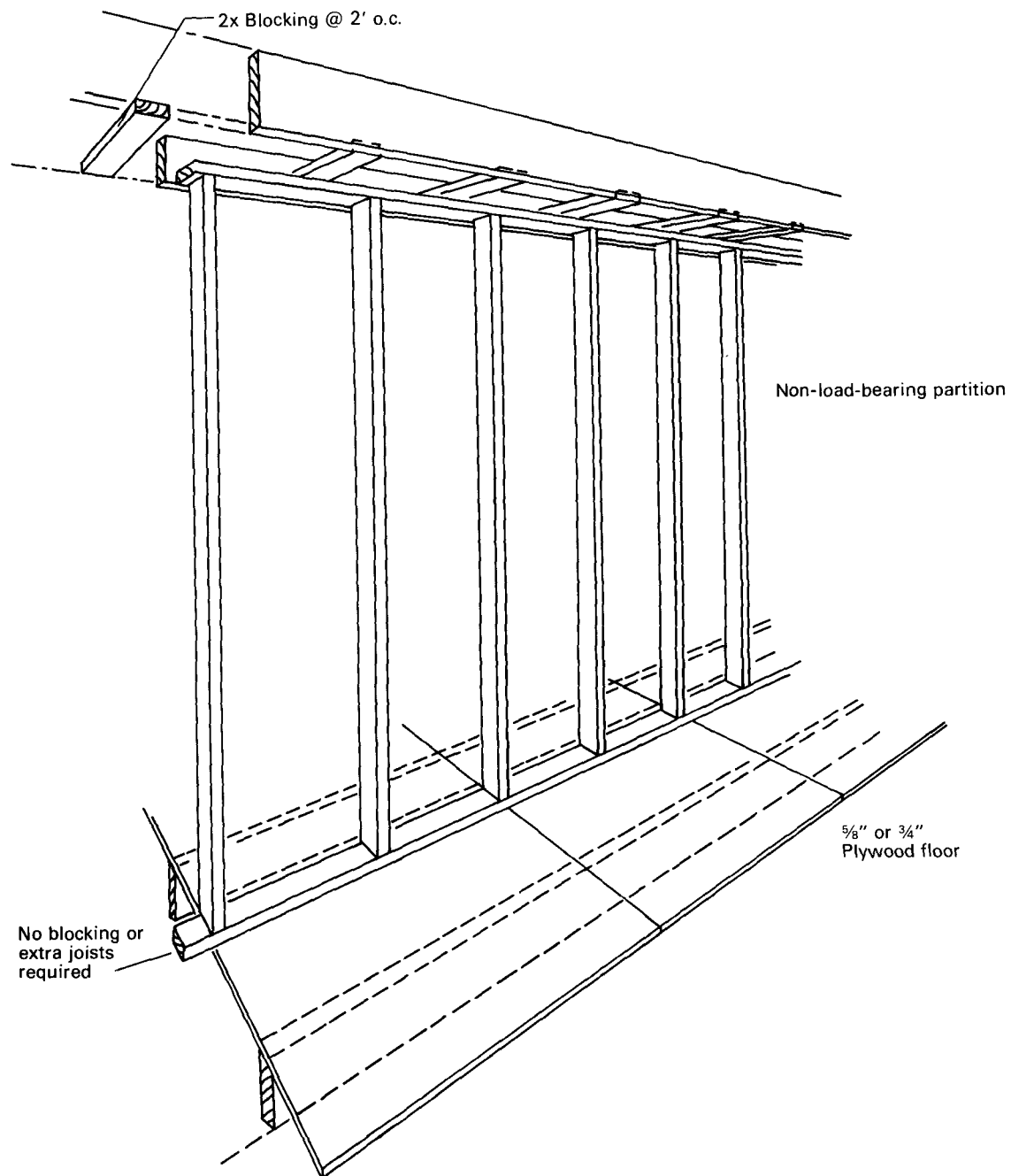
**Figure 34**—Typical platform construction.



**Figure 35** – Off-center spliced joist system allows use of one short joist in every pair of joists.



**Figure 36** – Non-load-bearing partitions need no extra floor framing or blocking with  $\frac{5}{8}$ -inch or thicker ply-wood floor.



#### *Bridging*

Bridging between wood joists is no longer required by any of the model building codes for normal house construction, that is, for spans not exceeding 15 feet and joist depth not exceeding 12 inches. Even with tight-fitting, well-installed bridging, there is no significant transfer of loads after subfloor and finish floor are installed. Bridging also increases the likelihood of floors squeaking if the subfloor is not glued to the joists.

#### *Details at floor openings*

Large openings in the floor, for items such as stairwells and fireplaces or chimneys, usually interrupt one or more joists. Such openings should be planned so that their long dimension is parallel to joists in order to minimize the number of joists that are interrupted. The opening should not disrupt the center beam or bearing partition that supports the floor. Wherever possible, the opening should be coordinated with the normal joist spacing on at least one

**Table 9 – Allowable spans for joists with ¾-inch glued plywood flooring spaced 24 inches on center for wood with modulus of elasticity values of 0.6 to 2.0 x 10<sup>6</sup> pounds per square inch**

	Length of maximum clear span							
	0.6 x 10 <sup>6</sup> psi	0.8 x 10 <sup>6</sup> psi	1.0 x 10 <sup>6</sup> psi	1.2 x 10 <sup>6</sup> psi	1.4 x 10 <sup>6</sup> psi	1.6 x 10 <sup>6</sup> psi	1.8 x 10 <sup>6</sup> psi	2.0 x 10 <sup>6</sup> psi
Living areas (40 lb/ft <sup>2</sup> live load)								
2 x 6 joists								
Minimum required bending stress (lb/in <sup>2</sup> )	1,100	1,270	1,415	1,545	1,655	1,755	1,855	1,950
Maximum span	8' 1"	8' 8"	9' 2"	9' 7"	9' 11"	10' 2"	10' 6"	10' 9"
2 x 8 joists								
Minimum required bending stress (lb/in <sup>2</sup> )	1,025	1,180	1,310	1,430	1,535	1,630	1,725	1,810
Maximum span	10' 3"	11' 0"	11' 7"	12' 2"	12' 7"	13' 0"	13' 4"	13' 8"
2 x 10 joists								
Minimum required bending stress (lb/in <sup>2</sup> )	970	1,110	1,230	1,345	1,445	1,535	1,625	1,710
Maximum span	12' 9"	13' 8"	14' 4"	15' 0"	15' 7"	16' 0"	16' 6"	16' 11"
2 x 12 joists								
Minimum required bending stress (lb/in <sup>2</sup> )	925	1,060	1,175	1,280	1,380	1,470	1,560	1,640
Maximum span	15' 2"	16' 2"	17' 1"	17' 10"	18' 6"	19' 1"	19' 8"	20' 2"
Sleeping areas (30 lb/ft <sup>2</sup> live load)								
2 x 6 joists								
Minimum required bending stress (lb/in <sup>2</sup> )	1,340	1,540	1,715	1,865	2,005	2,130	2,250	2,360
Maximum span	8' 11"	9' 7"	10' 1"	10' 6"	10' 11"	11' 3"	11' 7"	11' 10"
2 x 8 joists								
Minimum required bending stress (lb/in <sup>2</sup> )	1,245	1,430	1,590	1,730	1,860	1,975	2,085	2,190
Maximum span	11' 4"	12' 2"	12' 10"	13' 4"	13' 10"	14' 3"	14' 8"	15' 0"
2 x 10 joists								
Minimum required bending stress (lb/in <sup>2</sup> )	1,170	1,345	1,495	1,625	1,745	1,860	1,970	2,070
Maximum span	14' 0"	15' 0"	15' 10"	16' 6"	17' 1"	17' 9"	18' 2"	18' 8"
2 x 12 joists								
Minimum required bending stress (lb/in <sup>2</sup> )	1,120	1,280	1,425	1,550	1,670	1,780	1,890	1,985
Maximum span	16' 8"	17' 10"	18' 10"	19' 7"	20' 4"	21' 0"	21' 8"	22' 2"

Source: NAHB Research Foundation (1977). *Reducing Home Building Costs with OVE Design and Construction*.

The modulus of elasticity (E) measures stiffness and varies with the species and grade of lumber as shown in the technical note on design values. The bending stress (9 measures strength and varies with the species and grade of lumber as shown in the technical note on design values.

side to avoid the necessity for an additional trimmer joist to form the opening.

A single header is generally adequate for openings up to 4 feet in width. A single trimmer joist at each side of the opening is usually adequate to support single headers that are located within 4 feet of the end of joist spans (fig. 37). Tail joists under 6 feet in length may be fastened to the header with three 16d end nails and two 10d toe nails, or equivalent nailing. Tail joists over 6 feet in length should be attached with joist hangers. The header should be connected to trimmer joists in the same manner as tail joists are connected to the header.

Where wider openings are unavoidable, double headers are generally adequate up to 10 feet (fig. 38). Tail joists may be connected to double headers in the same manner and under the same conditions as specified above for sin-

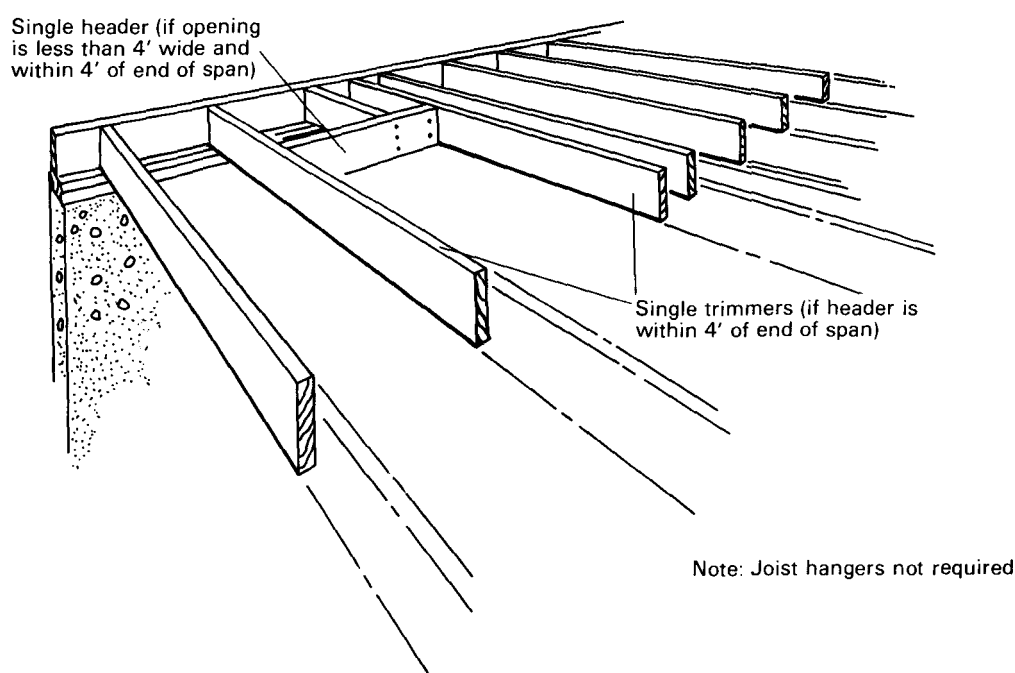
gle headers. Tail joists that are end nailed to a double header should be nailed prior to installation of the second member of the double header, to provide adequate nail penetration into the tail joist. A double header should always be attached to the trimmer with a joist hanger.

Trimmer joists at floor openings must be designed to support the concentrated loads imposed by headers where they attach to the trimmer. As noted previously, a single trimmer is adequate to support a single header located near the end of the span. All other trimmers should be at least doubled, and should be engineered for specific conditions.

### *Floor framing at projections*

The framing for wall projections such as a bay window, a wood chimney, or first- or second-floor extensions

**Figure 37** – Floor opening framed with single header and single trimmer joists.



beyond the lower wall should consist of the projection of the floor joists (fig. 39). This extension normally should not exceed 24 inches. The subflooring is carried to and sawed flush with the outer framing member. Greater projections for special designs may require special anchorage at the opposite ends of the joists.

Projections at right angles to the length of the floor joists should generally be limited to small areas and extensions of not more than 24 inches. If the projecting wall carries any significant load, it should be carried by doubled joists (fig. 39B). Joist hangers should be used at the ends of members.

In two-story houses, there is often a projection or overhang of the second floor for the purpose of architectural effect or to make second-floor siding flush with first-floor brick veneer. This overhang may vary from 2 to 15 inches or more. The overhang should ordinarily be on that side of the house where joist extensions can support the wall framing (fig. 40). Such extensions should be provided with insulation and a vapor retarder.

When the overhang parallels the second-floor joists, a doubled joist should be located back from the wall at a distance about twice the width of the overhang to which overhang blocks are attached. These blocks rest on top of and project beyond the outside wall.

#### ***Framing details for plumbing, heating, and other utilities***

It is desirable to limit cutting of framing members for

installation of plumbing lines and other utilities. This is more easily accomplished in one-story houses than in two-story houses. In a single-story house, most connections are made in the basement area; in two-story houses they must be made within the second floor. When it is necessary to cut or notch joists, it should be done in a manner least detrimental to their strength. (For more details see the section on cutting floor joists.)

#### ***Bathtub framing***

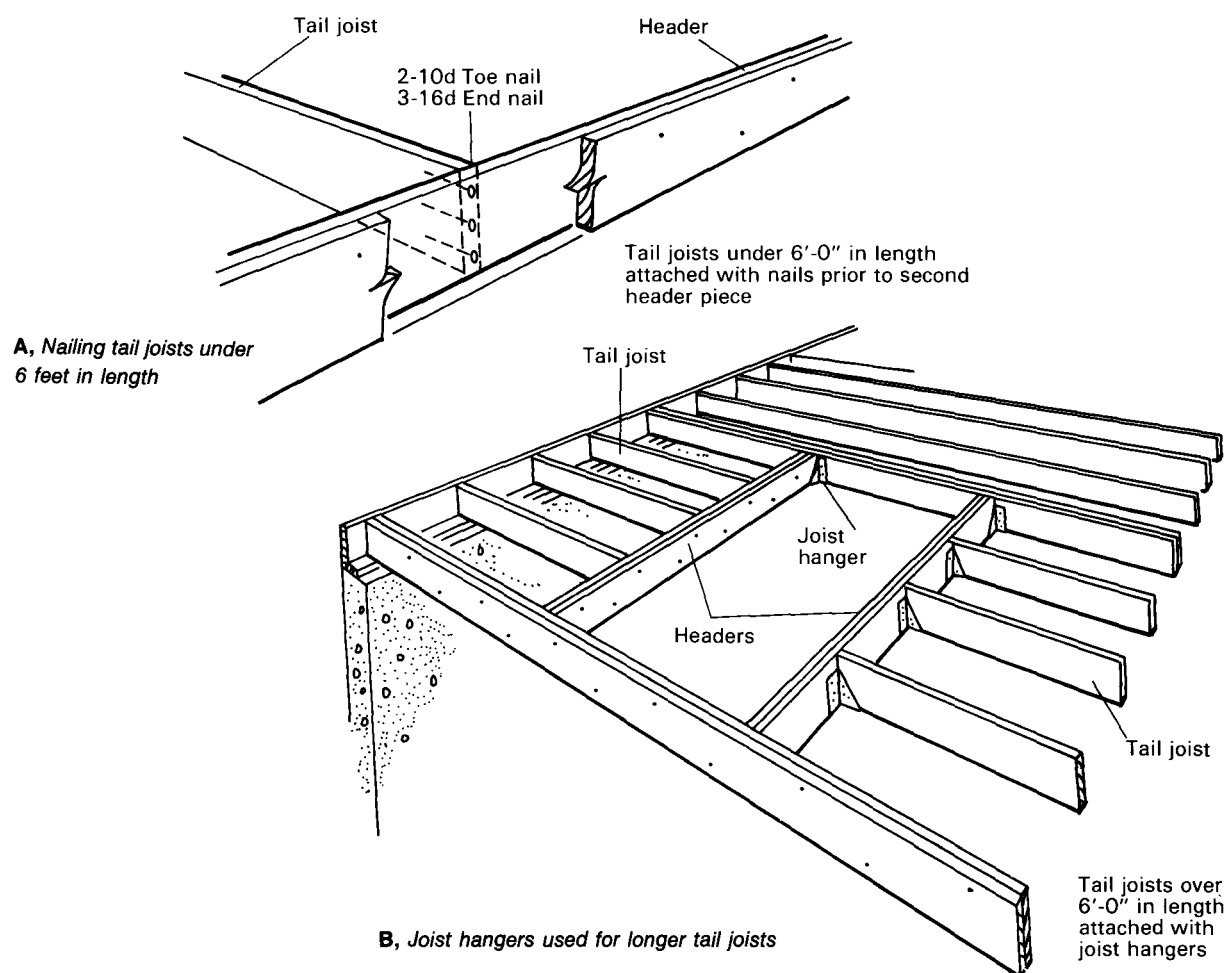
A bathtub full of water is heavy and may cause excessive deflection of floor joists. A doubled floor joist should be provided beneath the tub to support this load (fig. 41). The intermediate joist should be spaced to allow installation of the drain. Metal hangers or wood blocking should be used to support the edge of the tub at the wall.

#### ***Cutting floor joists***

It is sometimes necessary to cut, notch, or drill joists to conceal plumbing pipes or wiring (see below) in a floor. Joists or other structural members that have been cut or notched can sometimes be reinforced by nailing a reinforcing scab to each side or by adding an additional member.

Notching the top or bottom of the joist should be done only in the end one-third of the span and to no more than one-sixth of the depth. When greater alterations are required, headers and tail joists should be added around the altered area, as for a stair opening (fig. 37).

**Figure 38** – Floor opening framed with double header and double trimmer joists:



When necessary, holes may be bored in joists if the diameter is no greater than one-third of the joist depth and the edge of the hole is at least 2 inches from the top or bottom edge of the joist (fig. 42).

### ***Framing for heating ducts***

Forced air systems with large ducts for heating and air-conditioning are becoming a standard part of house construction. Framing should be laid out with structural members located to accommodate the duct system where possible, and joists should be located so that they do not have to be cut for installation of ducts. When a load-bearing partition requires a doubled parallel floor joist as well as a warm-air duct, the joists can be spaced apart to allow room for the duct (fig. 43).

### ***Wiring***

The effect of house wiring on floor framing is usually minor, and consists of holes drilled for the cable. Although these holes are of small diameter, they should

comply with procedures specified above. (See the section on cutting floor joists and fig. 42.)

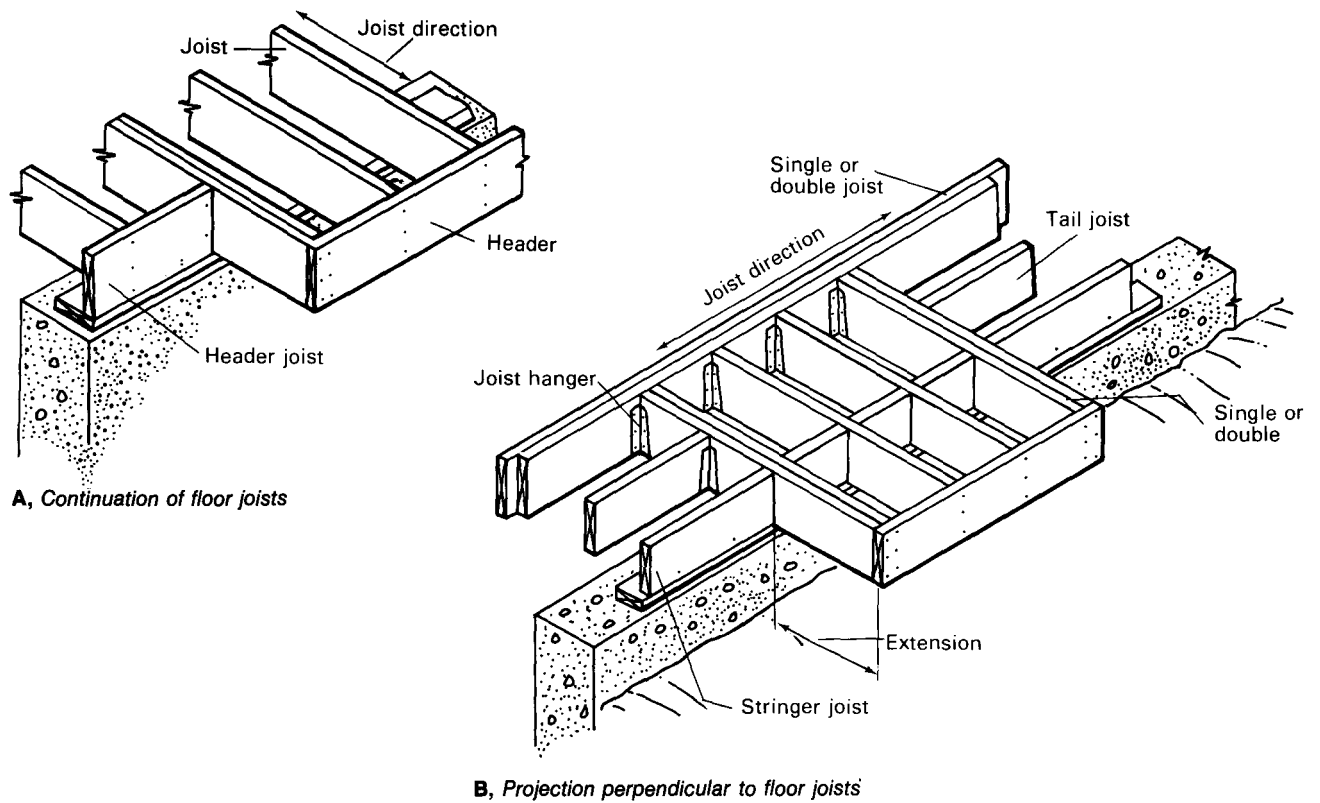
### ***Stairways***

Stairways should be designed to afford safety and adequate headroom as well as space for the passage of furniture. The two types of stairs are the finished main stairs leading between the levels of the living areas of the house and the service stairs leading to the basement or garage area. In special cases, folding stairs are used for attic access and exterior stairs are used for access to entrances above ground level. Main stairs are designed to provide easy ascent and descent and can be a feature of the interior design. Service stairs, being installed earlier, will be considered first. Safety and convenience are prime considerations in their design. They are usually constructed of less expensive materials and often do not have risers.

### ***Construction***

Both main and service stairs may be ordered prebuilt

**Figure 39 – Floor framing at wall projections:**



**Figure 40 – Floor framing at second-story wall projection.**

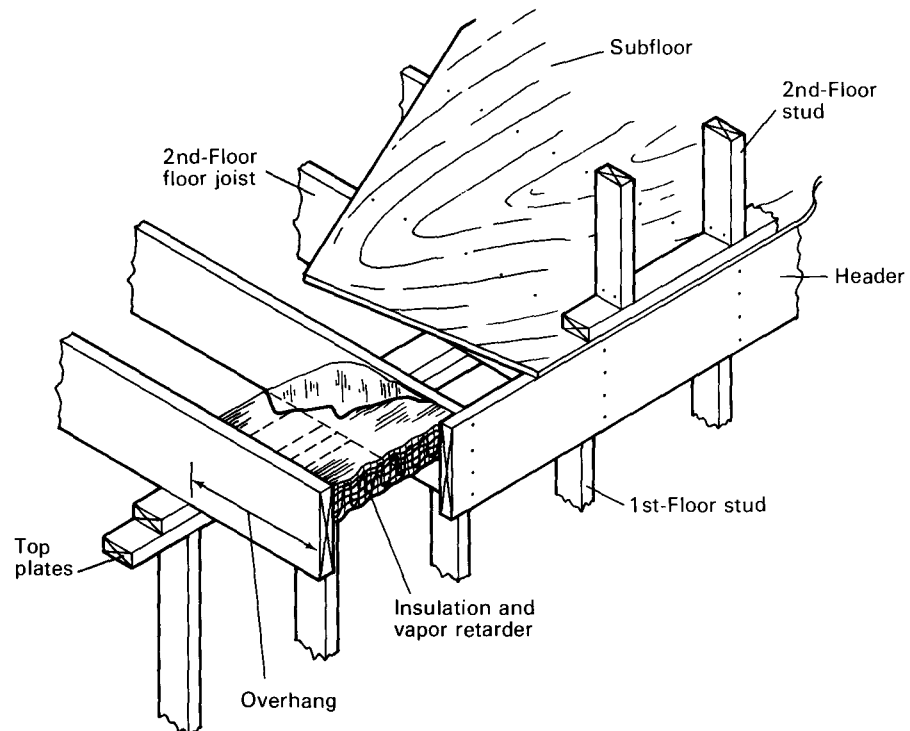


Figure 41—Framing for bathtub.

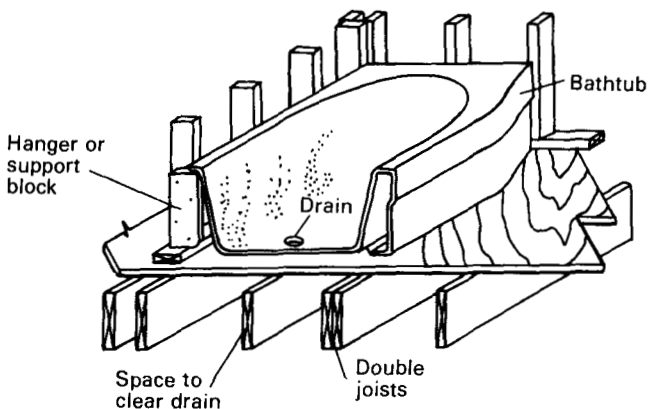


Figure 42—Drilled holes in joists.

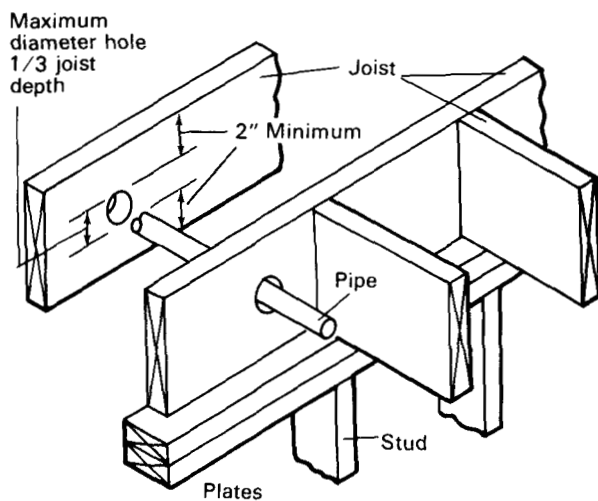
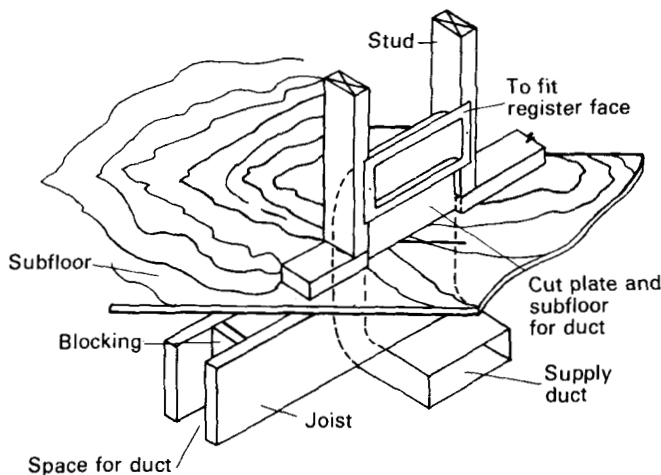


Figure 43—Spacing joists to allow installation of ductwork in load-bearing partitions.



from local millwork companies. Service stairs, however, are frequently constructed in place.

Stairs assembled by millwork companies require accurate measurement of the opening and floor-to-floor height of the rough-framed stairway to insure that the stairs delivered fit properly. It may be desirable for a millwork company representative to visit the house and take the measurements.

Service stairs can consist simply of 2- by 12-inch carriages or stringers, plank stair treads, and open risers (fig. 44). Construction and installation are discussed later in this section.

### Stairway design

Most stairway designs fall into two categories: straight run or stairway with landing. In the latter type, each flight should be considered as a separate run of stairs except that the individual riser height and tread width should be made the same on both flights. Straight-run stairs are generally the most economical but do not always satisfy space requirements.

Basic dimensions for stairway design include *headroom clearance*, *stairway width*, *stair tread run*, and *stair rise*. Generally accepted dimensions (fig. 44) are:

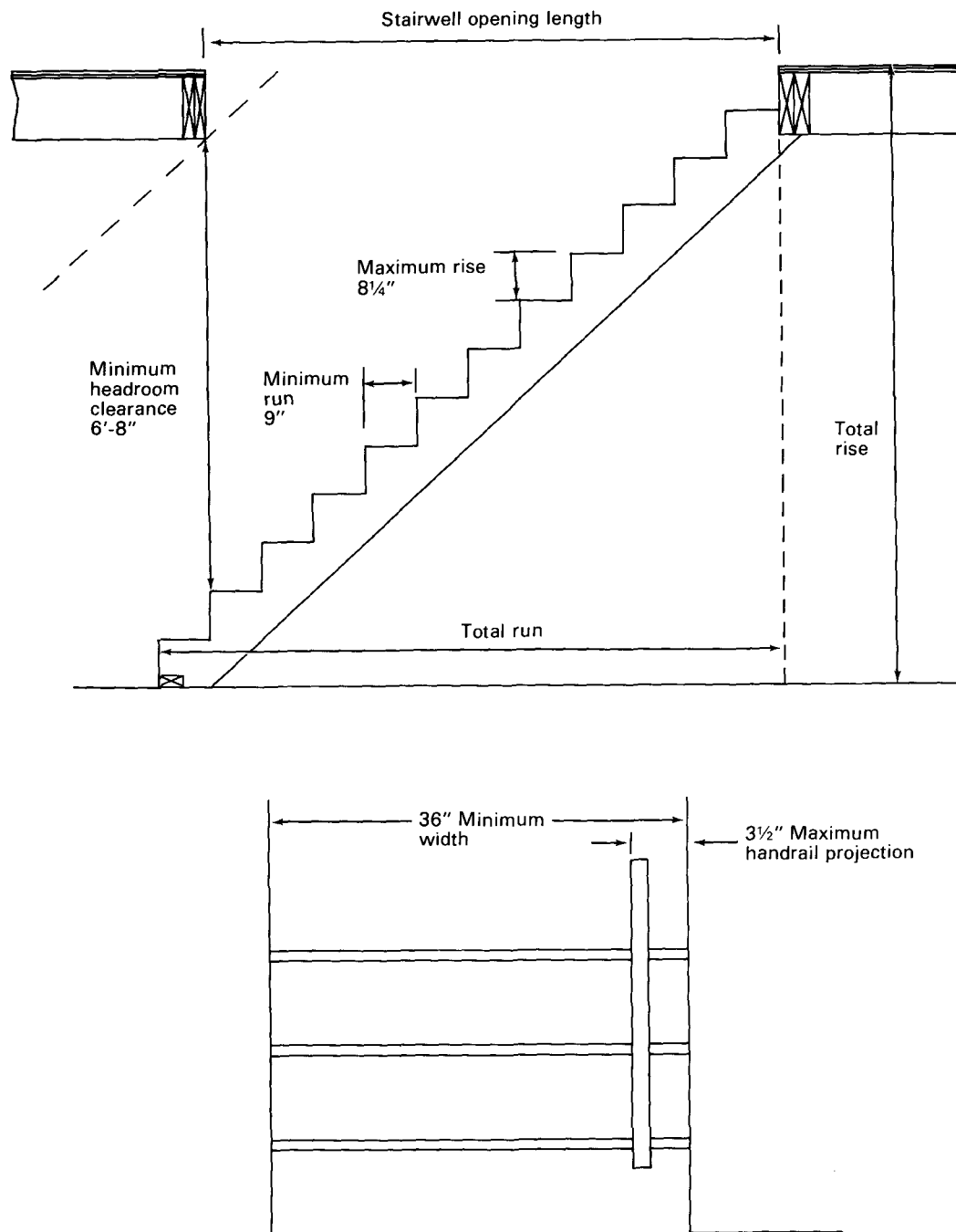
- Minimum headroom clearance 6 feet 8 inches
- Minimum stairway width 36 inches
- Minimum stair tread run 9 inches
- Maximum stair rise 8% inches

*Total rise* is the height from floor surface to floor surface. *Total run* is the total horizontal distance spanned from the front edge of the bottom riser to the back of the top riser; it is equal to the number of steps multiplied by the individual stair tread run.

An example will illustrate the method of calculation. In this example, the bottom of the ceiling joists are 8 feet 1½ inches above the floor surface; the ceiling consists of 9¼-inch joists; and the upper floor sheathing consists of ¾-inch tongue-and-groove underlayment-grade plywood. The total rise of the stairway between these two floors would be the sum of the ceiling height, the joist height, and the floor thickness, which totals 107% inches.

The first estimate of the number of step risers is arrived at by dividing the total rise by the maximum allowable tread rise (e.g., 8¼ inches). The result is just over 13. Since it is unsafe to build a stairway with one short riser, the next larger whole number should be selected. In this example the choice is 14 risers. The exact height of the 14 risers is then computed as the total rise of the stairway

**Figure 44** – Stairway design requirements and terminology.



divided by 14. In this example, this becomes 107.5 divided by 14 or 7.68 inches.

Since the number of stair treads is one less than the number of risers, the stairway in the example above would have 13 treads. If the stair design calls for a 10-inch tread, the total run of the completed stairway will be 130 inches.

The final calculation is to determine the length of the stairwell opening in the floor framing to provide adequate

headroom clearance. This calculation involves four dimensions: (1) the stair tread rise, (2) the stair tread run, (3) the required headroom clearance, and (4) the thickness of the upper floor including the joist and the layer(s) of the floor covering (excluding carpeting).

The stairwell opening length calculation is illustrated in figure 45. Continuing with the example, the rise was calculated to be 7.68 inches and the tread run was set at 10 inches. The upper floor thickness of 10 inches was

composed of a 9¼-inch joist plus a ¾-inch plywood underlayment. If the required headroom clearance is set at 6 feet 8 inches, and the equation in figure 45 is applied, the stairwell opening length would have to be 9 feet 10 inches plus 2 inches or more for finish trim. A minimum headroom clearance of 6 feet 8 inches is likely to cause people over 6 feet tall to duck their heads when using the stairway. It may therefore be appropriate to calculate the stairwell opening to allow headroom clearance of 7 feet or more.

### Landings

The total run of the stairway is a critical value only in those circumstances where the direction of the stairs causes them to terminate close to a wall. If there is insufficient space to construct a single straight-run stairway, a stairway with landing (fig. 46) must be considered. In certain instances such a stairway may also be

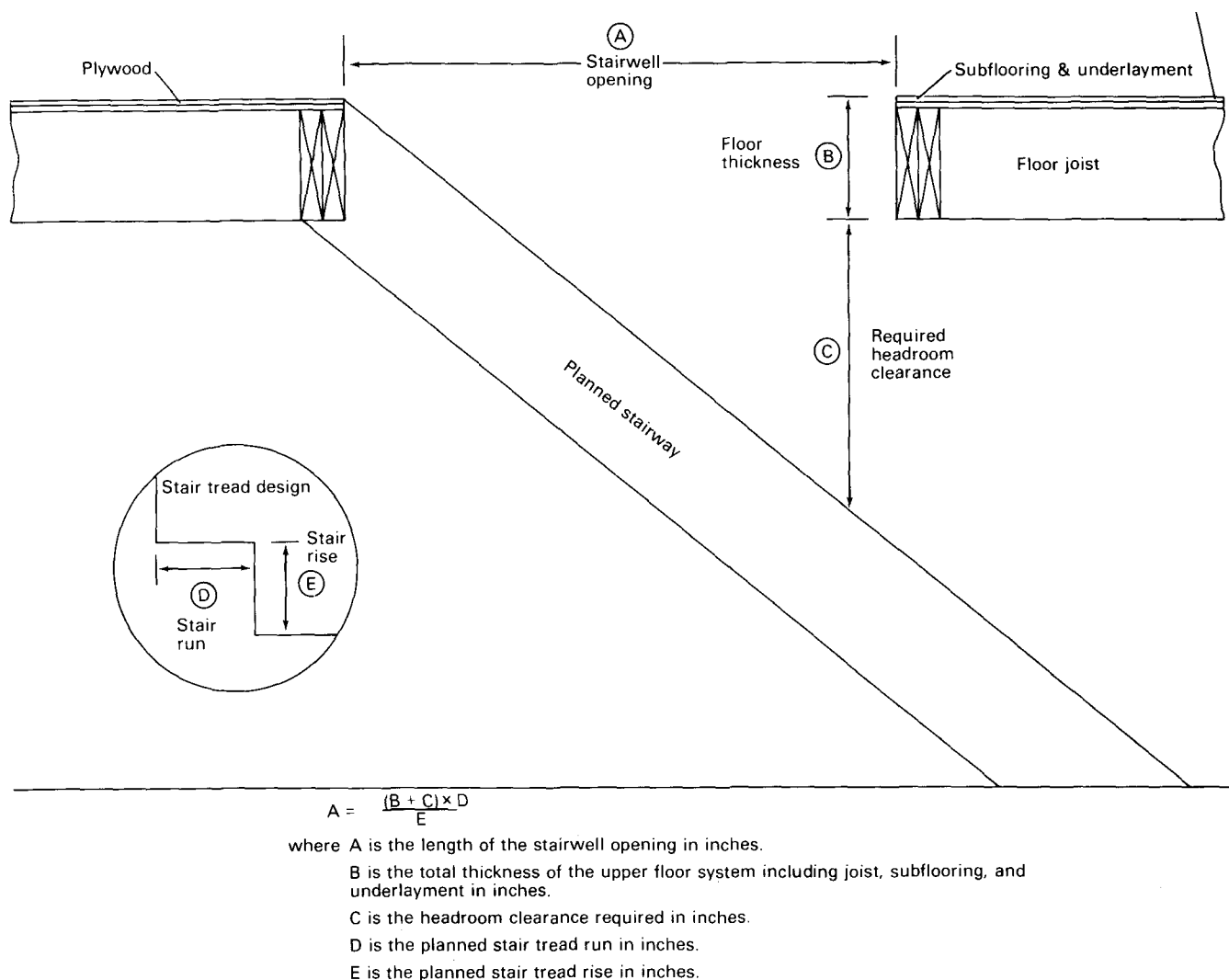
desired for esthetic reasons relating to the total design of the house.

The platform frame for the landing (fig. 47) should be nailed to the adjacent walls and should be supported by a post under the unsupported corner. The dimensions should align the landing with the stairway width. If the stairway is 36 inches wide, the landing can be 36 inches square.

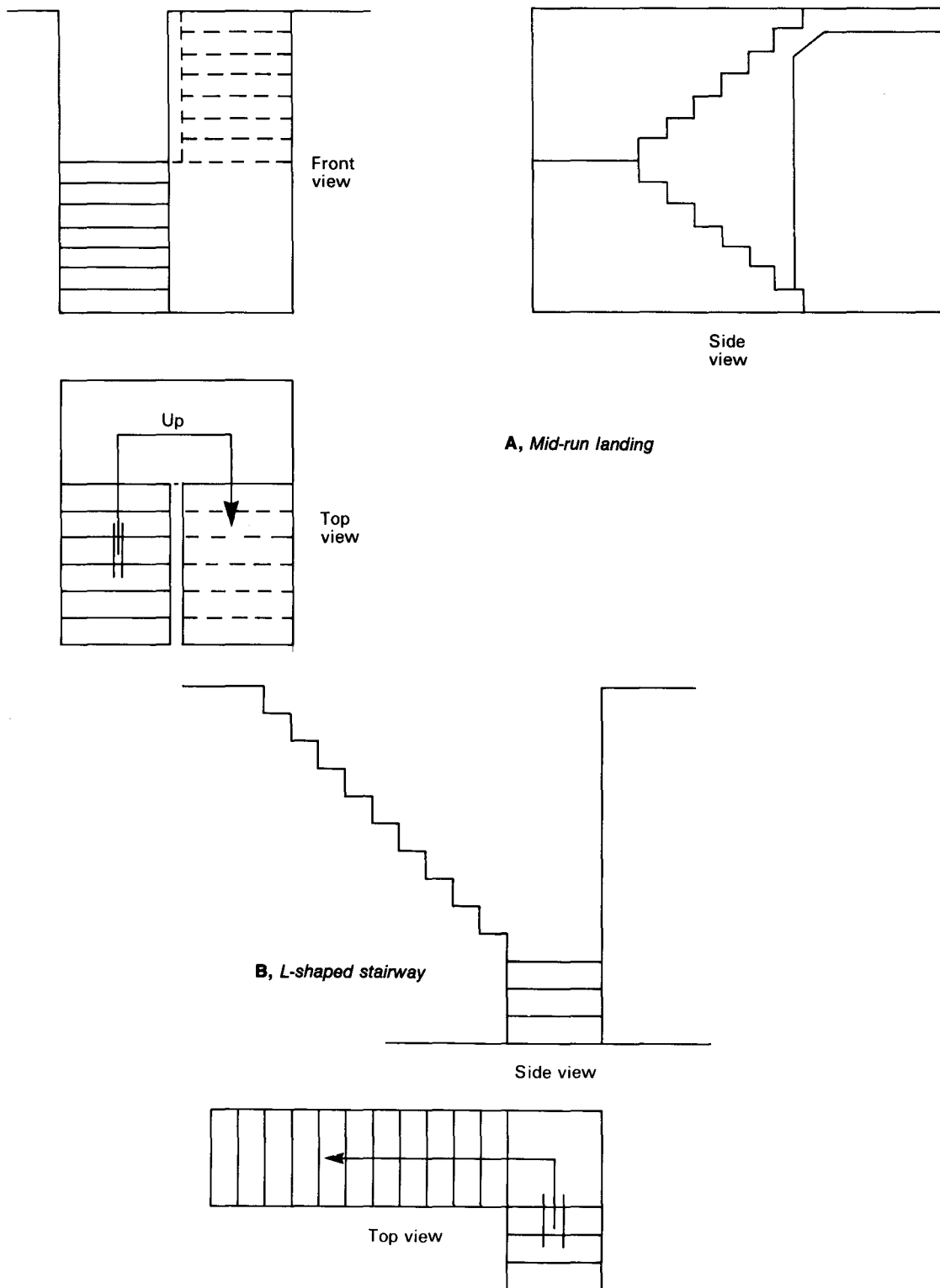
### Framing for stairway opening

The long dimension of stairway openings may be either parallel or at right angles to the joists. However, it is much easier to frame a stairway opening when its length is parallel to the joists. The opening is usually framed as shown in figure 48A when joists run perpendicular to the length of the opening and as shown in figure 48B when joists run parallel to the length of the opening.

Figure 45 – Calculating length of stairway floor opening.



**Figure 46 – Space-saving stair design:**

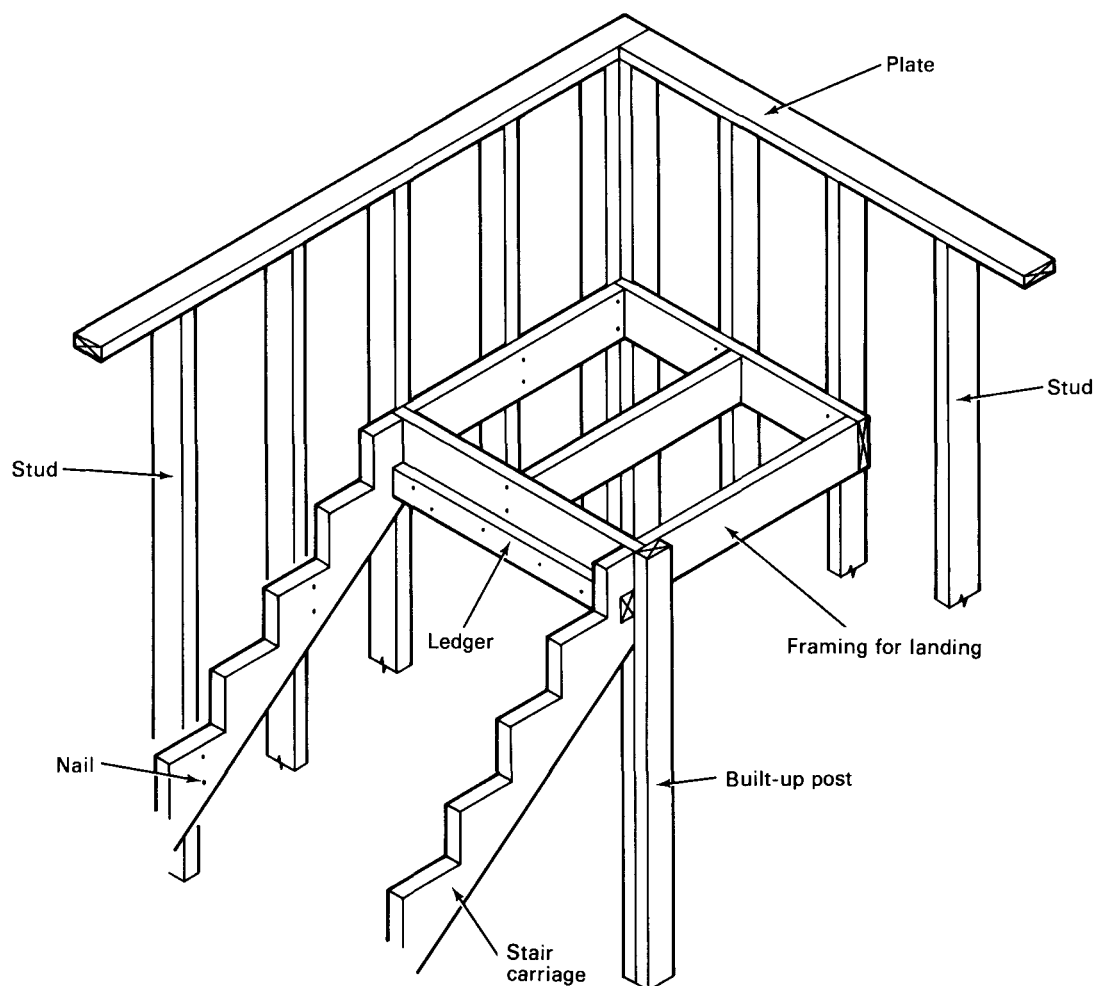


### *Service stairs*

Service stairs consist of the stair treads and the stringers or stair carriages that carry the treads and sup-

port the loads on the stairs. Service stairs are usually constructed without risers, but are sometimes constructed with risers to improve their appearance and/or to facilitate cleaning.

**Figure 47 – Framing for stair landing.**



Stringers are typically constructed of 2- by 12-inch lumber to provide a minimum of 3% inches between the lower edge of the stringer and the back of the tread (fig. 49A). When the stairway is 3 feet wide and the treads are cut from nominal 2-inch lumber, one stringer on each side of the stairway is adequate to support most loads. When thinner material is used for the stair treads, an intermediate stringer positioned at the center of the tread is required. Risers provide additional support for the front and rear of the treads and are typically cut from nominal 1-inch boards.

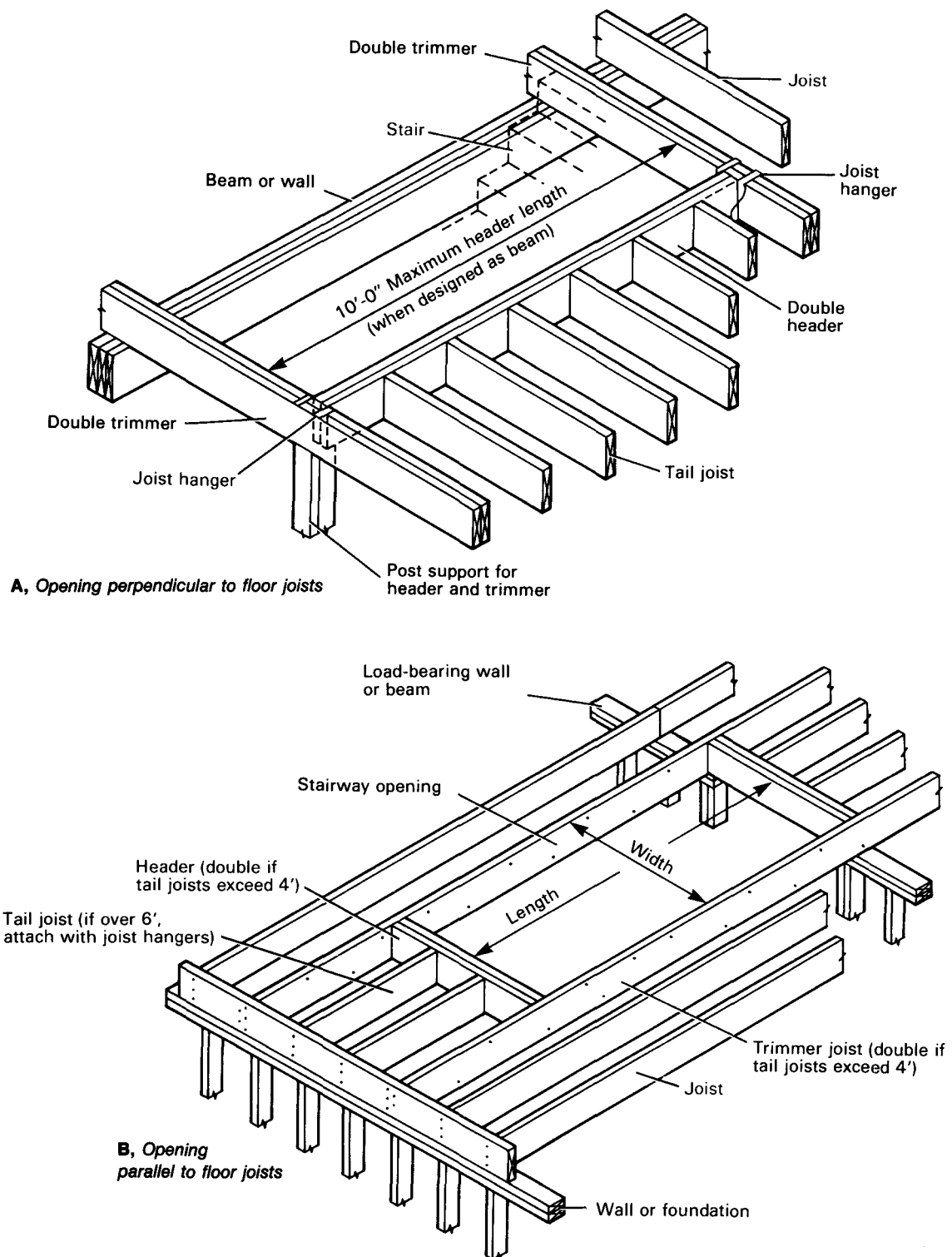
The stringers can be toenailed to the joist header at the top of the stairway (fig. 49B). At the bottom of the stairway the stringers rest on and can be anchored to a concrete footer or a basement floor. Alternatively, the stringers can be anchored to a 2- by 4-inch or 2- by 6-inch kicker plate of pressure-treated lumber firmly attached to the footer or basement floor as shown in figure 49C.

There are two approaches to laying out the cuts on the stringers or carriages for service stairs: using a steel carpenter's square and using a specially made pitch board.

In both techniques the stair stringers should be 2- by 10-inch or, preferably, 2- by 12-inch pieces of lumber. The choice of stringer dimension should be determined by the amount of lumber remaining between the bottom edge of the stringer and the apex of the notch cut out for the tread and riser. The portion of the stringer remaining uncut should be at least 3% inches (fig. 50).

The carpenter's square approach to stringer layout (fig. 50A) requires that the tread length be marked on one arm of the square and the riser height be marked on the other arm of the square. The square may then be placed on the stringer board with the two marks aligned with the edge of the board, and a pencil can be used to scribe a line on the board along the carpenter's square. This line forms the guide for cutting the stringer. The carpenter's square may be moved along the board until one of the marks is lined up with the scribe mark. Again a pencil

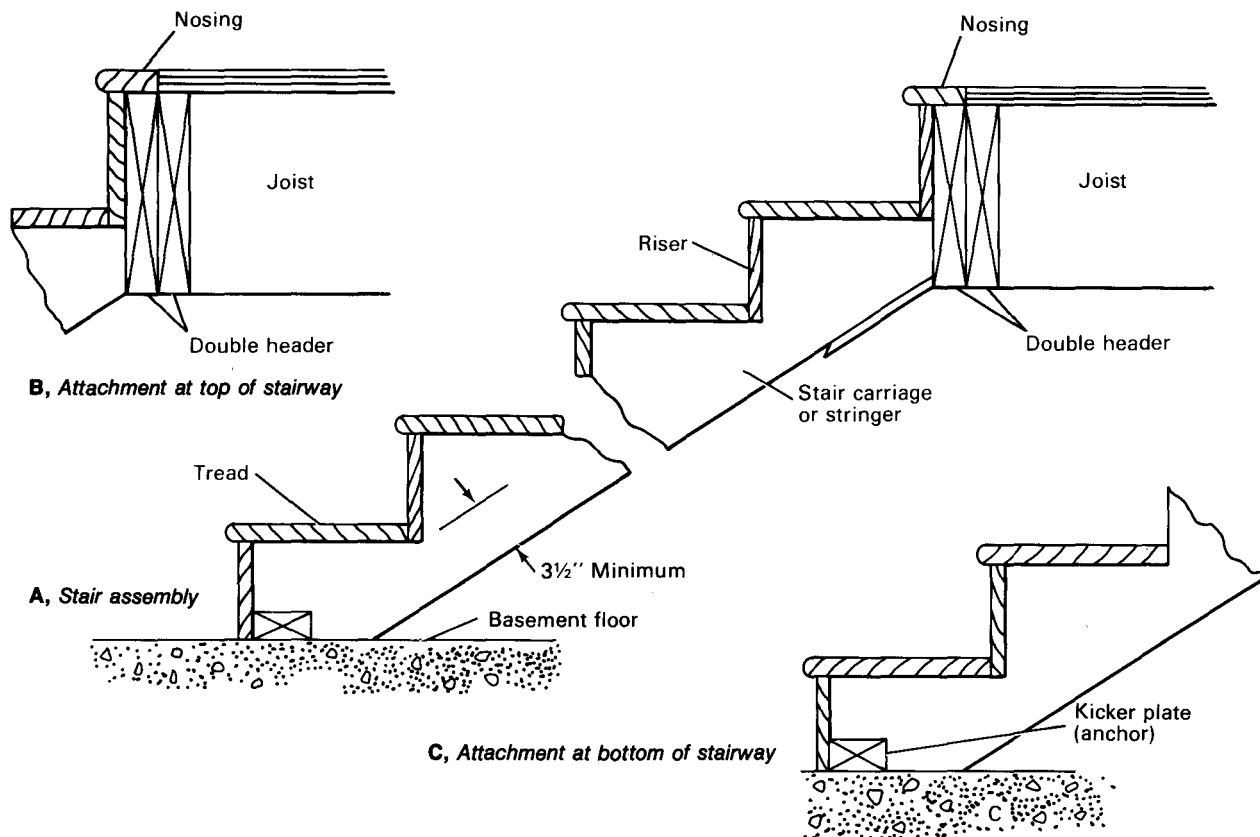
**Figure 48 – Floor framing for stairwell opening:**



can be used to mark the cutout for the step. This process is repeated for the number of treads and risers required in the stair. The riser height at the bottom step should be reduced by the thickness of the stair tread material.

The second method involves the assembly of a pitch board that serves as a template for marking the tread and riser dimensions (fig. 50B). Either plywood or a nominal 1-inch board may be used as material for the carefully cut

**Figure 49 – Utility stairs:**



triangular template. One leg of the triangular template should be the tread depth and the other should be the riser height. These two lines must meet in a 90° angle. The long side of the triangle is cut along a line connecting the ends of the two legs. The long side of the template should be screwed or nailed to the center of the flat side of a 2 by 4 to complete the pitch board. Using the 2 by 4 as a guide, the long edge of the pitch board should be placed along the edge of the stringer and the tread and riser outline scribed on the side of the stringer. The pitch board may then be moved along the stringer and the remaining tread and riser outlines scribed on the side of the stringer. The height of the riser from the bottom step should be reduced by the thickness of the tread material.

Both of these stringer layout methods presume that the stringer is to be cut so that the treads can be placed directly on the cuts. This type of stairway is referred to as an open stringer design. The alternative is the closed stringer stairway in which the stringer is not cut.

Either the carpenter's square technique or the pitch board technique may be used to mark the stringer for the location of the tread and riser dimensions for the closed stringer. Once the markings have been made, one of two methods is commonly used for supporting the stair treads

without cutting the stringers: routing the stringer, and attaching cleats.

In the routed stringer approach (fig. 51A), a groove is routed across the stringer above each tread line. The width of the groove should be the thickness of the tread material. The depth of the groove should be half the thickness of the stringer. When the grooves are completed in the two stringers, the stair treads should be inserted into the grooves and nailed at an angle through the tread into the stringer.

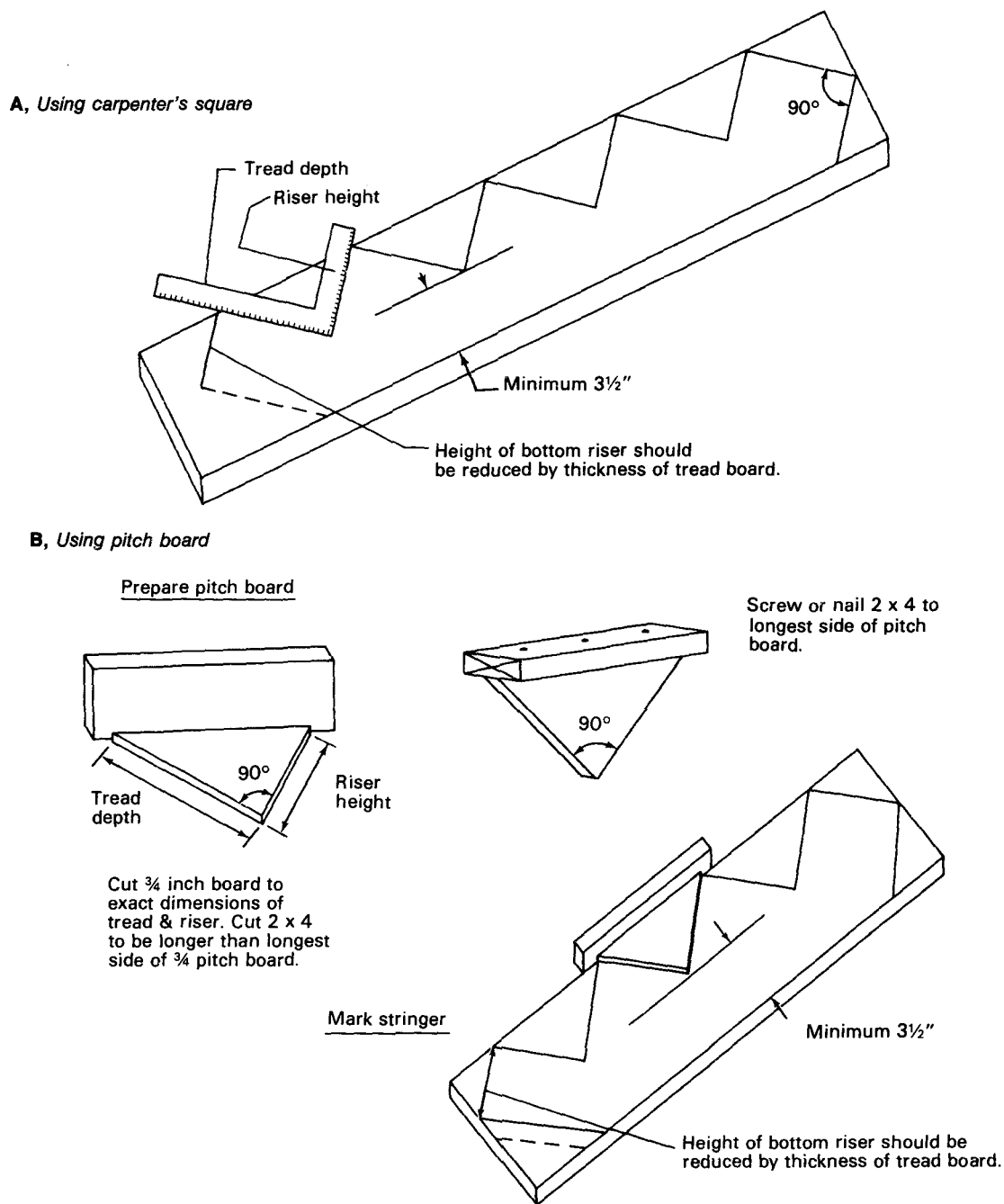
Perhaps the simplest technique for stair construction is to nail 1- by 3-inch or 2- by 2-inch cleats to the stringers below each tread line (fig. 51B). After treads are cut to the proper length they are placed between the stringers on top of the cleats. When the treads are in place, they are nailed at an angle through the tread and cleat and into the stringer.

### **Main stairway**

An open main stairway with railing and balusters ending in a newel post can be very decorative and pleasing in a house, whether the design is traditional or contemporary.

Main stairways generally differ from the types previously described in that they have such features as side

**Figure 50** – *Laying out a stringer:*



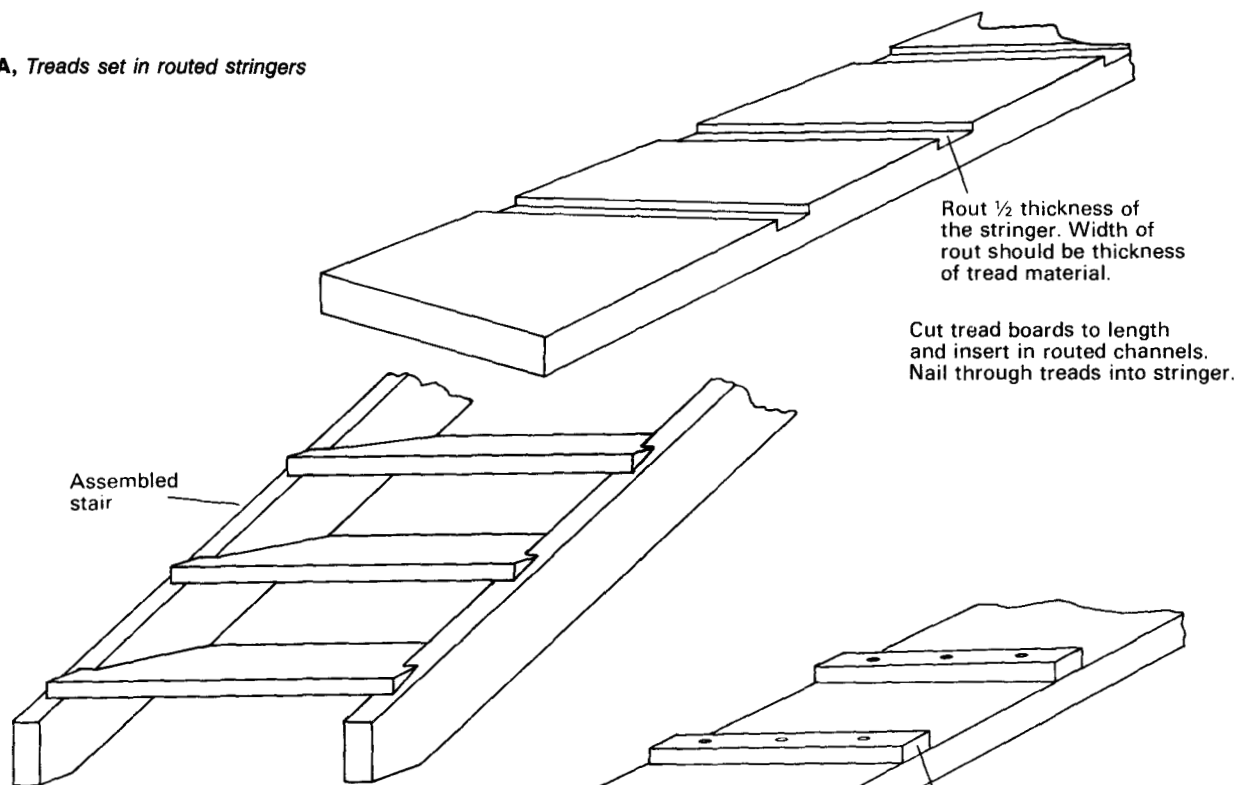
trim boards, cove moldings nailed beneath stair tread nosing and between trim boards and wall, and decorative railing and balusters; and that they are of wood species that are clear and can be given a durable natural finish.

Main stairs that are to be fully carpeted can be built with rough treads and risers and finished along both sides with trim board or skirt boards (fig. 52). The skirt boards should be nominal 1-inch boards that are free of knots.

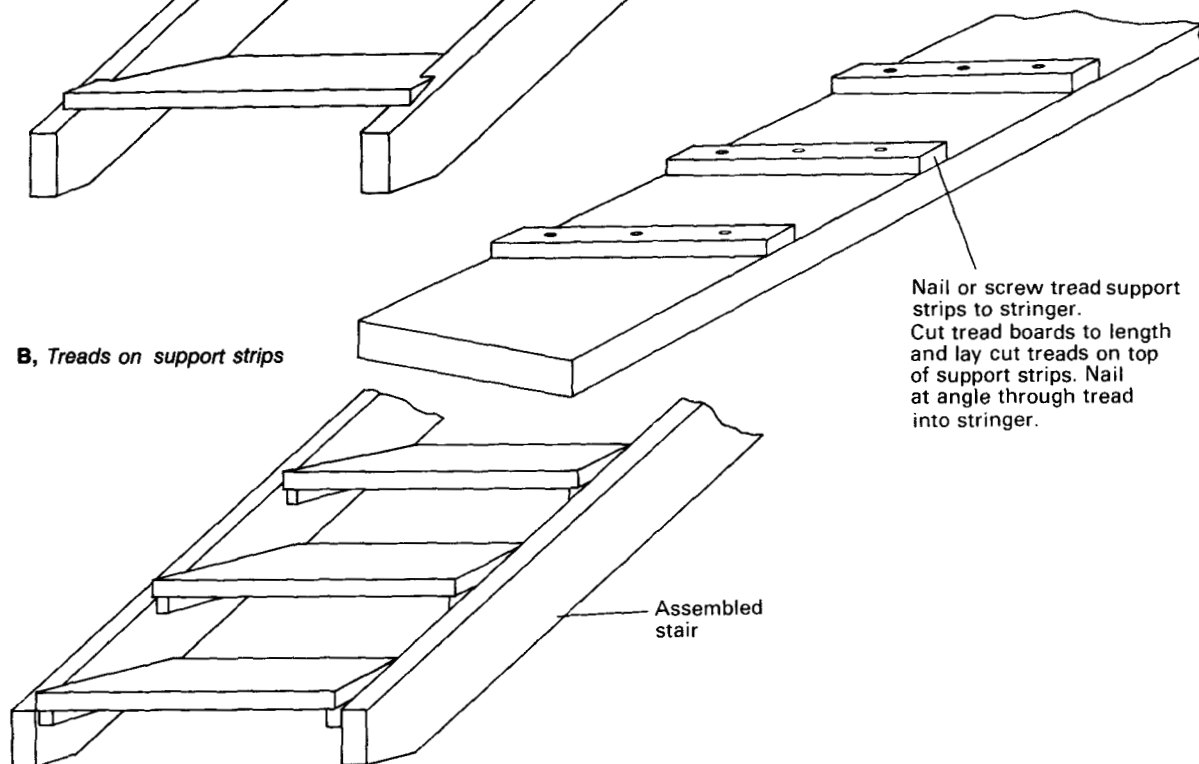
The skirt boards should be marked using the cut stringers as a pattern. The cut stringers are laid on top of the skirt boards and each tread and riser outline is marked on the face of the skirt boards. The resulting stair step pattern is then carefully cut from the boards. After the stringers, treads, and risers are installed, a  $\frac{3}{4}$ -inch-wide notch is cut out of the nosing at each side of each stair tread. After all notches are cut out, the skirt boards are slipped into the notches and seated snugly against the faces of the treads and risers.

**Figure 51 – Assembling stair treads and stringers:**

**A, Treads set in routed stringers**



**B, Treads on support strips**



The trim work required to produce an attractive and safe main stairway is often best performed by a local millwork contractor. In addition to possessing the skills and equipment, such a contractor is familiar with the local regulations that control stair design and construction.

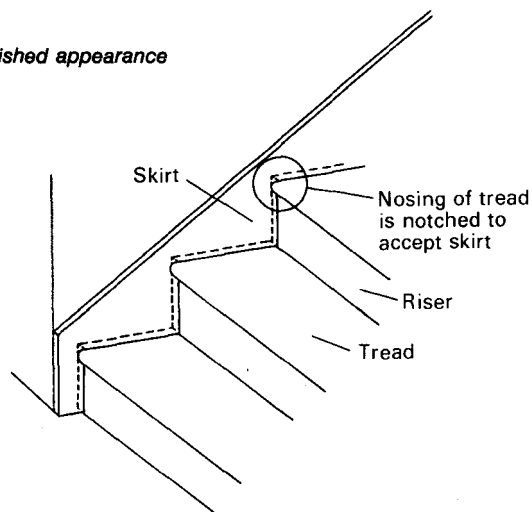
A millwork contractor provides guidance on the measurements needed to construct the stairs. Some contractors may visit the house under construction to make the necessary measurements.

**Attic folding stairs**

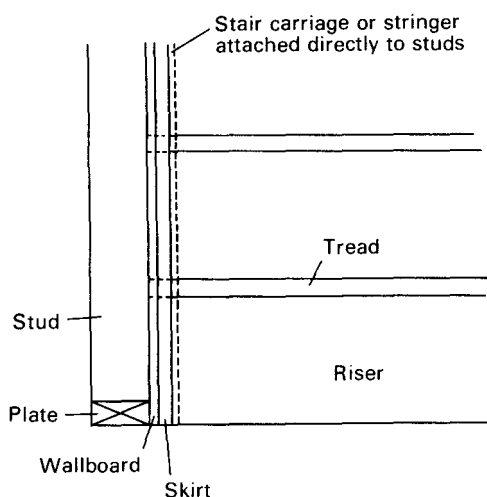
If attics are to be used for storage and space is not available for a fixed stairway, hinged or folding stairs are often used. These can be purchased ready to install. They operate through an opening in the ceiling and swing up into the attic space when not in use. When such stairs are to be installed, the attic floor joists should be designed for limited floor loading. One common size of folding stairs requires

**Figure 52 – Stairway skirt board:**

**A, Finished appearance**



**B, Front view detail**



only a 26- by 54-inch rough opening. The opening should be framed out as described for normal stair openings.

### **Exterior stairs**

In laying out porch steps or approaches to terraces, proportioning of risers and treads should be as carefully considered as in designing interior stairways. Similar riser/tread ratios can be used; however, the riser used in principal exterior steps should normally be between 6 and 7 inches in height. The need for a good support or foundation for outside steps is often overlooked. Where wood steps are used, the lumber should be pressure-treated to prevent insect and decay damage. Where the steps are located over backfill or disturbed soil, the footing should be carried down to undisturbed ground below the frost line.

## **Floor Sheathing**

Floor sheathing or subflooring is used over the floor joists to form a working platform and a base for floor finish. It usually consists of one of the following: (a) square-edge or tongue-and-groove plywood  $\frac{1}{2}$  inch to  $1\frac{1}{8}$  inches thick, depending on species, type of floor finish, and spacing of joists; (b) reconstituted wood panels such as structural flakeboard, similar in application to plywood; or (c) square-edge or tongue-and-groove boards no wider than 8 inches nor less than  $\frac{3}{4}$  inch thick. For special requirements for specific types of resilient floor coverings see the section on floor coverings in chapter 6.

### **Plywood**

Plywood can be obtained in a number of grades to meet a broad range of end-use requirements. Interior grades of plywood made with a waterproof adhesive are suitable for most applications. The waterproof (or exterior) adhesive provides resistance to intermittent exposure to moisture, such as in floors adjacent to plumbing fixtures or for subflooring that may be exposed during construction.

Plywood should be installed with the grain direction of the outer plies at right angles to the joists and staggered so that end joints in adjacent panels break over different joists. Plywood should be nailed to the joists at each bearing using 8d common or 6d threaded nails or  $1\frac{5}{8}$ -inch narrow crown staples for plywood  $\frac{1}{2}$  to  $\frac{3}{4}$  inch thick. Nails should be spaced 6 inches apart along all edges and 10 inches apart along intermediate members. Glue-nailing increases the stiffness and/or allowable span of the floor system and can eliminate or reduce the Occurrence of loose nails and squeaks that otherwise develop with even a small amount of joist shrinkage. Plywood should not be installed with tight joints whether used on the interior or exterior. The American Plywood Association recommends a  $\frac{1}{8}$ -inch spacing at panel ends and edges for plywood subfloor applications.

Plywood that is suitable for subfloor, such as Rated Sheathing and Structural I or II grades, has a panel identification index marking on each sheet. The markings indicate the allowable spacing of rafters and floor joists for the various thicknesses when the plywood is used as roof sheathing or subfloor. For example, an index mark of  $\frac{32}{16}$  indicates that the plywood panel is suitable for a maximum spacing of 32 inches for rafters and 16 inches for floor joists.

When some type of underlayment or wood floor finish is used over the plywood subfloor, a standard sheathing grade with square edges is generally used. The minimum acceptable thickness of plywood subfloor is generally  $\frac{1}{2}$  inch when joists are spaced 16 inches on center, and  $\frac{3}{4}$  inch when joists are spaced 24 inches on center.

A Rated Sturd-I-Floor grade plywood can serve as combined subfloor and underlayment. Separate underlayment can be eliminated because the plywood functions as both a structural subfloor and a good substrate for the floor finish. This applies to thin resilient flooring, carpeting, and other nonstructural floor finishes. Minimum thicknesses are similar to those for sheathing grade plywood subfloors used with underlayment. The plywood used in this manner must be tongue-and-groove or blocked with 2-inch lumber along the unsupported edges.

### ***Reconstituted wood panels***

Several types of reconstituted wood panels are used for floor sheathing: structural flakeboard (including waferboard and oriented strand board), particleboard, and composite panels (veneer faces bonded to reconstituted wood cores). These products are graded and installed in the same manner as plywood panels. Grade markings include the same index indicating allowable spacing of rafters and joists. The thickness of different products may vary for a given allowable spacing. This is not important except that 8d threaded nails should be used for panels thicker than  $\frac{3}{4}$  inch.

### ***Boards***

Subflooring boards are rarely used because they require extra labor. They may be applied either diagonally or at right angles to the joists. If wood floor finish is used over subflooring placed at right angles to the joists, the floor finish should be laid at right angles to the subflooring. Diagonal subflooring permits wood floor finish to be laid either parallel or at right angles to the joists. End joints of the boards should always be directly over the joists. Subflooring boards are nailed to each joist with two 8d nails for widths under 8 inches and three 8d nails for 8-inch widths.

The joist spacing should not exceed 16 inches on center when strip floor finish is laid parallel to the joists or when tile or parquet floor finish is used. An underlayment of plywood, particleboard, or hardboard is required over board subfloors where thin resilient floorings, carpet, or other nonstructural floor finish is to be used.

### **Exterior Wall Framing**

The floor framing and subfloor covering provide a working platform for construction of the wall framing. The term wall framing usually refers to exterior walls rather than interior partitions. It includes vertical studs and horizontal members, i.e., top and bottom plates and window and door headers. Exterior walls may be load-bearing and support ceilings, upper floor, and/or roof, or they may be non-load-bearing, that is, may not support a structural load, as under the gable-end of a one-story

house. Wall framing also serves as a nailing base for wall-covering materials.

Wall framing members are generally 2- by 4-inch studs spaced 16 inches or 24 inches on center, depending on vertical loads and the support requirements of the covering materials. Top plates and bottom plates are also 2 by 4 inches in size. An alternative is the use of 2- by 6-inch lumber for wall framing to provide space for greater amounts of insulation.

Headers over doors or windows in load-bearing walls consist of doubled 2- by 6-inch and deeper members, depending on the span of the opening.

### ***Requirements***

The requirements for wall framing lumber are stiffness, good nail-holding ability, and freedom from warp. Species used include Douglas-fir, white fir, hemlocks, spruces, and pines. As noted in the section on floor framing, the grades vary by species, but it is common practice to use a Stud grade for studs, and a No. 2 or Better grade for plates and for headers over doors and windows.

Lumber for wall framing, as for floor framing, should be reasonably dry. Moisture content of wall framing members, such as studs, plates, and headers, should not exceed 19 percent. A maximum moisture content of 15 percent is much more desirable. If the moisture content of the lumber is in question, it is advisable to take the steps describing the protection of materials (chapter 1) to reduce moisture content to in-service conditions before applying interior trim.

The ceiling height in most houses is nominally 8 feet. It is common practice to rough-frame the wall (subfloor to top of upper plate) to a height of 8 feet 1 inch. Precut studs are often supplied to a length of 92½ inches, allowing for a single bottom plate and a double top plate, each 1½ inches thick. If a single top plate is used, stud length is 94 inches. This height allows the use of two 4-foot sheets of gypsum wallboard, applied horizontally, to finish the interior of the wall, along with clearance for the ceiling finish, which is applied first. A lower ceiling height can be used to reduce exterior wall finish or to reduce stair rise/run ratio. However, finished ceiling height should not be less than 7 feet 6 inches (rough height 7 feet 7 inches). Areas under sloping ceilings may be as low as 5 feet provided that one-half of the floor area has a clearance of at least 7 feet 6 inches.

### ***Platform construction***

The wall framing in platform construction is erected over the subfloor, which extends to the outer edge of the building (fig. 53). The most common method of framing

is horizontal assembly on the subfloor and tilt-up of completed sections. When a sufficient work crew is available, full-length wall sections can be erected in this fashion. Otherwise, shorter sections are preferable because they can be easily handled by a small crew.

The horizontal assembly method involves laying down a top plate and a bottom plate with precut studs, window and door headers, window sills, and cripple studs (short-length studs) arranged between. Corner studs and headers are usually nailed together beforehand to form single units. Top and bottom plates are then nailed to studs. Headers and window aprons are nailed to adjoining studs with 12d or 16d nails. A 4- by 8-foot sheet of structural sheathing or siding should be installed at each end of the wall to provide resistance to racking. Alternative methods of providing racking resistance are to install let-in bracing, steel X-bracing, or rigid steel braces.

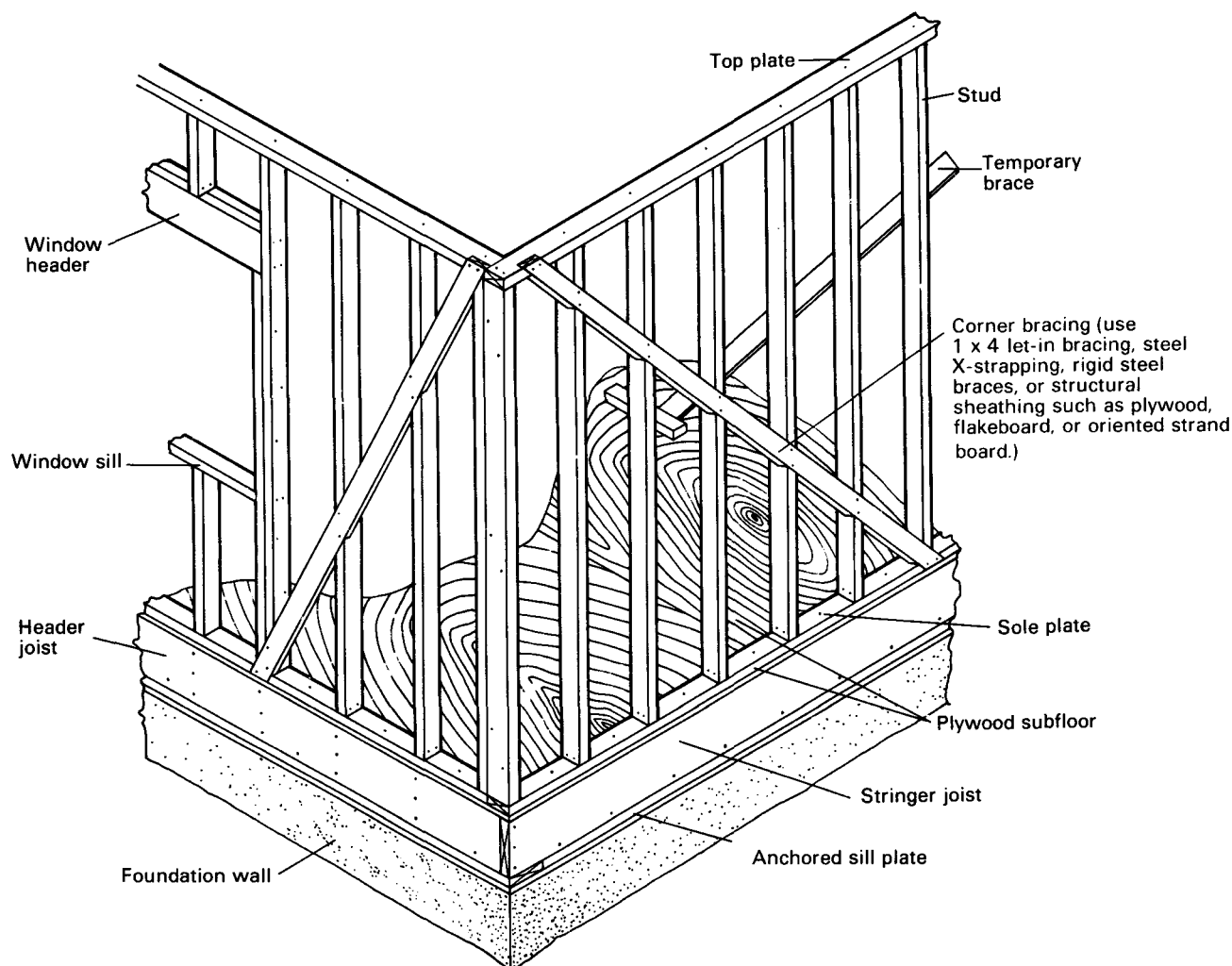
Wall sheathing and/or siding may be installed while the wall is in the horizontal position. Complete finished walls

with windows and door units in place can also be fabricated in this manner. The entire section is then tilted up, plumbed, and braced (fig. 53). Bottom plates are then nailed to the floor joists through the subfloor and the comers are joined.

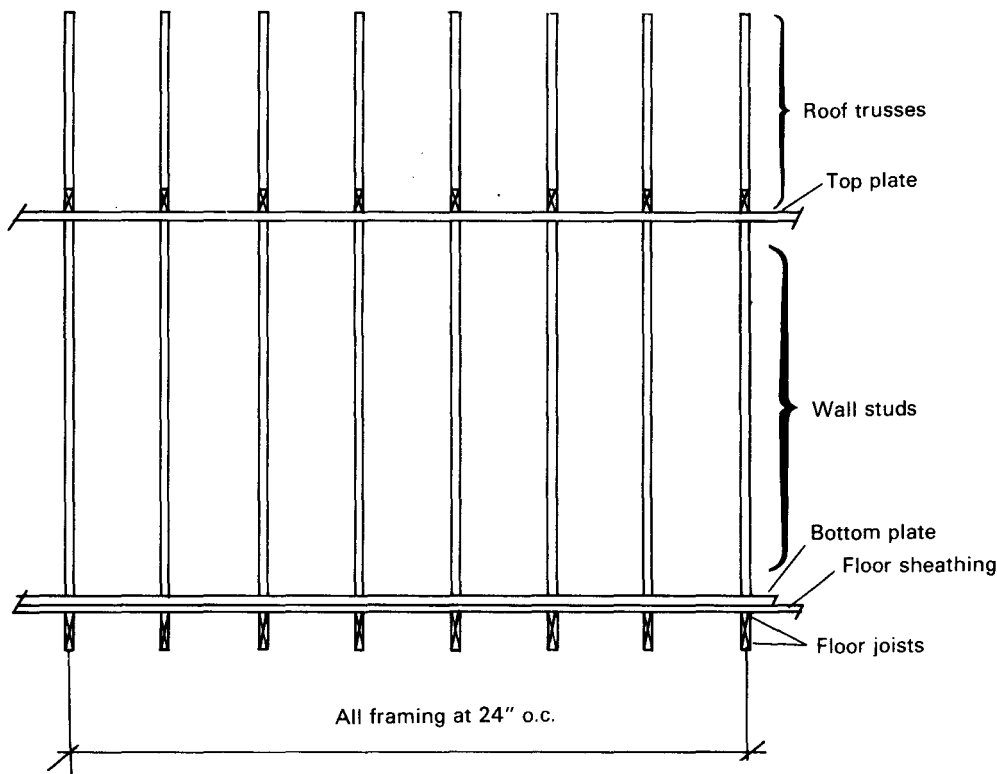
Where the structure is designed to have overhead roof or floor framing members bear directly over studs, a single top plate is used (fig. 54). However, if roof or floor framing members are to bear on the top plate between studs, the top plate must be doubled. Where a double top plate is used, the second top plate is added so that it laps the first plate at comers and at wall intersections. This provides an additional tie for the framed walls. The second top plate can be fastened in place when the wall is in a horizontal position or following erection. Top plates are nailed together with 12d or 16d nails spaced 24 inches apart and with two nails at each wall intersection.

In hurricane areas or areas with high winds, it is often advisable to fasten wall and floor framing to the anchored

**Figure 53** –Wall framing with platform construction.



**Figure 54** – Vertical alignment of framing members simplifies framing and transmits loads directly down through structural members.



foundation sill when sheathing does not provide this tie. Figure 55 illustrates one system of anchoring the studs to the floor framing with steel straps.

Several arrangements of studs at outside corners can be used in framing the walls. Blocking between two corner studs is the traditional method for providing a nailing edge for interior finish (fig. 56A). A variation of the traditional method is shown in figure 56B. A third alternative employing less lumber and providing more space for insulation is the use of wallboard backup clips as shown in figure 56C.

Interior walls should be fastened to all exterior walls where they intersect. This intersection should also provide backup support for the interior wall finish. Traditionally, this has been accomplished by doubling the studs in the exterior wall at the intersection with the interior wall (fig. 57A). However, there is no structural requirement for extra studs at such an intersection. A midheight block between exterior wall studs can be used to support the partition stud. This method requires the use of wallboard backup clips to support the drywall (fig. 57B).

### ***Second-story framing***

Figure 58 shows a commonly used method of wall and

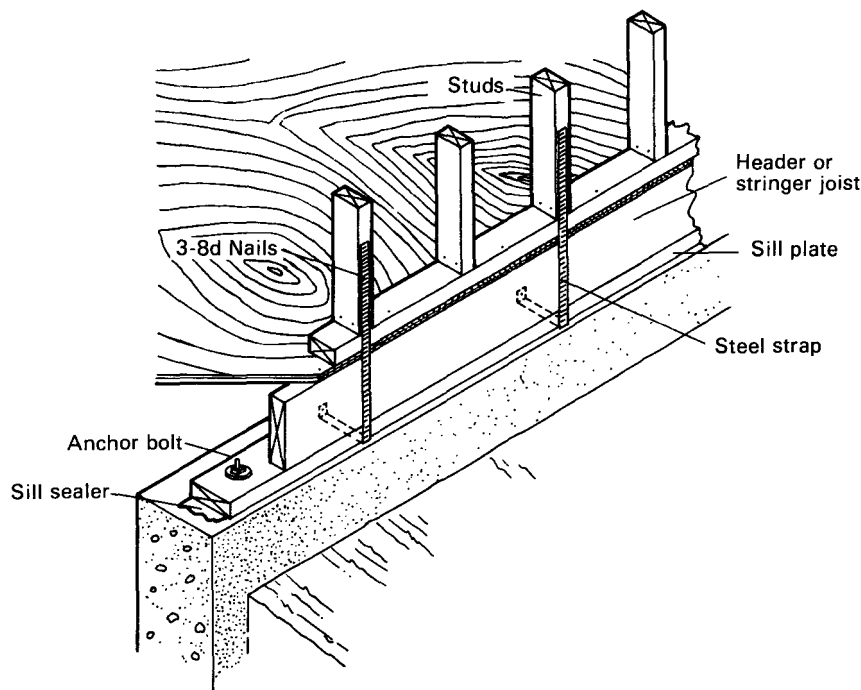
ceiling framing for platform construction in 1½-story or 2-story houses with finished rooms above the first floor. The edge floor joist is toenailed to the top wall plate with 8d nails spaced 24 inches on center. The subfloor and wall framing are then installed in the same manner as for the first floor.

### ***Window and door framing***

The members used to span over window and door openings are called headers or lintels (fig. 59). As the span of the opening increases, it is necessary to increase the depth of these members to support the ceiling and roof loads. A header is traditionally made up of two 2-inch members spaced with ¾-inch lath or plywood strips, all of which are nailed together for convenience in handling. However, from a structural point of view, it is not necessary to nail these members together, or even to space them apart. The lath or plywood spacers are used only to bring the faces of header flush with the edges of the studs. In addition, lighter loads may not require more than a single header member.

Headers are supported at the ends by the inner studs or jack studs of the double stud assembly at each side of the window or door opening. Species and grades of wood normally used for floor joists are appropriate for headers. An abbreviated list of allowable spans for 2- by 8-inch

**Figure 55** – Anchoring wall framing to floor framing.



headers appears in table 10. It is good practice to ask the local building official to review in advance the species, grade, and dimension of material planned for headers.

A structural header can also be made by applying a plywood skin to framing members above openings in a load-bearing wall. Plywood  $\frac{1}{2}$  inch thick may be nailed or glue-nailed to framing members to form a plywood box header over openings (fig. 60). The plywood may be applied to the inside or outside, or both sides of the framing. AD interior grade plywood may be used on the interior side and may be taped and spackled to blend with standard  $\frac{5}{8}$ -inch gypsum wallboard. CDX sheathing or better exterior grade plywood should be used on the exterior side. As shown in figure 60, stiffeners can be used to prevent flexing of the plywood skin.

One benefit of plywood box headers is that they can be fully insulated. Another benefit is that shrinkage such as is possible with a lumber header is almost eliminated. A typical plywood header with the plywood nailed to the exterior side only is shown in figure 60.

The studs, headers, and aprons should provide a rough opening as recommended by the manufacturer of the door or window unit. The dimensions of the rough openings required for installation of doors and windows should be carefully checked. It is good practice to make a list of these dimensions and to keep the list available for quick reference during framing. The framing height to the bottom of the window and door headers should be based on

the door heights, normally 6 feet 8 inches for the main floor. To allow for the thickness and clearance of the head jams of window and door frames, the bottoms of the headers are usually located 6 feet 10 inches or 6 feet 11 inches above the subfloor, depending on the type of floor finish used. This dimension conveniently permits a 2- by 8-inch header to be installed immediately beneath a single top plate in a wall 7 feet 7 inches high, eliminating the need for short cripples in walls of the traditional height, 8 feet 1 inch.

### **Exterior Wall Sheathing**

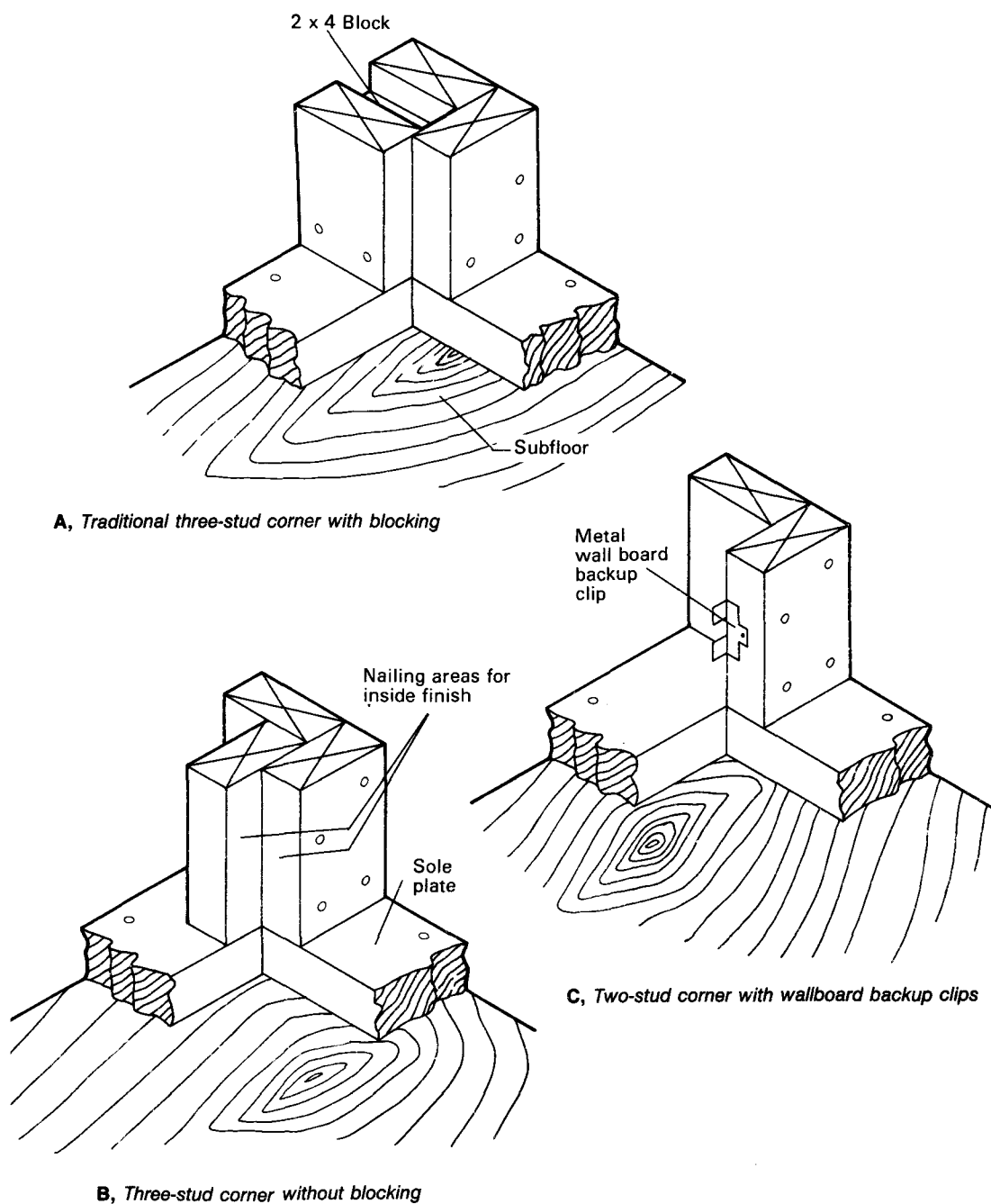
Exterior wall sheathing is the covering applied over the outside wall framework of studs, plates, and window and door headers. It forms a base upon which the exterior finish can be applied. Certain types of sheathing and methods of application can provide great rigidity to the house, eliminating the need for special corner bracing. Sheathing also serves to reduce air infiltration and, in certain forms, provides significant insulation.

Some sheet materials serve both as sheathing and siding, eliminating the need for separate sheathing and siding layers.

### **Types of sheathing**

Types of sheathing include plywood, reconstituted wood panels, wood boards, insulating fiberboards, foil-faced laminated paperboards, gypsum boards, and a variety of rigid formed-plastic boards with or without facings.

**Figure 56** – Corner stud assembly:



**Plywood.** This sheathing is available in thicknesses ranging from  $\frac{5}{16}$  inch to  $\frac{3}{4}$  inch in various grades and constructions for stud spacings of 16 inches and 24 inches on center. When plywood sheathing is adequately nailed, additional corner bracing is not required. Entire walls can be sheathed with 4- by 8-foot sheets applied vertically or horizontally. Alternatively, plywood sheathing can be used at corners only, the remainder of the wall being covered with other sheathing materials. In this method, plywood panels replace corner bracing.

Specific recommendations on selection and use of plywood and reconstituted wood panel sheathing materials appear in American Plywood Association publications cited among additional readings.

**Reconstituted wood panels.** Several types of reconstituted wood panels are used for wall sheathing: structural flakeboard (including waferboard and oriented strandboard), particleboard, and composite panels.

**Figure 57** – Intersection of interior partition and exterior wall:

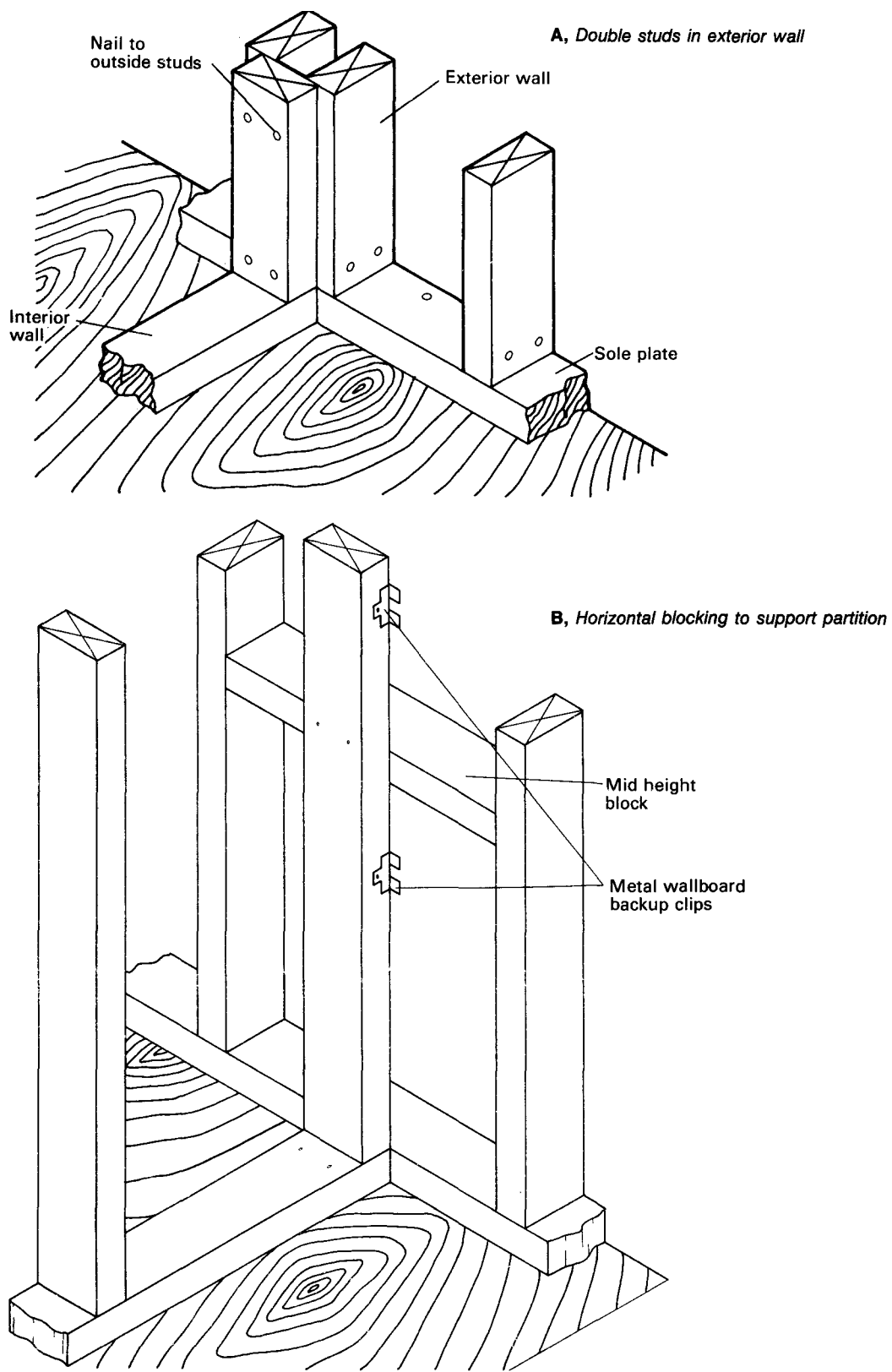
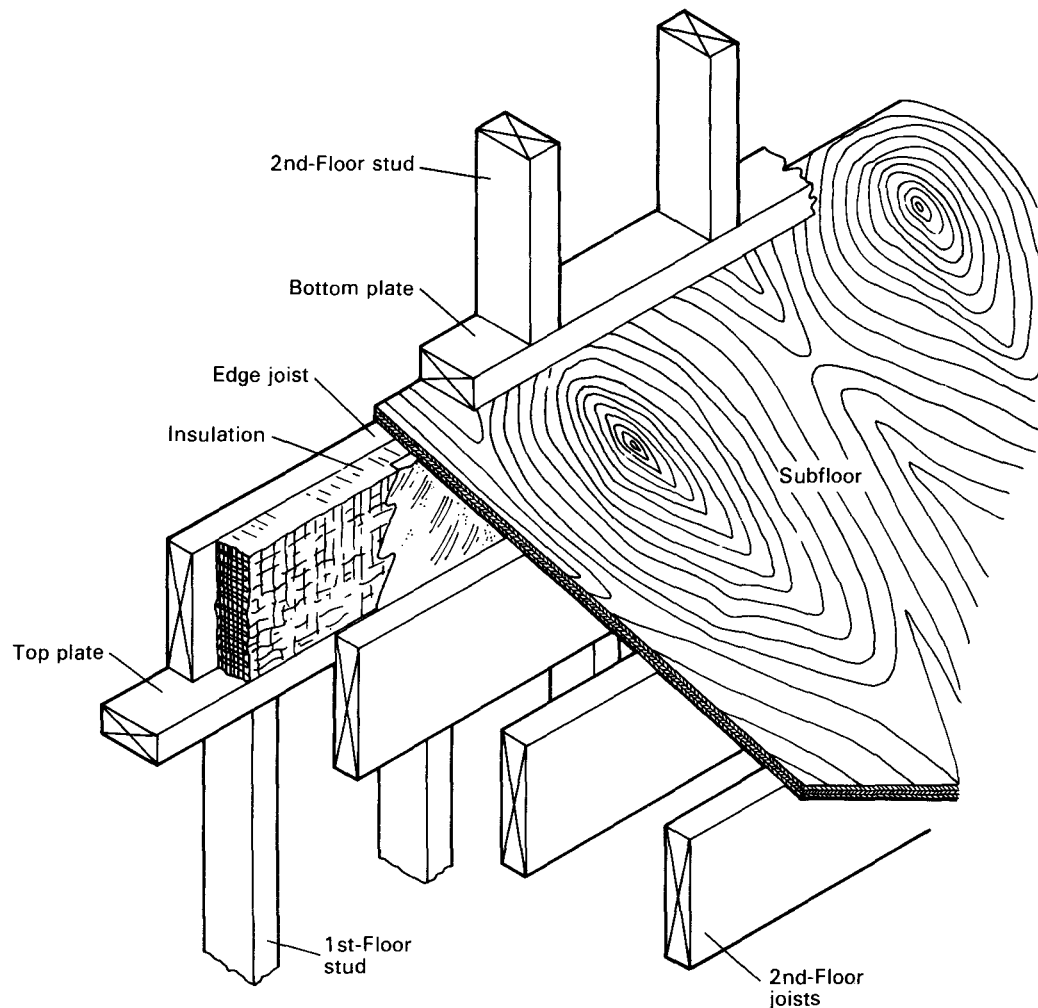


Figure 58 – Second-story framing for platform construction.



Waferboard, described in a later section on roof sheathing, is commonly available in thicknesses ranging from  $\frac{7}{16}$  inch to  $\frac{3}{4}$  inch. The most common panel size is 4 by 8 feet, but it can be obtained in sizes up to 4 by 16 feet or larger.

Waferboard sheathing is installed in much the same manner as plywood sheathing, although many local codes require that the waferboard be  $\frac{1}{8}$  inch thicker than plywood for the same applications.

Oriented strandboard, often called OSB, is a composite panel of compressed strand-like wood particles arranged in layers, usually three to five, oriented at right angles to each other in the same fashion as plywood. Bonding is accomplished with a phenolic resin as with waferboard. Production thicknesses and panel sizes are similar to waferboard.

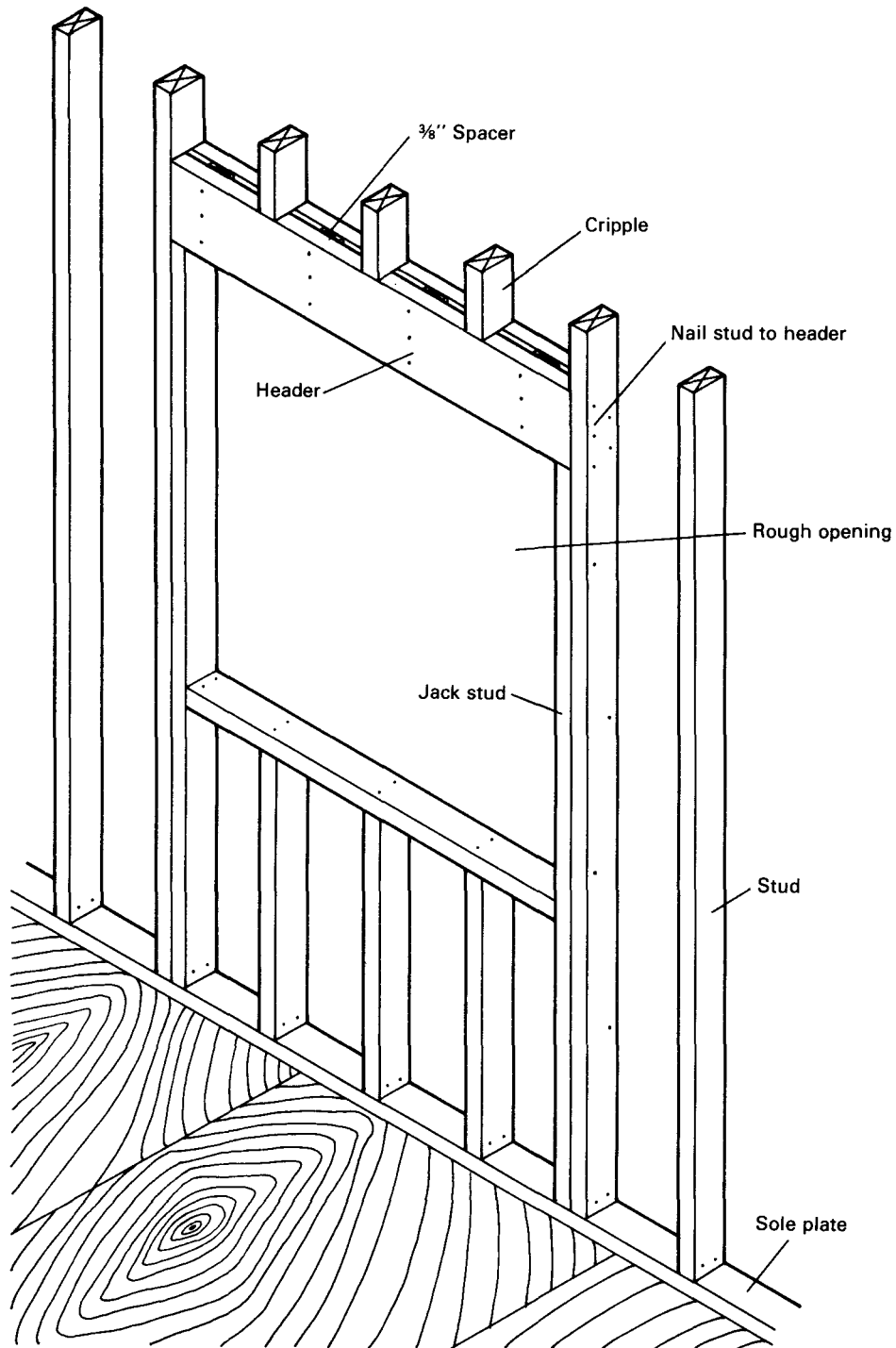
Particleboard is composed of small wood particles usually arranged in layers by particle size, but not usually

with a particular strand orientation. As with other reconstituted wood panel sheathing materials, the particles are bonded together with a phenolic resin. Available thicknesses and panel sizes are similar to waferboard.

Composite panels consist of a reconstituted wood core bonded between wood veneer face and back plies. This material has a surface appearance similar to plywood and, like plywood, is available in various thickness and panel sizes.

Wood boards. These are the oldest form of sheathing, but are now infrequently used and may be unavailable in some areas. When available, wood sheathing is usually of nominal 1-inch thickness or resawn  $\frac{5}{8}$ -inch boards in a square-edge pattern. Widths used are 6, 8, and 10 inches. The boards may be applied horizontally or diagonally. When they are applied diagonally, corner bracing can be eliminated.

**Figure 59** – Traditional header assembly over window or door openings in load-bearing wall.



**Insulating fiberboard.** These sheathings consist of an organic fiber that is coated or impregnated with asphalt or otherwise given treatment for water resistance. Occasional wetting and drying that might occur during construction does not damage the sheathing significantly. Galvanized or other corrosion-resistant fasteners are recommended for installation.

Three types of insulating fiberboards are regular density, intermediate density, and nail base. Regular density is used for cover only, where no racking resistance or structural support is needed. Where structural support is required, intermediate density is used. Nail-base fiberboard will hold nails; it is well suited as a sheathing beneath sidings that require nailing at other than stud

**Table 10 – Allowable 2 by 8 header spans for different load conditions**

Load carried by header	Minimum required bending stress (lb/in²)	Minimum required horizontal shear (lb/in²)	Header compo- sition (no. 2x8's)	Length of maximum clear span for various house depths				
				24 ft	26 ft	28 ft	30 ft	32 ft
Live and dead loads: floor = 50 lb/ft²; roof = 30 lb/ft²								
Floor only	1,000	75	1	3'8"	3'5"	3'3"	3'1"	2'11"
			2	6'8"	6'6"	6'3"	6'1"	5'10"
Roof only	1,000	75	1	4'0"	3'9"	3'6"	3'3"	3'1"
			2	7'0"	6'9"	6'6"	6'4"	6'2"
Roof & floor	1,000	75	1	2'1"	2'0"	—	—	—
			2	4'3"	4'0"	3'9'	3'6"	3'4
Floor only	1,500	90	1	4'5"	4'2"	3'11"	3'8"	3'6"
			2	8'2"	7'11"	7'8"	7'5"	7'0"
Roof only	1,500	90	1	4'10"	4'6"	4'2"	3'11"	3'8"
			2	8'6"	8'3"	8'0"	7'9"	7'6"
Roof & floor	1,500	90	1	2'6"	2'4"	2'3"	3'1"	2'0"
			2	5'0"	4'9"	4'5"	4'2"	4'0"
Live and dead loads: floor = 50 lb/ft²; roof = 40 lb/ft²								
Roof only	1,000	75	1	3'0"	2'10"	2'7"	2'5"	2'4"
			2	6'0"	5'7"	5'3"	4'11"	4'7"
Roof & floor	1,000	75	1	—	—	—	—	—
			2	3'7"	3'4"	3'2"	3'0"	2'10"
Roof only	1,500	90	1	3'7"	3'4"	3'2"	2'11"	2'9"
			2	7'3"	6'9"	6'3"	5'11"	5'7"
Roof & floor	1,500	90	1	2'2"	2'0"	—	—	—
			2	4'4"	4'0"	3'9"	3'7"	3'4"
Live and dead loads: floor = 50 lb/ft²; roof = 50 lb/ft²								
Roof only	1,000	75	1	2'5"	2'3"	2'1"	2'0"	—
			2	4'9"	4'6"	4'2"	3'11"	3'8"
Roof & floor	1,000	75	1	—	—	—	—	—
			2	3'2"	2'11"	2'9"	2'7"	2'5"
Roof only	1,500	90	1	2'10"	2'8"	2'6"	2'4"	2'3"
			2	5'9"	5'4"	5'0"	4'8"	4'5"
Roof & floor	1,500	90	1	—	—	—	—	—
			2	3'9"	3'6"	3'4"	3'1"	2'11"

Source: NAHB Research Foundation (1977). *Reducing Home Building Costs with OVE Design and Construction*.

The minimum required bending stress (f) varies with species and grade of lumber as shown in the technical note on design values.  
horizontal shear (H) varies with species and grade of lumber as shown in the technical note on design values.

locations. Additional corner bracing is usually not required for intermediate and nail-base sheathing when they are properly applied with long edges aligned vertically. Shingles used for siding can be applied directly to nail-base sheathing if they are fastened with special annular-grooved nails.

Insulating fiberboards are manufactured in ½-inch thickness and in 4- by 8-foot and 4- by 9-foot sizes for vertical applications of ½-inch regular-density sheathing. Insulating board sheathing should be fastened to the wall framing with 1½-inch roofing nails or with crown staples 1<sup>5</sup>/<sub>8</sub>-inches wide.

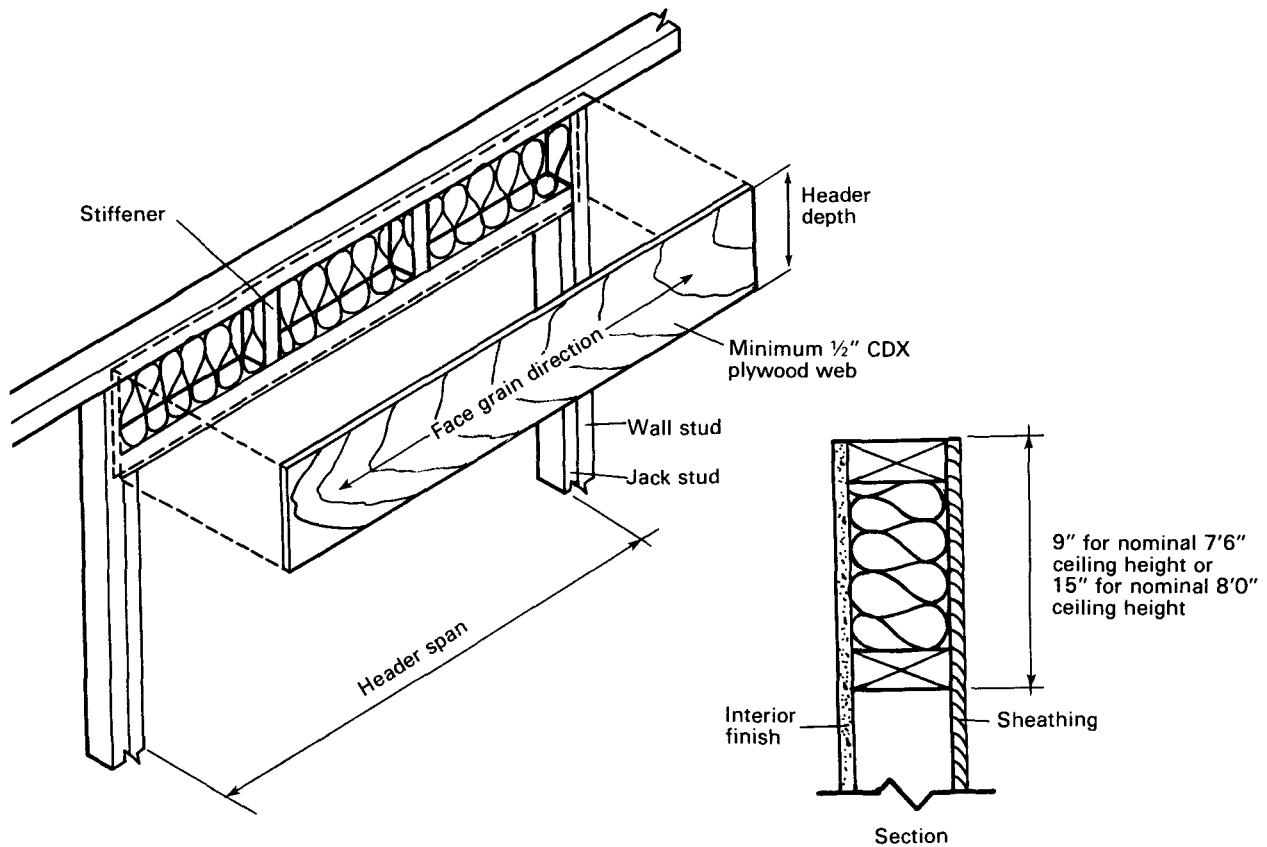
**Foil-faced laminated paperboard.** Available in structural grades from several manufacturers, this material is composed of a laminated paperboard core treated for water resistance, over which aluminum foil facings are applied. Panels are available in 4- by 8-foot and 4- by 9-foot sizes. Some are produced in 48¾-inch widths for

overlapping. Thickness is commonly slightly less than ¼ inch. When panels are nailed in accordance with the manufacturers' recommendations, corner bracing may be eliminated.

**Gypsum wallboard.** This sheathing is composed of treated gypsum filler faced on two sides with water-resistant paper. Panels are ½ inch thick, and are either 2 by 8 feet in size for horizontal application, or 4 by 8 feet or 4 by 9 feet for vertical application. The 2- by 8-foot size either has one edge grooved and the other with a matched V-edge, or has square-edged sides. The 4- by 8-foot and 4- by 9-foot sizes have square edges only. If panels are properly nailed, corner bracing is not required.

**Rigid foam plastic.** This sheathing consists of polystyrene, urethane, isocyanurate, or phenolic foam panels, in some instances faced with aluminum foil, aluminum foil laminated kraft paper, or polyethylene sheet on one or both sides. These materials, with thermal resistance (R)

**Figure 60** – Nail-only plywood open box header for spans up to 8 feet (plywood on exterior side).



values ranging from less than R-4 to over R-8 per inch of material thickness, are used primarily to enhance the total thermal resistance values of wall construction. All are nonstructural; that is, some form of wall corner bracing is required. Panels for wall sheathing are usually produced in thicknesses from  $\frac{3}{8}$  inch to 1 inch and in panel sizes of 2 by 8 feet, 4 by 8 feet, 4 by 9 feet, or longer.

### **Comer bracing**

Comer bracing provides rigidity to the structure, and resistance to the racking forces of wind or earthquakes. External comers of houses should be braced when the type of sheathing used does not provide the bracing required.

Comer bracing materials include structural sheathing panels, 1- by 4-inch boards, or patented light-gauge steel comer braces available in several configurations. Structural sheathing bracing consists of panels of  $\frac{1}{2}$ -inch plywood or structural flakeboard applied vertically at the comers. When 1- by 4-inch boards are used, they should be let in to the outside face of the studs and set at a 45° angle from the bottom of the sole plate to the top of the wall plate or comer stud (fig. 53). Where window openings near the comer interfere with 45° braces, the angle can be increased, but the full length of the brace should cover at least three stud spaces.

### **Installation of sheathing**

Plywood and reconstituted wood panel materials should be 4 by 8 feet or longer, and should be applied vertically with perimeter nailing to eliminate the need for comer bracing. Sixpenny nails or narrow crown staples  $1\frac{5}{8}$  inches long are used for plywood ranging from  $\frac{5}{16}$  inch through  $\frac{1}{2}$  inch in thickness. Spacing of the fasteners should be 6 inches at all edges and 12 inches at intermediate framing members.

These sheathing materials may also be applied horizontally, but this orientation somewhat reduces rigidity and strength. When it is done, some codes require blocking between studs for horizontal edge nailing to improve rigidity and eliminate the need for bracing. Edge spacing of  $\frac{1}{8}$  inch and end spacing of  $\frac{1}{16}$  inch should be maintained between panel sheets.

If this type of sheathing is installed only at comers to eliminate let-in wood bracing,  $\frac{1}{2}$ -inch thickness should be used. The panels should be nailed with  $1\frac{1}{2}$ -inch galvanized roofing nails spaced 4 inches on center along panel edges, and 8 inches on center at intermediate supports.

Minimum thickness of wood boards for sheathing is generally  $\frac{3}{4}$  inch, and widths are usually 6, 8, and 10 inches. Sheathing boards should be nailed at each stud crossing, with two nails for the 6-inch and 8-inch widths and three nails for the 10-inch and 12-inch widths.

Board sheathing is commonly applied horizontally because it is easy to apply in this fashion and because less lumber is wasted than in the diagonal pattern. Horizontal sheathing, however, requires diagonal corner bracing for wall framework. Diagonal wood sheathing should be applied at a  $45^\circ$  angle. This method of sheathing adds greatly to the rigidity of the wall and eliminates the need for corner bracing. When diagonal sheathing is used, one more nail can be used at each stud; for example, three nails for 8-inch sheathing. Joints should be placed over the center of studs.

Vertical application of structural insulating board in 4- by 8-foot sheets is usually recommended by manufacturers. When so specified by local building regulations, spacing nails 3 inches on edges and 6 inches at intermediate framing members can eliminate the requirement for corner bracing when  $\frac{1}{2}$ -inch medium density or nail-base structural insulating board sheathing is used. Galvanized roofing nails  $1\frac{1}{2}$  inches long or wide crown staples  $1\frac{3}{8}$  inches long should be used to attach the boards to the framing. Manufacturers usually recommend  $\frac{1}{8}$ -inch spacing between sheets to allow the sheathing panel to expand without buckling. Joints should be centered on framing members.

Structural grades of foil-faced laminated paperboard sheathing should be applied vertically on the framing in 4- by 8-foot or longer sheets. Manufacturer's recommendations generally specify the use of galvanized roofing nails  $1\frac{1}{4}$  inches long spaced at 3 inches on center around panel edges, and 6 inches on center on all intermediate members, for 16-inch stud spacing. Some manufacturers supply a heavier grade of sheathing for 24-inch stud spacing, with a similar nailing schedule. Corner bracing is not needed when these materials are fastened in accordance with the manufacturer's instructions.

Gypsum sheathing is generally  $\frac{1}{2}$  inch thick. It should be applied horizontally; vertical joints should be staggered. Sheathing in 2- by 8-foot sheets should be nailed to the framing with  $1\frac{1}{2}$ -inch galvanized roofing nails spaced about  $3\frac{1}{2}$  inches apart to produce seven nails in the 2-foot height. This eliminates the need for corner bracing. If corner bracing is used, the nail spacing can be increased to 8 inches on center. With 4- by 8-foot or 4- by 9-foot sheets,  $1\frac{1}{2}$ -inch galvanized roofing nails should be used, spaced 4 inches on center around the edges and 7 inches on center along intermediate members.

### ***Sheathing paper***

Sheathing paper may be applied over the sheathing material. The sheathing paper should have a "perm" value of 6.0 or more, allowing the movement of water vapor but resisting the entry of water in liquid form and aiding in the control of air infiltration. Fifteen-pound asphalt felt paper is a satisfactory material.

Ordinarily, sheathing paper is not used over plywood, fiberboard, or other water-resistant material, except for 8-inch or wider strips applied around window and door openings to minimize air infiltration.

Wood board sheathing must be covered with sheathing paper.

When the house is to be covered by a stucco or masonry veneer, a sheathing paper should be installed regardless of the sheathing material used.

Sheathing paper should be installed horizontally, starting at the bottom of the wall. Succeeding layers should lap about 4 inches.

### ***Air infiltration barrier materials***

Air infiltration barrier sheet materials may consist of any of a variety of products, ranging from nonwoven fabrics to perforated plastic membranes. These materials are resistant to the passage of moving air but allow water vapor to escape. They can be used in all parts of the country, but are particularly effective in cold and/or windy climates. They are usually supplied in roll form in widths of 4 or 8 feet. Installation instructions are supplied by the manufacturer.

### ***Ceiling and Roof Framing***

Roof frames provide structural members to which roofing, vents, and materials to finish the ceiling may be attached and within which insulation materials may be placed. Pitching of roof surfaces creates storage space and living space that costs less than main floor space, because no additional foundation is required and because roof costs do not increase proportionately with the increase in living space.

### ***Roof designs***

Roofs sometimes use one structural member as both ceiling and roofing support, for example, flat roofs and shed roofs that have the same angle of roof and ceiling. The most common roof configuration, however, is an isosceles triangle. Rafters or top chords of trusses form equal-length sloping sides to which roofing materials are attached. Ceiling joists or bottom truss chords form the horizontal base to which ceiling materials are fastened.

In a single-member roof, support must be provided at both ends by walls or beams. In the triangular roof, the ceiling joists require intermediate bearing support within the house but the roof rafters usually do not. Since their weight and the weight they support is all transferred to the bottom, the rafters tend to push out at the bottom and fall in the center where they meet. They are restrained from doing so by the ceiling joists, which are placed in tension and consequently must be securely fastened to the rafters and to each other where spliced.

Most species of softwood framing lumber are acceptable for roof framing, subject to maximum allowable spans for the particular species, grade, and use. Because species vary in strength, the cross-sectional dimensions for a given span, determined from the designs for a given span, must be larger for weaker species. All framing lumber should be well seasoned (dried). Lumber 2 inches thick and less should have a maximum moisture content not over 19 percent, 15 percent being more desirable.

Most frequently, roofs are built with triangular trusses in which the three sides of the triangle are fastened together with steel plates and reinforced with interior web members. Wood trusses can span up to 50 feet, and they are designed to require support only at the two ends of the base or bottom chord.

The slope of a roof is generally expressed as the number of inches of vertical rise in 12 inches of horizontal run. The rise is given first: for example, 4 in 12 or 4/12 pitch.

The architectural style of a house often determines the type of roof and roof slope, a contemporary design having a flat or slightly pitched roof, a rambler or ranch style having an intermediate slope, and a Cape Cod cottage having a steep slope.

In deciding roof slope, another consideration is the type of roofing desired. For example, a built-up roof is permitted on flat roofs or slopes up to 2 in 12, depending on the type of asphalt or coal-tar pitch and aggregate surfacing materials used. Rolled roofing can be used on pitches of 1 in 12 or steeper. Wood or asphalt shingles are permitted on 4 in 12 pitches or steeper.

The most popular roof style is the gable roof, a triangular roof system in which the triangles are terminated at the ends of the house by triangular end walls called gables, which close in the attic space. Next most common is the hip roof—another triangular roof in which the ends of the attic space are enclosed by sloping triangular roof sections set at right angles to the main roof planes and equal to them in pitch. Cape Cod and saltbox styles use large second-floor shed dormers on the back and, often, eye dormers on the front to expand the attic space, admit light, and improve ventilation. Mansard, gambrel, and

A-frame roofs use one frame member for both walls and roof. Post and beam, shed roofs, and flat roofs use one member to support both ceiling finishes and roofing.

Overhangs from any roof can be used to protect windows and siding from falling rain and to shade windows from the sun. Properly sized overhangs allow sun to penetrate south-facing windows in winter, when solar heat is desired, but not in the summer, when the sun is at a higher angle in the sky.

### ***Manufactured wood rooftrusses***

After exterior walls are plumbed and braced, manufactured wood roof trusses, when used, are normally placed across the width of the house and nailed to the top plates.

The roof truss is a rigid framework of triangular shapes which replaces rafters and ceiling joists. Roof sheathing is fastened to the top of the truss and gypsum wallboard or other ceiling finish is fastened to the bottom. The truss is capable of supporting roof and ceiling loads over long spans without intermediate support. For house construction, the typical roof truss spans from 24 to 40 feet but roof trusses are manufactured to span from 12 to 50 feet or more.

Trusses use less material than equivalent rafter plus ceiling joist systems. Trusses erected by crane require much less labor than other roof framing and permit the house to be enclosed in a shorter time. Because no interior bearing walls are required, the entire house becomes one large workroom. Trusses also allow greater flexibility for interior planning because partitions can be placed without regard to structural requirements.

**Design and fabrication.** Trusses should be professionally engineered. Truss designs are based on (a) analysis of the probable loadings of snow, wind, and roof and ceiling materials; (b) the span over which the loads are to be carried; (c) the shape of the truss; (d) the location of bearing points; and (e) the connectors used in joining the members. Assistance in truss design is available from truss dealers and fabricators.

Most trusses are available with horizontal blocks called returns extending from the outer end of the overhang to the exterior of the wall to which soffit materials are fastened.

Trusses are normally specified by span, pitch, spacing (normally 24 in on center), style, length of overhang, special loadings other than plywood roof sheathing, shingles, and ½-inch gypsum wallboard, and the quantities of trusses and gable trusses. The number of trusses required for a gable-roof house with the trusses installed on a 24-inch spacing equals the house length divided by two,

rounded up, minus one. A gable end truss is required for each end of the roof. For example, a gable house 51 feet long requires 25 trusses plus 2 gable trusses.

**Types of trusses.** Local prices, span, and design load requirements for snow, wind, and other conditions determine the best type of truss to use.

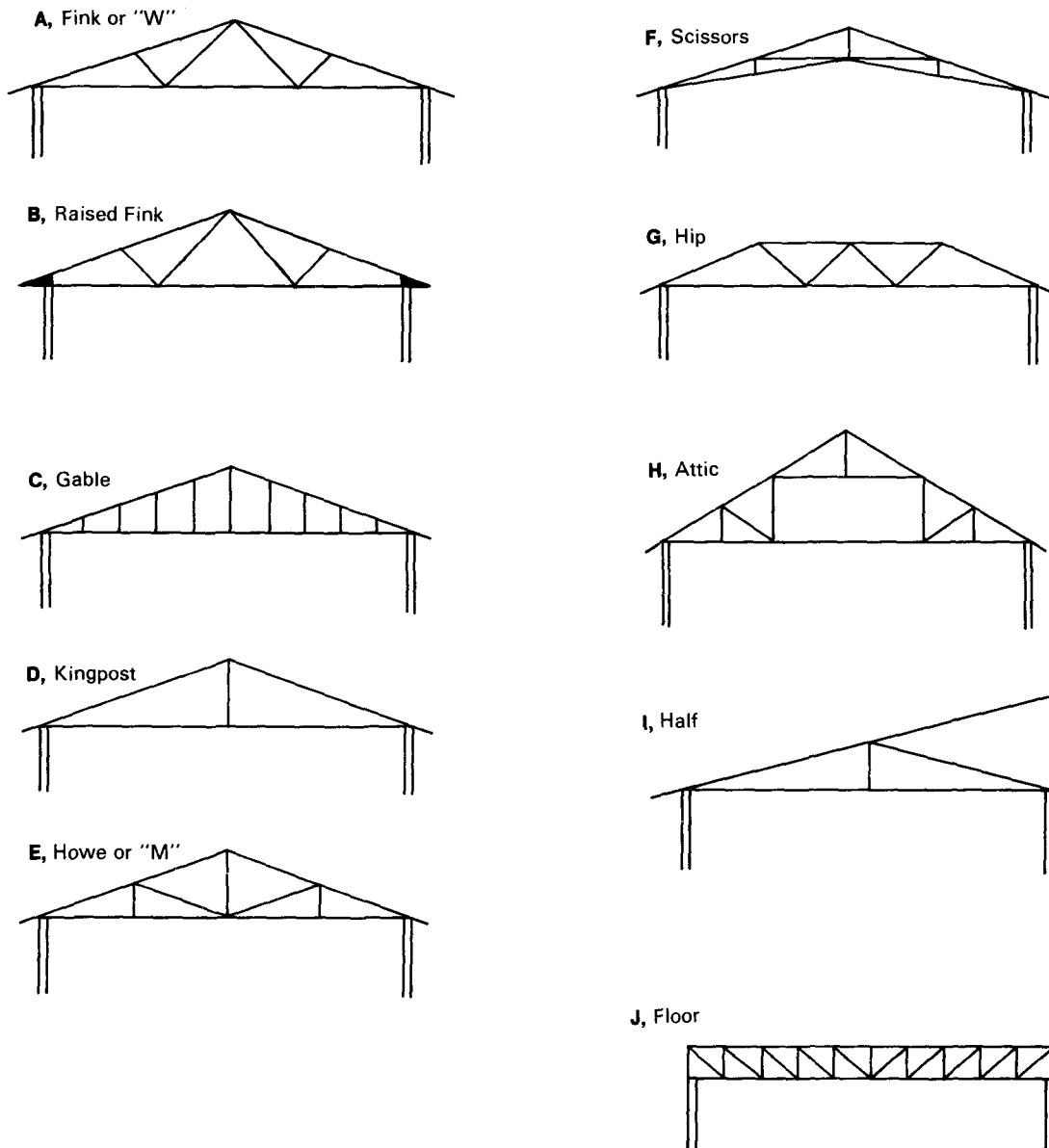
The wood trusses used most commonly for houses are the Fink truss (web members form a W), the raised Fink, the gable, the kingpost (one vertical web member), the Howe (web members form an M), the scissors (sloping bottom chords provide a vaulted ceiling), the hip (flat top), the attic (enclosing a rectangle of wall studs, bottom

chord, and ceiling joist), and the floor truss (horizontal top and bottom chords). The general shapes of these common truss are shown in figure 61.

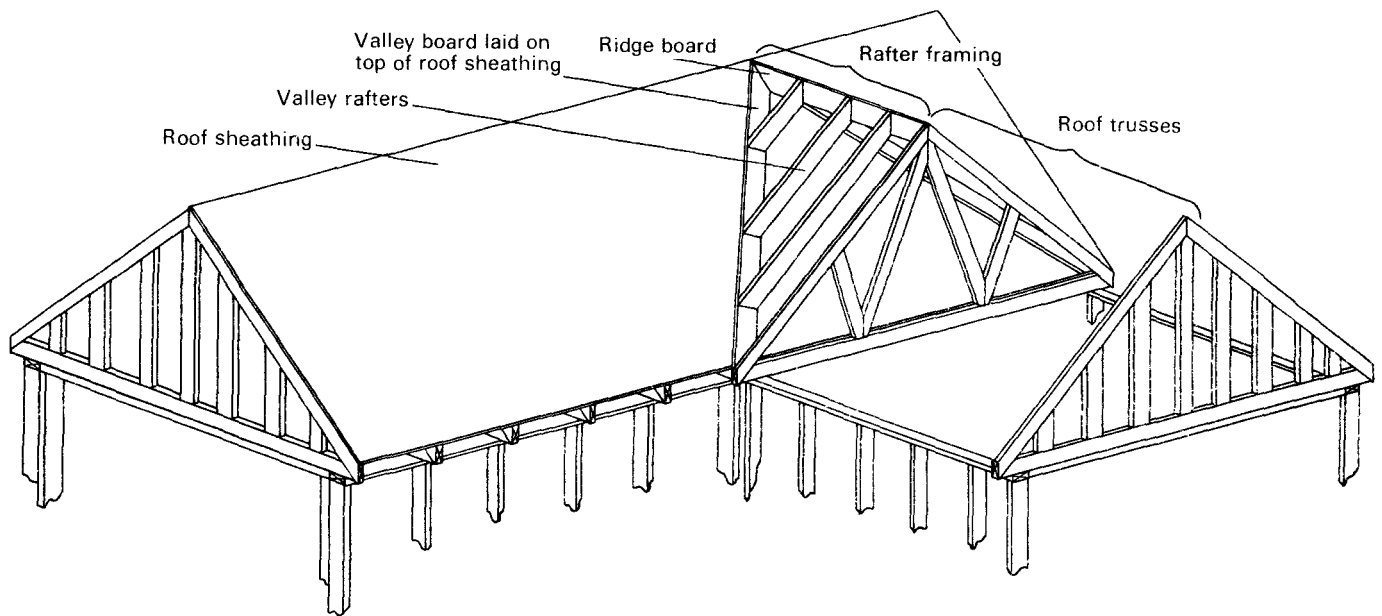
On L-shaped houses, trusses are used on most of the roof. A small portion of the roof joining the ridges and forming two valleys is completed by framing rafters on top of the trusses (fig. 62).

Trusses are commonly designed for 2-foot spacing. Three 12d common nails are used to fasten the bottom truss chord to each top wall plate. Plywood or waferboard sheathing  $\frac{3}{8}$  inch or  $\frac{1}{2}$  inch thick is nailed or stapled to the top with H-clip supports between the trusses on the sheathing edges.

**Figure 61**—Common truss designs.



**Figure 62** – Rafter framing joining perpendicular truss roof segments.



**Fink truss.** The Fink or W-type truss (fig. 61A) is perhaps the most popular and extensively used of the light wood trusses. Two web members extending from the peak divide the bottom chord into three equal segments. From these points, web members return to the top chords, dividing them in half. The spans on the top chord are thus reduced, increasing their strength and stiffness and allowing them to be built of smaller size and/or lower grade lumber.

**Raised Fink or cantilevered truss.** The raised Fink or cantilevered truss (fig. 61B) is a Fink truss in which the bottom chord cantilevers over the outside house walls and extends to the outer edge of the overhang. The weight of the roof is transferred to the walls by triangular heel wedges or compression blocks. This type of truss raises the height of the top chord where it passes over the outside wall. This permits a full thickness of ceiling insulation to be installed to the extreme outer edge of the exterior walls and allows additional vertical space for air to pass from soffit vents into the attic.

**Gable truss.** Gable trusses (fig. 61C) have flat, vertical members 16 inches or 24 inches apart to which sheathing and siding are attached. Having no triangular pattern of members, gable trusses are not as strong as other trusses and, if required to carry a load over a span, must be professionally engineered. Normally, gable trusses are supported over their entire length by an exterior wall.

**Kingpost truss.** The kingpost (fig. 61D), the simplest form of truss used for houses, is composed only of top

and bottom chords and one center vertical web member or post. Lumber sizes must be greater and/or grades must be higher than those in the Fink (W-type) truss, since the span of the top chord is not broken by a web member, and the bottom chord span is divided into two spans rather than three.

For short and medium spans, the kingpost truss is probably more economical than other types because it has fewer pieces and can be more easily fabricated.

**Howe truss.** The Howe or M-type truss (fig. 61E) is a kingpost truss with additional web members starting at the bottom of the vertical center member, dividing the top chord, and returning vertically to the bottom chord. The Howe truss design divides the bottom chord into four equal segments. Assuming lumber of equal size and grade, the Howe truss can carry a heavier ceiling load than the Fink truss design, which supports the bottom chord in two places instead of three.

**Scissors truss.** The scissors truss (fig. 61F) provides a sloping interior ceiling without the need for center bearing for rafters on walls or ridge beams and posts. The top chords of the scissors truss are normally two or three pitches steeper than the bottom chords.

**Hip truss.** Hip trusses (fig. 61G) provide an easy way to construct a hip roof, which normally requires rafters of many different lengths with compound angle cuts. Hip trusses are trapezoids with equal pitch sides sloping up to flat tops.

Each hip roof requires a set of trusses ranging from a tall truss with a small flat top and long sloping sides to a short truss with a long flat top and short sloping sides. To complete the framing, short overhang rafters spaced 2 feet on center are extended at a right angle from the lowest truss over the end wall to the outer edge of the overhang.

**Attic truss.** The attic truss (fig. 61H) is a steep-pitch truss designed to create second-story living or storage space. The bottom chord is normally a 2- by 8-inch or 2- by 10-inch floor joist which must usually be supported by a wall or beam near the center. Vertical studs run from the bottom chord to the sloping top chords, and a horizontal “ceiling joist” is positioned at a right angle to the top of the studs.

The attic truss is sometimes too high for highway transportation. The top triangle of the truss is therefore sometimes made separately to reduce the truss height for shipment.

**Half truss.** The half truss (fig. 61I) is a right triangle with the hypotenuse serving as the roof slope. It is frequently used in shed roof architecture.

**Floor truss.** Floor trusses (fig. 61J) can be used for flat, slightly sloped roofs. These trusses have horizontal top and bottom chords and diagonal and vertical web members. The trusses are usually a minimum of 16 inches high. Some floor trusses are designed to provide space for ductwork.

**Handling trusses.** Unusual stresses should not be placed on completed trusses during handling and storage. They are designed to carry roof loads in a vertical position, and should be lifted and stored in an upright position. If they must be handled flat, enough workers or supports should be used to minimize lateral bending. When in a flat position, trusses should never be supported only at the center, or only at each end.

**Truss erection.** Five workers can install house trusses under 30 feet in length and up to 6 in 12 pitch. One sits on each wall to nail the trusses to the walls; another works at the center of the truss, standing on the bottom chord, to nail the top of the truss to a temporary 2- by 4-inch ridge brace on exact 2-foot centers; and the remaining members carry and hand the trusses up. With a crane, one less crew member is required on the ground.

The tops of the side walls and the temporary 2- by 4-inch ridge brace are marked on 2-foot centers. A gable truss is then set on top of the end wall, securely fastened to the wall on which it rests, and braced to the ground (fig. 63, step 1). Because all other trusses are to be fastened to this gable truss by means of the ridge brace, gable bracing must be firm.

A 2- by 4-inch block is nailed in a horizontal position close to the top of the wall at the opposite end of the house from the gable truss. This block should extend out the precise width of, and at the exact height of, the planned roof overhang. A line is then strung the full length of the house between the end of this block and the end of the gable truss. Some builders set both gables first and string the line between the ends of their overhangs. Half-inch blocks are placed behind this string. Each truss, when it is installed, is brought to within ½ inch of the string, using a ¾-inch gauge block. The gauge block is used to prevent the trusses from pushing out on the string.

Next, a truss is slid horizontally over the top of the house wall and placed on the house, with the ends resting on the walls and the point facing down within the house (fig. 63, step 2). The truss is tipped up, using a long 2 by 4 piece with a short 2 by 4 piece nailed on the end to form a “Y.” The truss is positioned on the 2-foot markings located on the wall and on the temporary 2 by 4 ridge brace; brought to the proper distance from the overhang guide string; nailed to the wall top plate with three 12d nails; and nailed to the temporary 2 by 4 ridge brace with one 10d duplex nail (fig. 63, step 3).

After six or seven trusses are erected, a temporary diagonal brace should be installed on top of the trusses running from the bottom of the gable truss to the top of the last truss on both sides of the house. This brace is then nailed into every truss with duplex nails. Temporary braces can prevent sudden gusts of wind from knocking down the trusses. These temporary braces should be removed in calm air, just before they are replaced with permanent braces and sheathing.

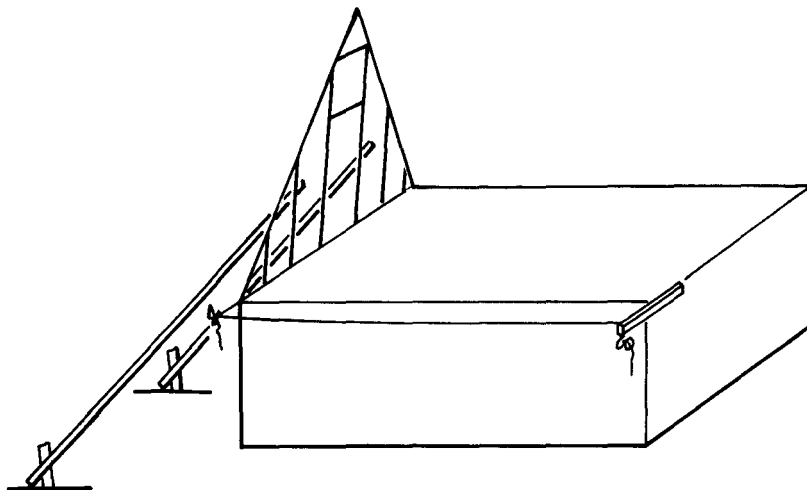
Trusses should be provided with permanent bracing according to the manufacturer’s instructions. Diagonal braces are frequently placed at a 45° angle from the top of the gables to a bottom truss chord. In addition, continuous braces running the full length of the house are often required on top of the bottom chords beside the web members and, on larger trusses, halfway up the web members.

In hurricane zones, twisted steel tiedown straps are recommended to secure the truss more firmly to the wall. These straps extend from the side of each truss to the face of the stud.

L-shaped houses have a wing attached perpendicular to the main house. Roof trusses are erected and sheathing installed on the main portion of the house. The roof trusses are then erected and the sheathing installed on the wing portion of the house. The two perpendicular rooflines are connected with rafter framing as shown in figure 62. A 2- by 8-inch ridge board is installed between the peak of the roof trusses on the wing and the peak of the roof trusses on the main house. Valley boards of

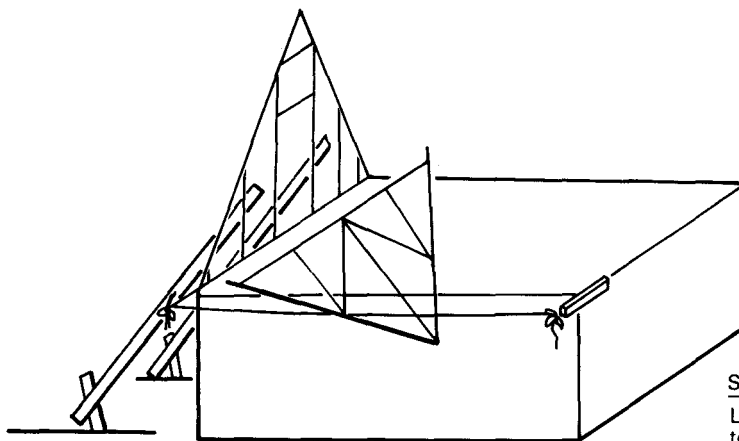
**Figure 63 – Erection of roof trusses.**

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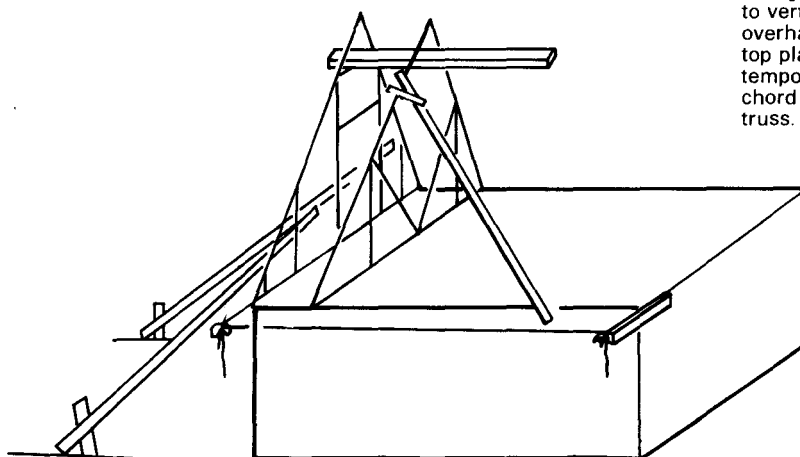
**Step 1**

Erect gable truss vertically and with correct overhang. Nail bottom chord to top plate of wall. Install braces to the ground. Install overhang guide block at opposite end of side wall and install guide string.



**Step 2**

Lift roof truss into position with top pointing down.



**Step 3**

Using 2 x 4 pole, tilt roof truss to vertical, adjust spacing and overhang, nail bottom chord to top plates of wall, nail 2 x 4 temporary ridge brace to top chord of gable truss and roof truss.

2- by 8-inch lumber are installed on top of the main house roof sheathing between the ridge board and the outer ends of the roof trusses on the house wing. Valley rafters of 2- by 6-inch lumber are installed on 16-inch centers between the ridge board and the valley boards. Roof sheathing is then applied on top of the rafter framing.

The ends of the main house roof trusses must be supported where the wing joins the main house. This support can be provided by an interior load-bearing wall. An alternative is to install a doubled or tripled roof truss on the wing at the exterior wall line of the main house. These trusses should be bolted together, and the main house roof trusses connected to and supported by their bottom chords with the aid of metal joist hangers. A truss manufacturer can provide the engineering necessary to determine the proper design of this configuration.

### *Ceiling joists and rafters*

Roofs can be framed on site using rafters and ceiling joists in lieu of manufactured trusses. This is usually more expensive and time-consuming than using prebuilt trusses.

**Ceiling joists.** Ceiling joists serve the same purpose as the bottom chords of a truss. They support ceiling finishes and serve as tension members to prevent the bottom of the roof rafters and tops of the walls from spreading outward. Ceiling joists often act as floor joists for second-story or attic floors, and as ties between exterior walls and interior partitions.

Ceilings can be framed on site from 2- by 6-inch or 2- by 8-inch lumber resting on exterior and interior walls. After the walls are plumbed and braced and the top plates added, ceiling joists are positioned and nailed into place. They are placed across the width of the house as are the rafters.

When possible, partitions should be located so that ceiling joists of even lengths such as 12, 14, 16 feet, or longer can be used without waste to span from exterior walls to load-bearing interior walls. Joist sizes depend on span, wood species, spacing between joists, and the load they are designed to support. Correct sizes for various conditions are designated by joist tables or local building code requirements.

Because ceiling joists serve as tension members to resist the thrust of the rafters on triangular roofs, they must be securely nailed to the plate at outer and inner walls. They are also nailed together, directly or with wood or metal cleats, where they lap or join at the interior load-bearing partition (fig. 64A) and to the rafter at the exterior walls (fig. 64B).

In areas of severe winds, it is good practice to use metal strapping or other systems of anchoring ceiling and roof framing to the wall.

The in-line joist system described in the section on floor framing can be adapted to ceiling or second-floor joists.

**Flush ceiling joist framing.** In many house designs, the living room and the dining or family room form an open L. A wide, continuous ceiling area between the two rooms is often desirable. This can be created with a flush beam that replaces the load-bearing partitions used in the remainder of the house. The ends of the joists are supported by nail-laminated built-up beams to carry the ceiling load. Joists are toenailed into the beam and further supported by metal joist hangers (fig. 65A) or 2- by 2-inch wood ledgers (fig. 65B).

**Gable roofs.** The simplest form of triangular roof is the gable roof. The end walls of the house have triangular tops, or gables, which close off the ends of the roof structure and attic space (fig. 66A). All rafters are cut to the same length and pattern. Each pair of rafters is fastened at the top to a ridge board. The ridge board, usually a 1- by 8-inch member for 2- by 6-inch rafters, provides support and a nailing area for the rafter ends.

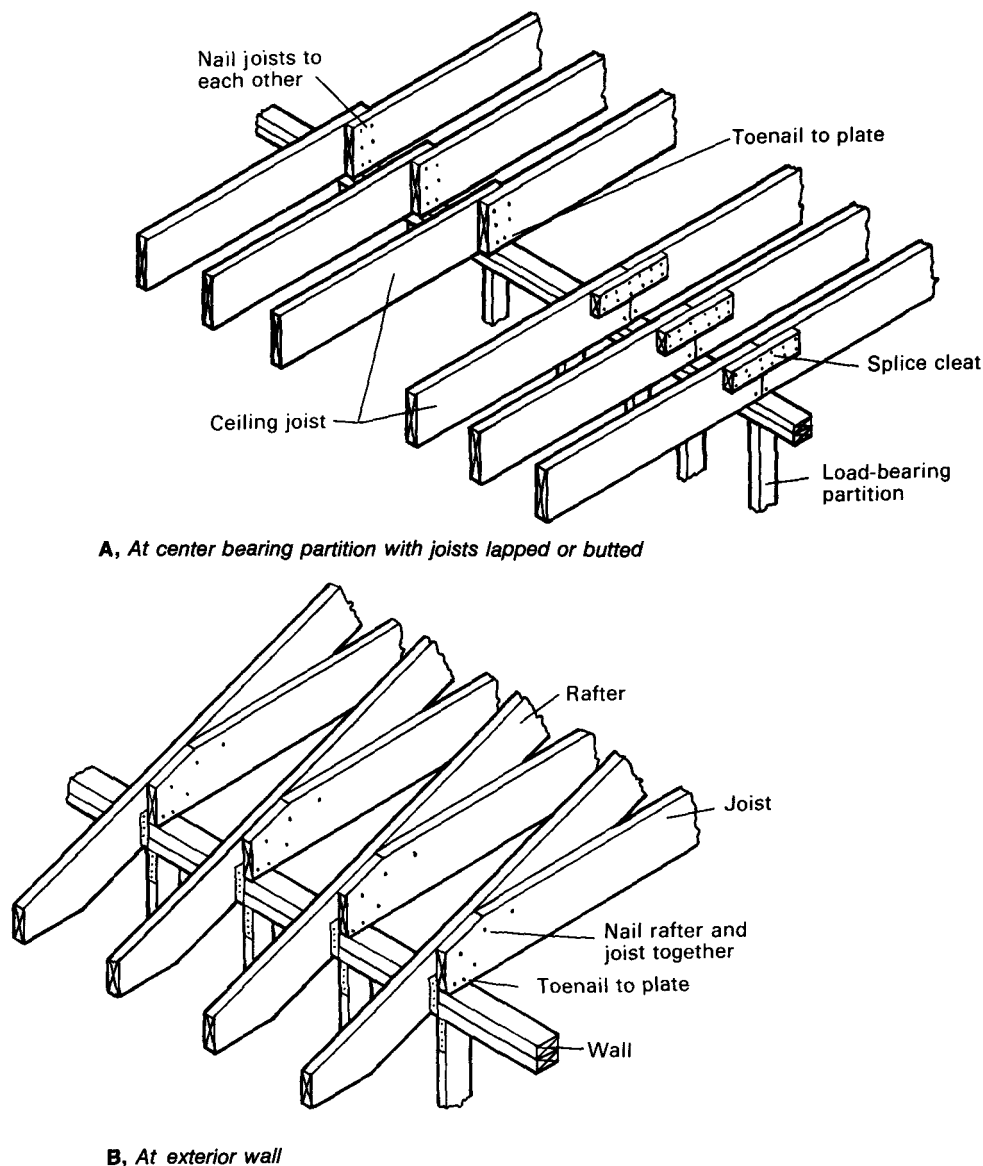
**Rafters.** In pitched roof construction, the ceiling joists are nailed in place after the interior and the exterior wall framing are complete. Rafters should not be erected until ceiling joists are fastened in place, because the outward thrust of the rafters may push out the exterior walls.

Rafters are usually precut to length, with the proper angles cut at the ridge and eave and with notches cut to rest on the top plates of the exterior walls (fig. 67). Rafters are erected in pairs. Studs for gable end walls are notched to fit under and past the end rafter, and are nailed to the end rafter and the top plate of the end wall (fig. 67).

When roof spans are long and slopes are flat, it is common practice to use collar beams between opposing rafters. Steeper slopes and shorter spans may also require collar beams, but only between every third pair of rafters. Collar beams can be 1- by 6-inch material. In 1½-story houses, 2- by 4-inch or larger collar beams are used at each pair of rafters, and serve also as ceiling joists for the upper story finished rooms.

**Overhang rafters.** With a gable (rake) overhang, an overhang or fly rafter is used beyond the end rafter and is fastened to the overhang blocking and to the sheathing. Additional construction details applicable to roof framing are given in the section on exterior trim.

Figure 64 – Ceiling joist connections:



**Valley rafters.** A valley is the internal angle formed by the juncture of the two sloping planes of perpendicular roof sections. The key member in valley construction is termed the valley rafter. In the intersection of two equal-size roof sections, the valley rafter is doubled (fig. 68) to carry the roof load, and is 2 inches deeper than the other rafter members to provide full contact with jack rafters. Jack rafters are nailed to the ridge board and toenailed to the valley rafter with three 10d nails.

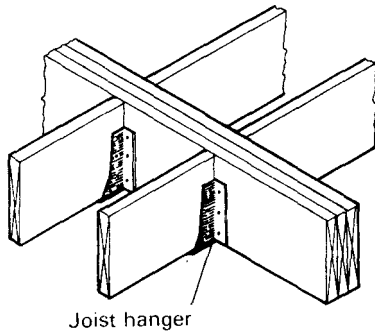
**Hip roof.** The hip roof (fig. 66C) has no gable end. Center rafters are tied to the ridge board, and hip rafters (fig. 69) supply support for the shorter jack rafters. Cornice lines are carried around the entire perimeter of the building. Hip roofs are framed in the same fashion as a gable roof at the center section of a rectangular house.

The ends are framed with hip rafters which extend from each outside corner of the wall to the ridge board at a 45° angle. Jack rafters extend from the top plates to the hip rafters (fig. 69).

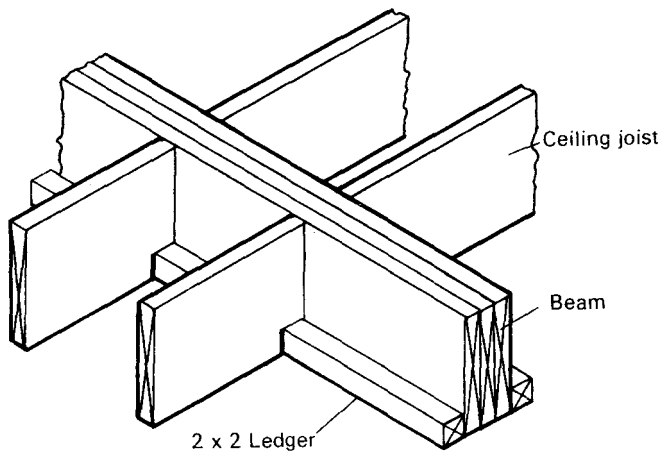
**Cape Cod and saltbox.** A variation of the gable roof, used for Cape Cod or saltbox house styles, includes the use of shed and gable dormers (see fig. 66B). The ridge-line on the Cape Cod is in the center of the roof; on the saltbox the ridgeline is off center. Both are 1½-story houses with about half as much living space upstairs as down. Second-floor space and light are provided by shed or gable dormers for bedrooms and bath. Roof slopes for this style may vary from 9 in 12 to 12 in 12 to provide the needed upper story headroom.

**Figure 65 – Framing of flush ceiling beam:**

**A, Joists attached with metal joist hangers**



**B, Joists bearing on 2- by 2-inch ledger**



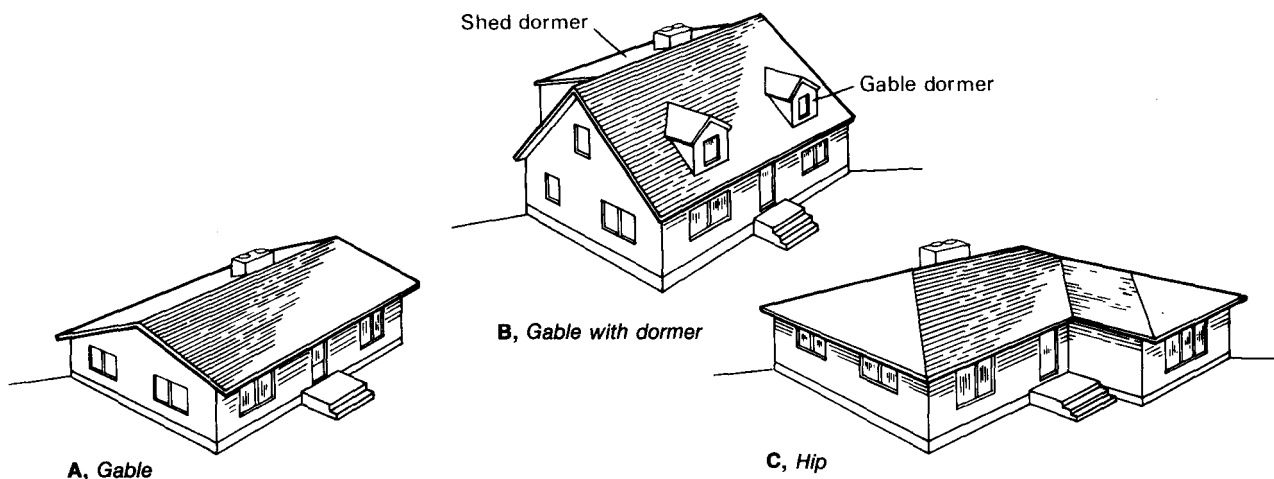
**Gable dormers.** In construction of small gable (eye) dormers, the rafters at each side of the dormer opening are doubled. The side studs and the short valley rafter rest on these members (fig. 70). Side studs can be carried past the rafters to bear on a bottom plate nailed to the floor framing and subfloor. This type of framing can be used for the side walls of shed dormers. The valley rafter is also tied to the roof framing at the roofline by a header. Methods of fastening at top plates conform to those previously described. Where future expansion is contemplated or where additional rooms may be built in an attic, consideration should be given to framing and enclosing such dormers when the house is built.

**Joistless post and beam framing.** Sloping ceilings are often used in contemporary interior design. These can be constructed with scissors trusses, or with single-member framing in which the ends of rafters bear on walls or beams at different elevations (fig. 71).

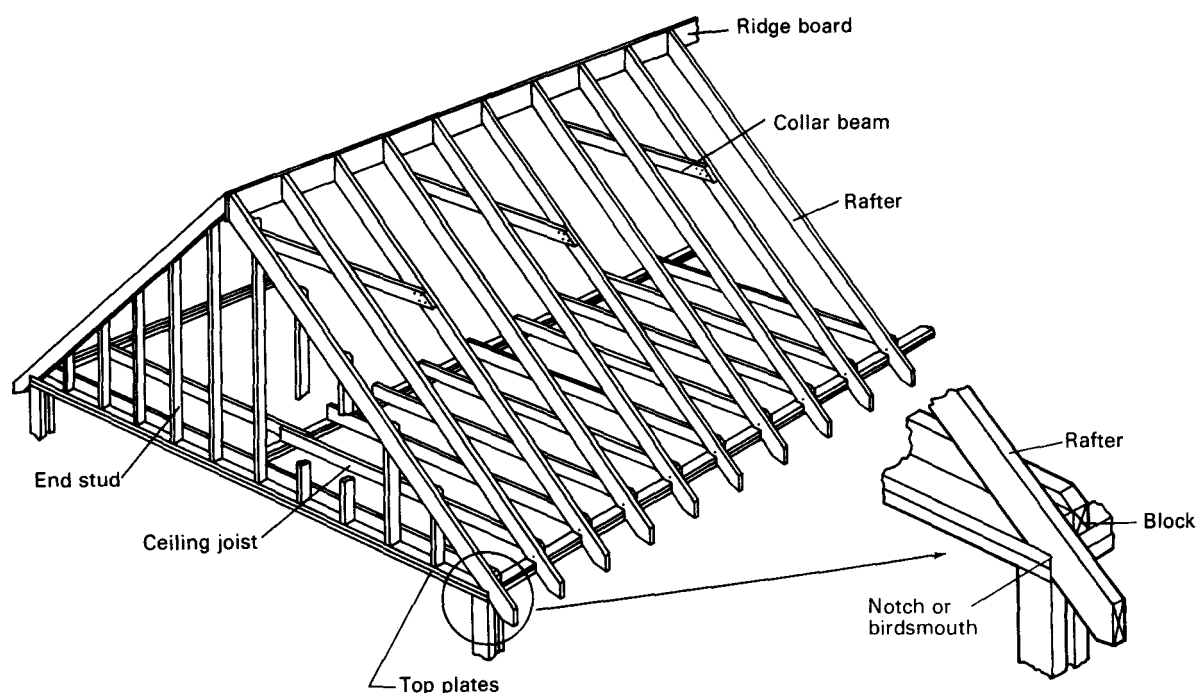
By replacing interior load-bearing partitions with beams bearing on posts, larger rooms can be formed. The combination of vaulted ceilings and fewer interior walls increases the feeling of spaciousness. Enough interior shear walls must be used, however, to provide sufficient racking strength.

The beams can be made of 4- by 8-inch, 4- by 10-inch, or 4- by 12-inch solid timbers; 2-inch boards nailed together; or, on long spans, plywood box construction, glue-laminated wood, or steel. Post size is usually 4 by 4 inches. Unusually long posts or those carrying unusually heavy loads may need to be 6 by 6 inches or larger. Post and beam sizes, grades, and configurations should be professionally determined.

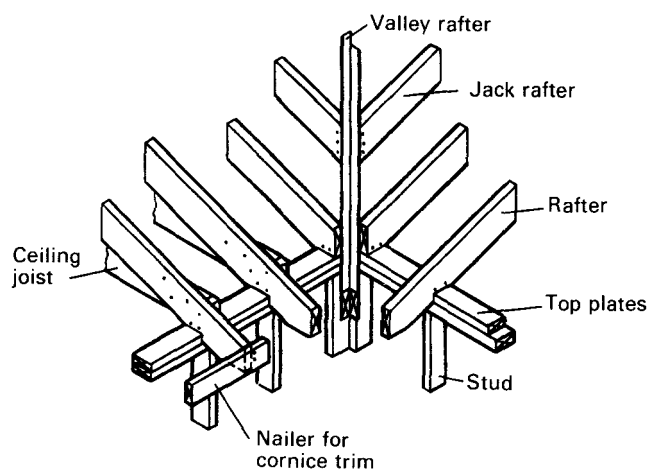
**Figure 66 —Pitched roof types:**



**Figure 67** – Typical rafter framing for pitched roof.



**Figure 68** – Framing at valley in rafter roof.



Frequently, one end of the rafter bears on exterior walls and the other end bears on a ridge beam. Sometimes intermediate beams are also used. There is no need for horizontal ties because the rafters are supported on both ends and the weight from the roof is carried to beams and posts in the center of the house as well as to the outside walls. Ceiling joists and collar ties can be eliminated.

Exposed 4- by 6-inch or 4- by 8-inch rafters may be installed on a 32-inch or 48-inch spacing. Decking of 2-

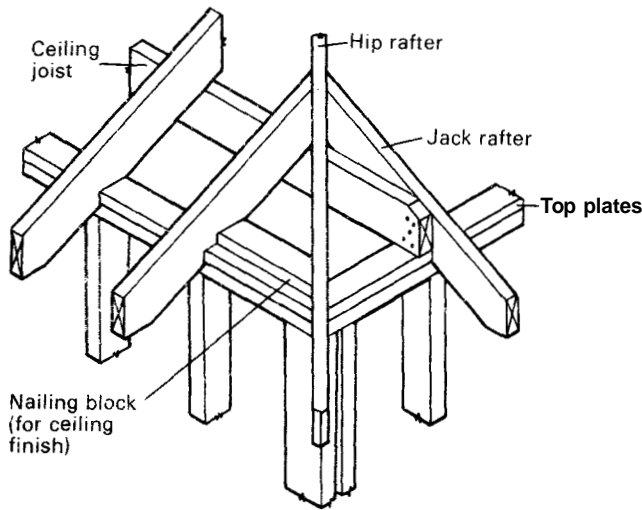
by 6-inch tongue-and-groove material is frequently used to span from joist to joist, wall to beam, or beam to beam. This decking serves both as structural sheathing and as interior ceiling finish material. Rigid foam insulation can be placed on top of the decking and covered with shingles fastened with long nails.

In other cases, rafters are concealed. Insulation is placed between them with a minimum 1-inch ventilation space between the top of the insulation and the underside of the roof sheathing. This should be combined with continuous soffit and ridge venting. Rigid foam insulation can be nailed to the bottom of the rafters with the finish ceiling material installed below the insulation following code or manufacturer's recommendations (fig. 72).

**Flat roofs.** Flat or low-pitched roofs, sometimes known as shed roofs, can take a number of forms (fig. 73). Low-pitched roofs require larger members than steeper pitched roofs because they carry both roof and ceiling loads. In constructing flat roofs a major concern is the increased likelihood of roof leaks.

Roof joists for flat roofs are laid level or with a slight pitch. Roof sheathing and roofing are placed on top, and the underside supports the ceiling. A slight slope for roof drainage can be provided by tapering the joist or adding a cant strip to the top.

**Figure 69** – Framing at corner of hip rafter roof.



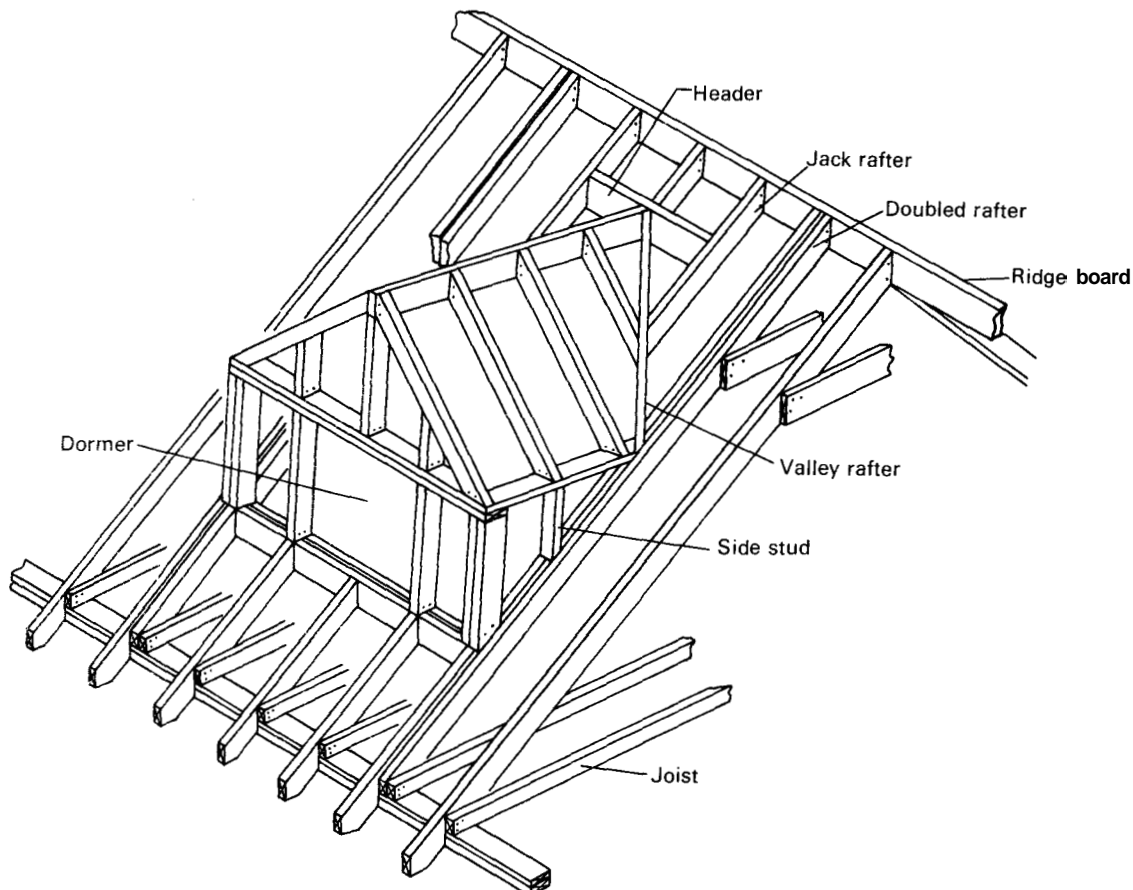
Flat roof design usually includes an overhang of the roof beyond the wall. Insulation is installed with an air-way directly under the roof sheathing to minimize condensation problems in winter.

When solid wood decking on beams is used, the beams eliminate the need for joists. Roof decking used between beams serves as supporting members, interior finish, and roof sheathing. It also provides a moderate amount of insulation (about R-2 for 1½-inch-thick decking). In cold climates, rigid insulating materials are used over the decking to reduce heat loss further.

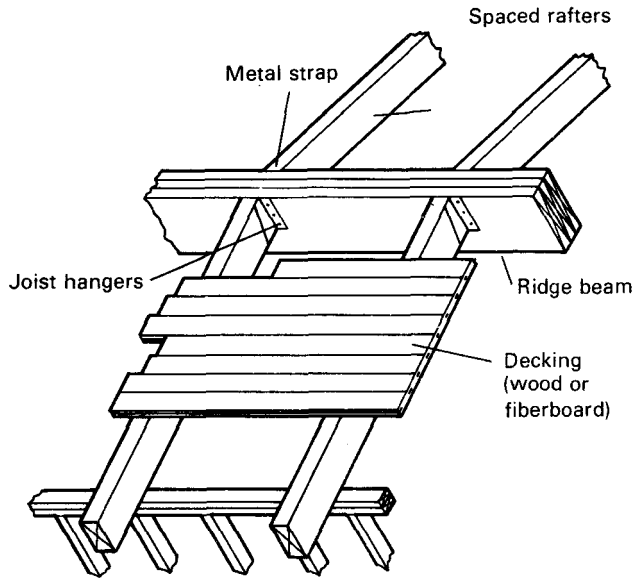
When flat roofs have an overhang on all sides, rafters called lookouts are ordinarily used (fig. 74). These are nailed to a doubled header and toenailed to the wall plate. The distance from the doubled header to the wall line is usually twice the overhang width. Rafter ends may be finished with a nailing header for fastening soffit and fascia boards. Care should be taken to provide ventilation for these soffit areas (see later section).

The above roof types are the most common; other types include the mansard and the A-frame where the same members serve for wall and roof.

**Figure 70** – Gable dormer framing.



**Figure 71** – Wood decking over exposed beams.



### Roof Sheathing

Roof sheathing is the covering applied over roof rafters and trusses to give racking resistance to the roof framing and to provide surface for attachment of materials covering

the roof. Plywood is the material most commonly used for sheathing roofs, but structural flakeboard and 1-inch lumber can also be used. Regardless of material, sheathing must be thick enough to span between supports and to provide a solid base for fastening the roofing material.

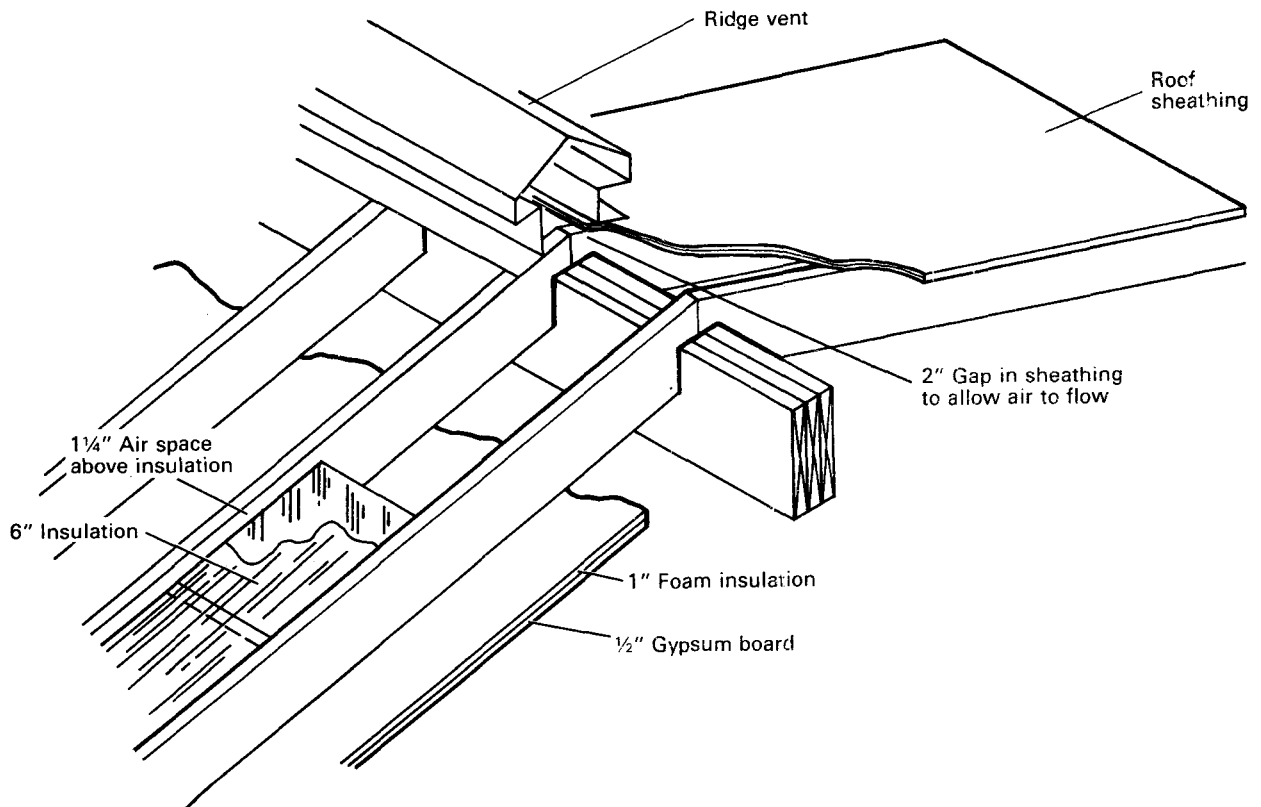
In some types of flat or low-pitched roofs, plank roof decking or fiberboard roof decking can be employed.

Plywood and structural flakeboard roof sheathing are commonly designated standard sheathing grade. For lumber sheathing, lower grades of species such as pine, redwood, hemlock, western larch, fir, and spruce are commonly used. It is important that seasoned lumber be used with asphalt shingles. Unseasoned wood shrinks in width as it dries, and its use may result in buckled or lifted shingles. Fifteen percent is usually considered to be the maximum allowable moisture content for wood sheathing.

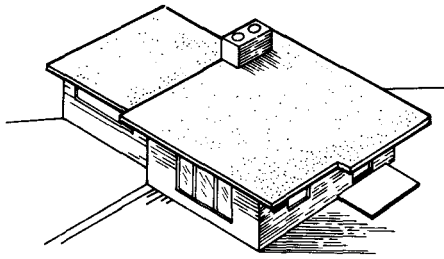
### Plywood

U.S. Voluntary Standard PS 1 provides that standard plywood grades be marked for allowable spacing of rafters or trusses. For rafter spacing of 24 inches on center,  $\frac{3}{8}$ -inch plywood is the minimal thickness where wood shingles or shakes, or asphalt shingles, are to be used. For rafter spacing of 16 inches on center,  $\frac{5}{16}$ -inch plywood sheathing is the minimum. To provide better

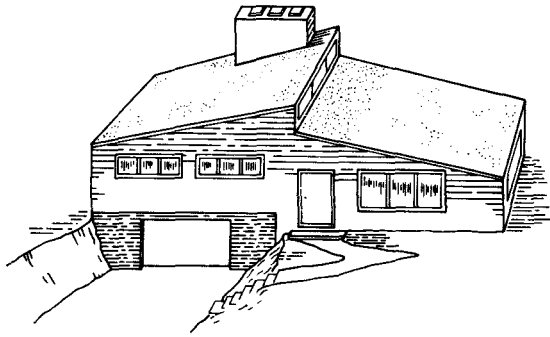
**Figure 72** – Sloping ceiling in post and beam construction.



**Figure 73 – Roof types with single-member construction:**



**A, Flat roof**



**B, Low-pitched roof**

penetration for nails used for the shingles, better racking resistance, and a smoother roof appearance, it is sometimes desirable to use material above the minimum thickness. For slate and similar heavy roofing materials,  $\frac{5}{8}$ -inch plywood is considered minimal for rafters spaced 24 inches on center and  $\frac{1}{2}$ -inch plywood for those spaced 16 inches on center.

Plywood roof sheathing should be laid with the face grain perpendicular to the rafters (fig. 75). Where damp conditions may occur, it is desirable to use a standard sheathing grade with exterior glue. It is unnecessary to stagger plywood end joints over alternate trusses. Full sheets can be applied, starting from either end. This simplifies sheathing layout and application and may reduce the number of cuts.

Plywood should be fastened at each bearing, 6 inches on center along the edges of the panel and 12 inches on center along intermediate members. A 6d common nail, 5d threaded nail, or  $1\frac{3}{8}$ -inch narrow crown staple should be used for  $\frac{5}{16}$ -inch and  $\frac{3}{8}$ -inch plywood. An 8d common nail, 7d threaded nail, or  $1\frac{5}{8}$ -inch staple should be used for greater thicknesses.

Care should be taken during nailing to prevent nailing in a permanent set or deflection in the plywood between

trusses. Such deflection is caused by the weight of the installer standing or kneeling on the plywood while the nailing is being performed. It is better practice for the installer to stand either on the trusses or on adjacent plywood panels that already have been nailed into place.

Unless plywood has an exterior glue line, raw edges should not be exposed to the weather at the gable end or at the eave, but should be protected by the trim or an aluminum drip edge. A  $\frac{1}{8}$ -inch edge space and a  $\frac{1}{16}$ -inch end space should be left between sheets when installing to allow for possible expansion.

Most plywood roof sheathing edges that run perpendicular to the roof framing must be supported by wood blocking or fastened together with metal fasteners. These metal fasteners are called plyclips or H-clips (fig. 75) and are the least costly method of providing the necessary edge support. No special edge support is required if the plywood roof sheathing has tongue-and-groove edges or if the plywood is  $\frac{1}{8}$ -inch thicker than the minimum thickness required by the spacing of the roof framing. Blocking between trusses at the roof ridge and supporting the sheathing edges at the ridge are unnecessary.

### **Structural flakeboard**

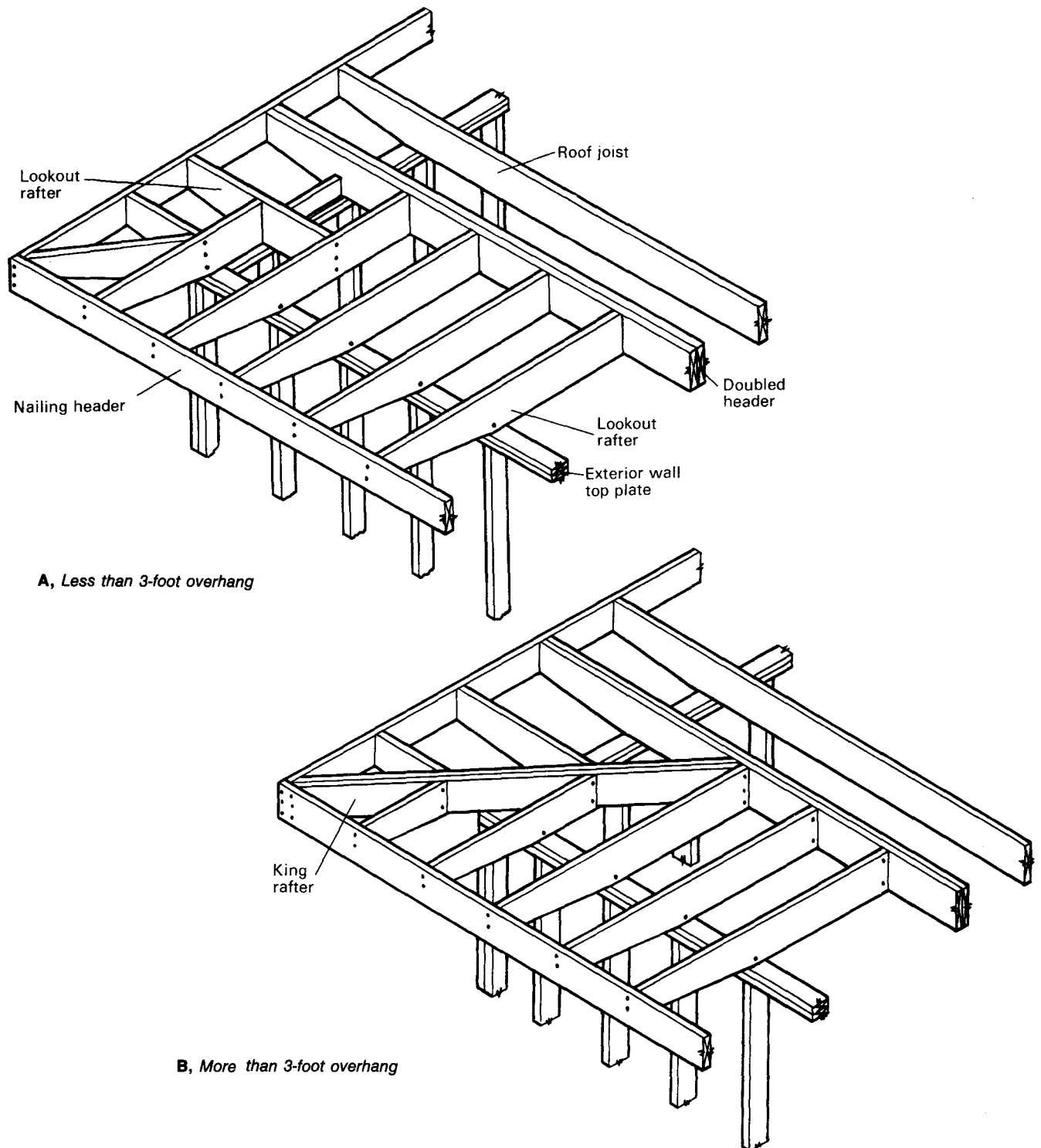
Structural flakeboards (including waferboard and OSB) are applied like plywood: rafter or truss spacing, nailing, and edge treatments are the same, and the same thicknesses are used. Some structural flakeboard panels have flakes or strands aligned to increase the directional strength parallel to the length of the panel. These products should be laid with the long alignment dimension perpendicular to supports.

### **Board**

Board sheathing used under asphalt shingles, metal sheet roofing, or other materials that require continuous support should be laid without spacing (fig. 76). Wood shingles can also be used over such sheathing; see discussion below.

Boards may be tongue-and-groove, shiplapped, or square-edged. End joints should be made over the center line of rafters. It is preferable to use boards no wider than 6 to 8 inches to minimize problems caused by shrinkage. Boards should have a minimum thickness of  $\frac{3}{4}$  inch for rafters spaced 16 inches to 24 inches, and should be nailed with two 8d common or 7d threaded nails for each board at each bearing. End-matched tongue-and-groove boards can also be used and joints made between rafters. However, the joints of adjoining boards should not be made over the same rafter space. Each board should be supported by at least two rafters.

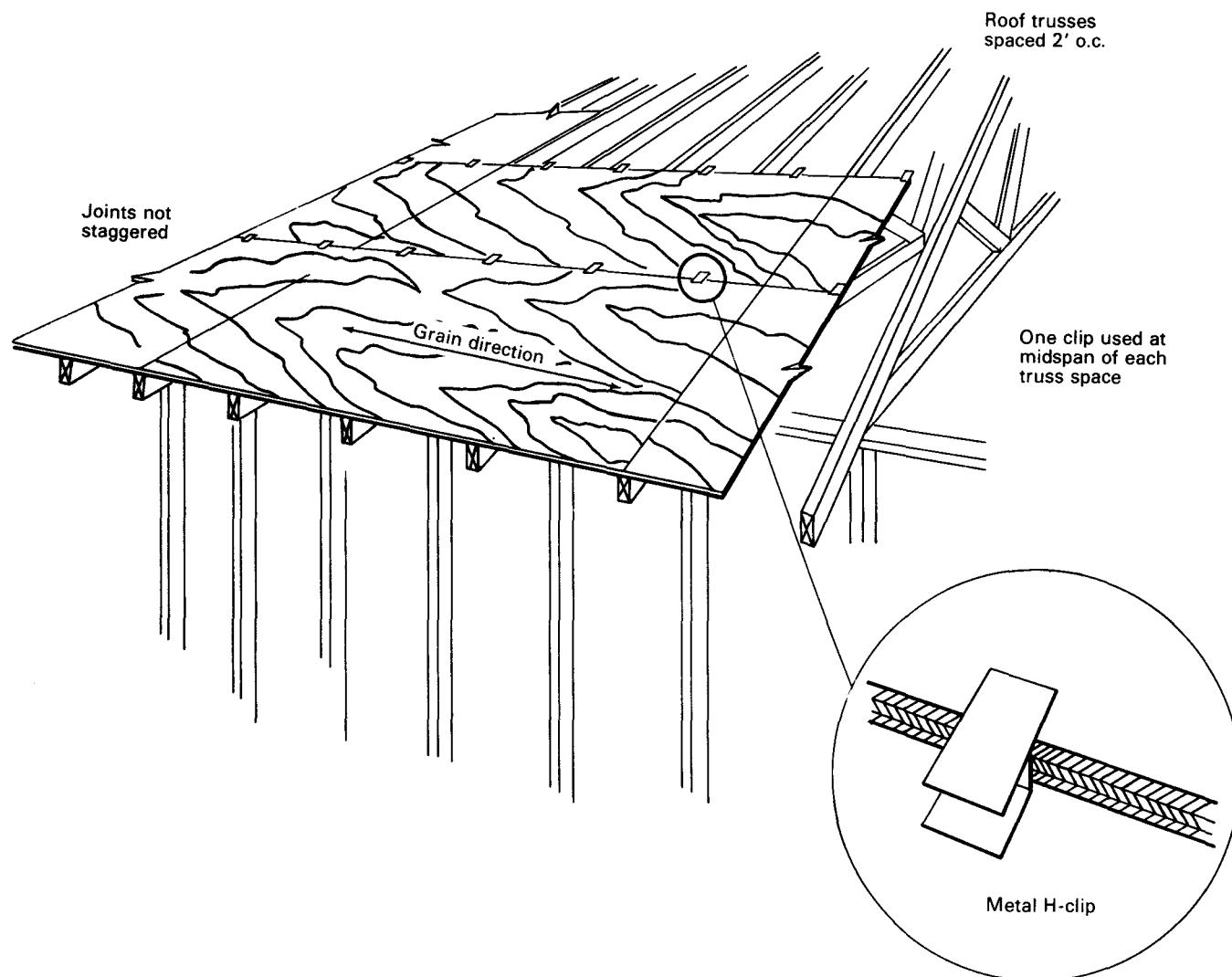
**Figure 74** – Single-member roof construction with overhang:



When wood shingles or shakes are used in damp climates, it is common to have spaced roof boards (fig. 76). Wood nailing strips in nominal 1- by 3-inch or 1- by 4-inch size are spaced the same distance on centers as the

shingle exposure. For example, if the shingle exposure to the weather is 5 inches and nominal 1- by 4-inch strips are used, the space between adjacent boards would be  $1\frac{3}{8}$  to  $1\frac{1}{2}$  inches.

**Figure 75** – Plywood roof sheathing with H-clips for edge support.



### ***Plank roof decking***

Plank roof decking, consisting of nominal 2-inch or thicker tongue-and-groove wood planking, is often used in post-and-beam construction. Common sizes are nominal 2 by 6 inches, 3 by 6 inches, and 4 by 6 inches, the thicker planking being suitable for spans up to 10 or 12 feet.

The decking is nailed through the tongue and also facenailed at each support. In the 4- by 6-inch size, it is predrilled for edge nailing (fig. 77). Maximum span for 2-inch planking is 8 feet when it is continuous over two or more supports. Special load requirements may reduce this allowable span.

Roof decking can serve both as an interior ceiling finish and as a base for roofing. However, because of the relatively low insulating value of plank roof decking, various

types of rigid insulating sheathing are often laid over the decking. These include fiberboard, foam, and sandwiched insulation panels. A vapor retarder should also be used between the top of the plank and the roof insulation unless the insulation has an integral vapor retarder.

### ***Fiberboard roof decking***

Fiberboard roof decking is used the same way as wood plank decking except that supports must be spaced closer together. Fiberboard decking is usually supplied in 2- by 8-foot “planks” with tongue-and-groove edges. Thicknesses of planks and spacing of supports vary with the product but are typically as follows:

Minimum thickness	Maximum joist spacing
1½ inches	24 inches
2 inches	32 inches
3 inches	48 inches

Fiberboard planks are fastened to the wood members with corrosion-resistant nails spaced not more than 5 inches on center. Nails should be long enough to penetrate the joist or beam at least 1½ inches.

### *Gable ends*

The suggested method for installing board or plywood roof sheathing at gable ends of the roof is shown in figure 78. Where there is no roof overhang at gable ends, roof sheathing is placed flush with the outside of the wall sheathing.

Roof sheathing that extends beyond gable end walls to form a rake overhang should span at least two rafter or truss spaces to insure proper anchorage (fig. 78). An overhang of 12 inches or less does not require special framing for support if the roof sheathing is at least ¾ inch thick. When the projection is greater than 12 inches, ladder framing should be used to support the overhang as described in the section on exterior trim.

Plywood extension beyond the end wall can be adjusted to minimize waste. Thus, a 16-inch overhang might be most efficient where rafters are spaced 16 inches on center, and a 12-inch overhang where spaced 24 inches on center.

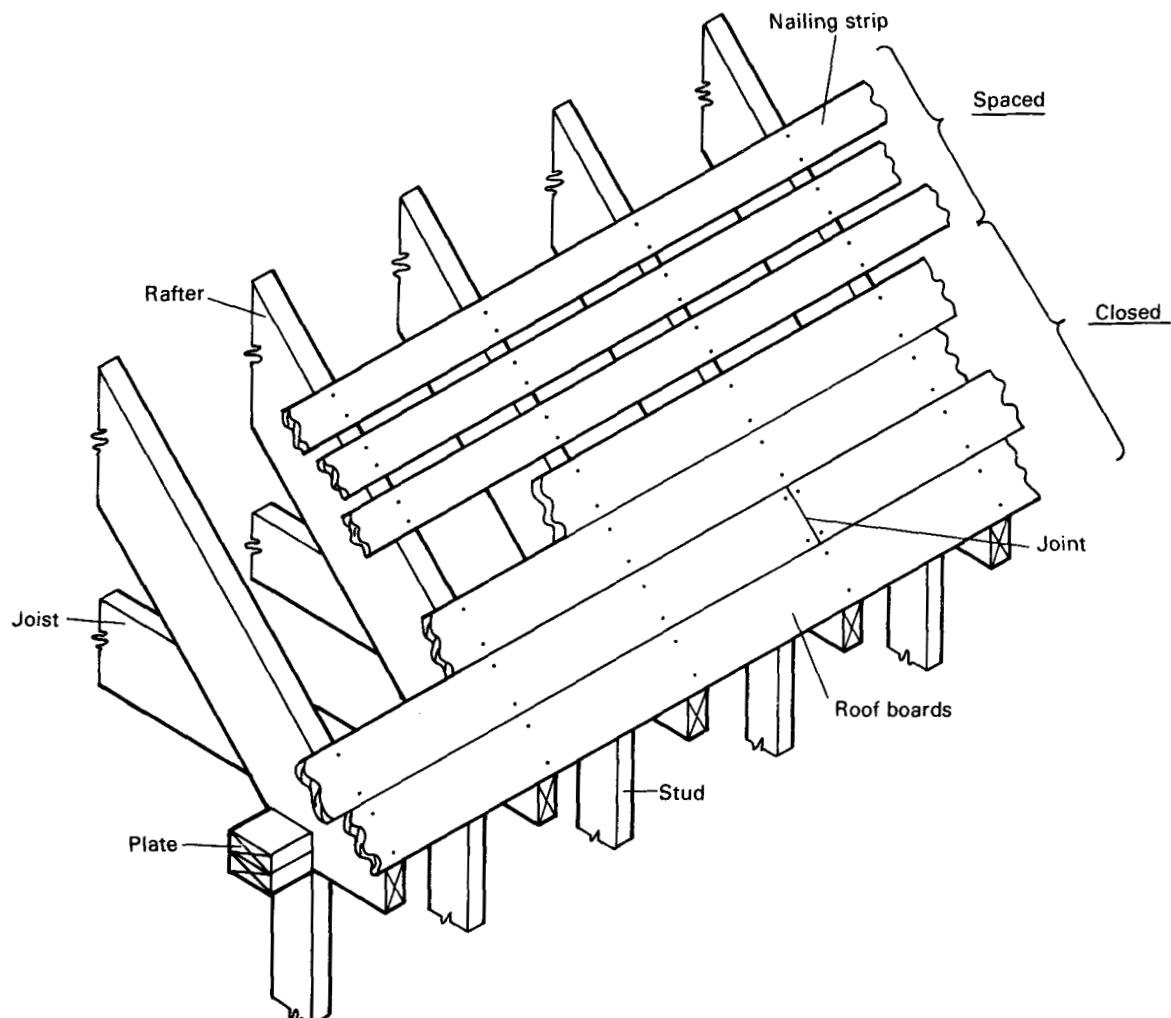
### *Chimney openings*

Where chimney openings occur within the roof area, the roof sheathing should have a clearance of ¾ inch from the finished masonry on all sides (fig. 79). Rafters and headers around the opening should have a clearance of at least 2 inches from the masonry or other clearance as specified by the local code for fire protection.

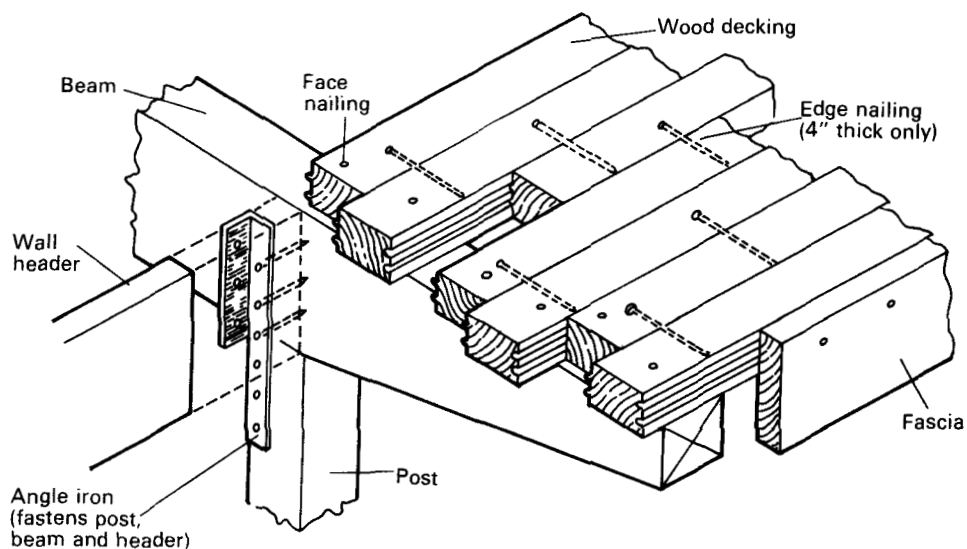
### **Roof Coverings**

The choice of roofing materials is influenced by initial cost, local code requirements, house design, and/or builder preferences. Wood and asphalt shingles, shakes,

**Figure 76** – Board roof sheathing showing both closed and spaced boards.



**Figure 77** – Plank roof decking common in post and beam construction.



tile, slate, and sheet materials such as roll roofing, aluminum, copper, and tin are used for pitched roofs. Flat or low-pitched roofs often employ built-up construction with a gravel topping or cap sheet. Plastic films can also be used on low-slope roofs.

### *Ice dams*

In areas with moderate to severe snowfall, ice dams can form along roof edges at the cornice overhang. Ice dams form as a result of the melting of snow that has fallen on the warmer attic areas of the roof. The water from the melted snow runs down the roof to the colder cornice area where it freezes again, forming the ice dam. As more water runs down the roof, ice gradually becomes deeper, forming a trough that catches water, causing water to back up under the roof covering material and leak through to the ceiling and walls (fig. 80A).

The possibility of leakage caused by ice dams is reduced by increasing the vertical distance the backed-up water must travel to reach the interior of the house or by tightening the seal between the layers of materials covering the roof.

The vertical distance the water must travel can be increased by increasing the overlap of successive layers of the roof covering or by making the pitch of the roof steeper, or both.

The seal between roof covering layers can be tightened by applying a sealer such as roll roofing adhesive between the layers.

As an additional protection against water penetrating under roof covering, it is good practice to apply an underlay of 30-pound or heavier, smooth-surface roll roofing beneath the roof covering materials. The underlay should be placed on top of the roof sheathing, beginning at the eave line and extending up the roof sheathing to a point 24 inches inside the inner surface of the exterior wall (fig. 80B). If it is necessary to overlap the underlay, a double layer of 15-pound roll roofing should be lapped 18 inches on each side of the underlay joint and completely sealed with roll roofing adhesive.

Good attic ventilation and sufficient ceiling insulation serve to keep attic temperatures low enough to minimize snow melt and are important in eliminating formation of the potentially harmful ice dam.

### *Shingles*

With wood and asphalt shingles and shakes, the area of exposure is important. The distance a shingle is exposed generally depends on the roof slope and the type of material and, for asphalt or wood shingles of standard size, may vary from 5 inches on a moderately steep slope to about 3½ inches on flatter slopes, as specified by the manufacturer.

Roof underlay material of 15-pound or 30-pound asphalt-saturated felt is often used in roofs with moderate or low slopes covered with asphalt, asbestos, slate shingles or tiles. Underlayment is not commonly used with wood shingles or shakes. Manufacturers' requirements for installation of underlay should be followed to insure protection under warranty.

To reduce the likelihood of leakage if an ice dam should form, it is good practice to apply an underlay of 30-pound or heavier roll roofing along the eave line as described above (fig. 80B).

**Wood shingles and shakes.** Wood shingles that are all heartwood give greater resistance to decay than do shingles that contain sapwood; wood shakes are 100 percent heartwood. Shingles are less likely to warp if edge-grained than if flat-grained. The tendency to warp is also less if shingles are thicker butted and narrower. Western redcedar, northern white-cedar, and redwood are the principal commercial shingle species because their heartwood has high resistance to decay and low shrinkage. Shingles are of various widths, the narrower shingles being in the lower grades.

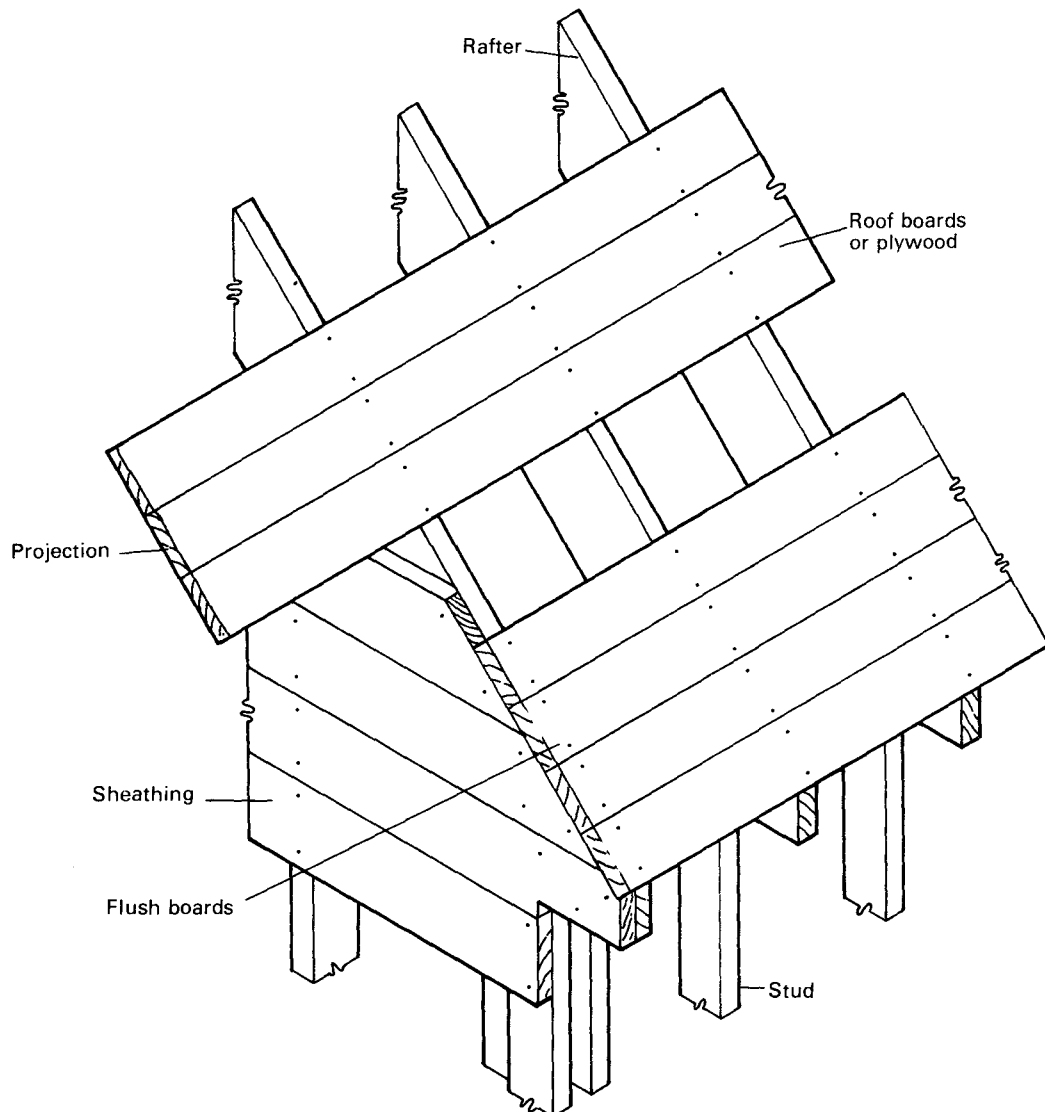
Recommended exposures for standard shingle sizes are shown in table 11. Four bundles of 16-inch shingles laid with a 5-inch exposure cover 100 ft<sup>2</sup>.

Figure 81 illustrates the proper method of applying a wood shingle roof. Underlay or roofing felt is not required for wood shingles except for protection in ice dam areas (discussed above). Spaced roof boards under wood shingles are common, and solid sheathing is a good alternative.

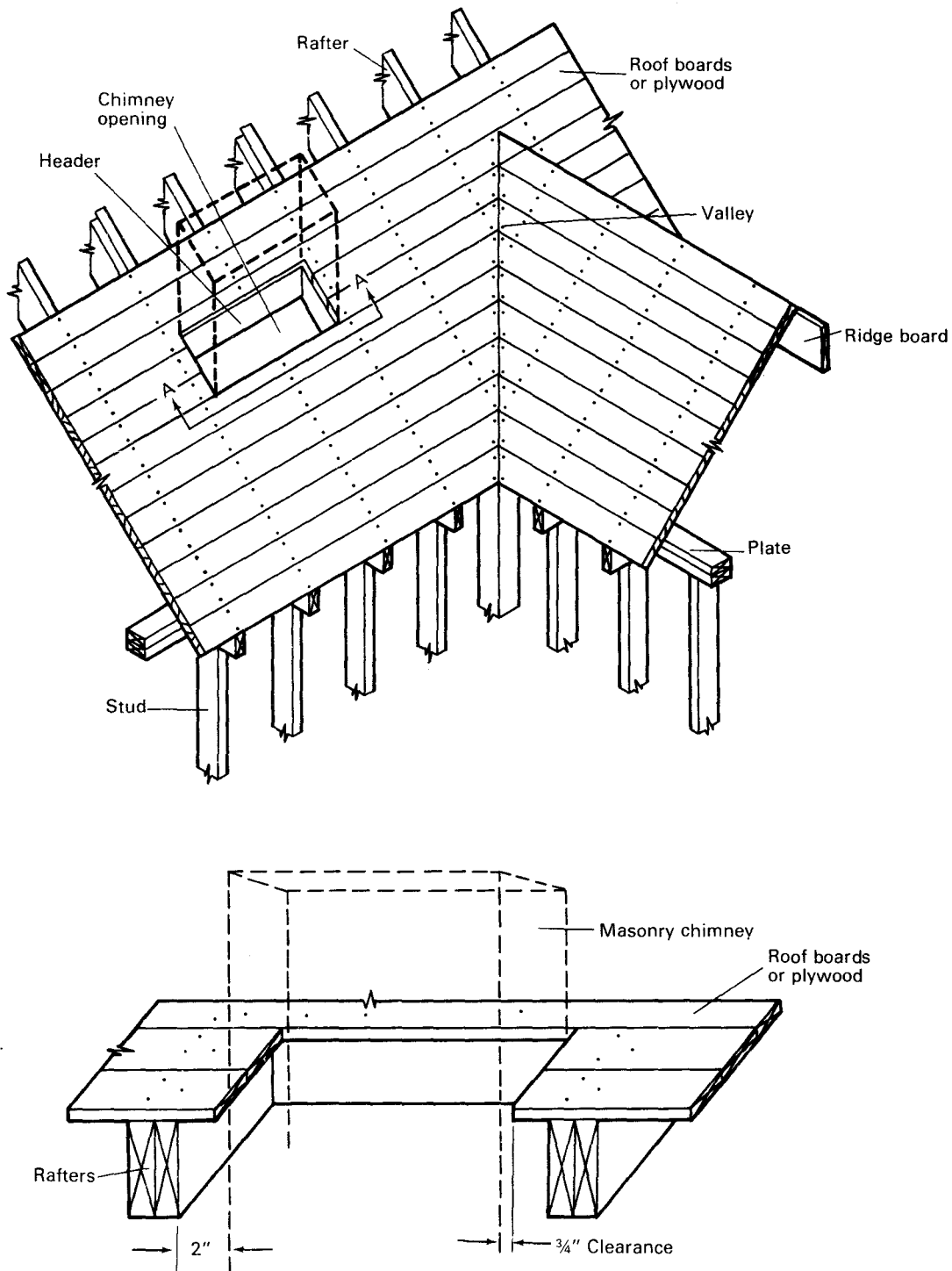
The following general rules should be followed in applying wood shingles:

1. Shingles should extend about 1½ inches beyond the eave line and about ¾ inch beyond the rake (gable) edge.

**Figure 78** – Board roof sheathing at gable ends.

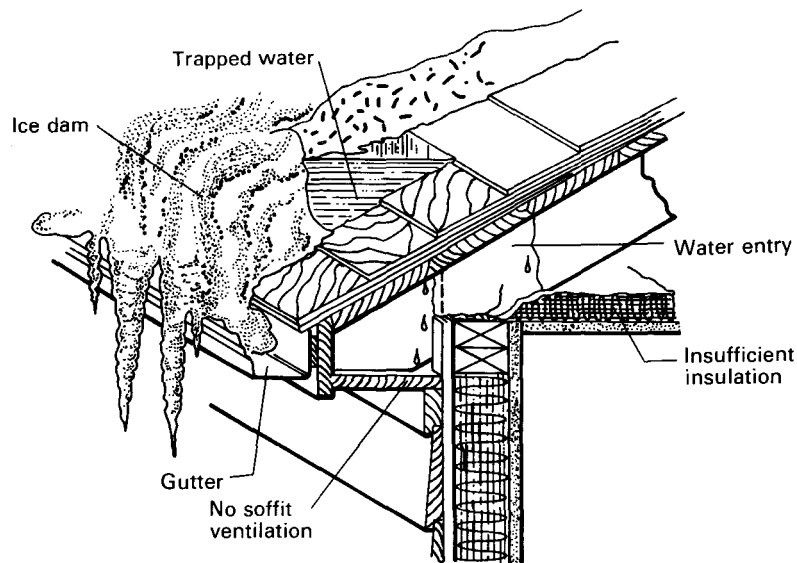


**Figure 79** – Board roof sheathing at valley and chimney opening. Section AA shows clearance at chimney.

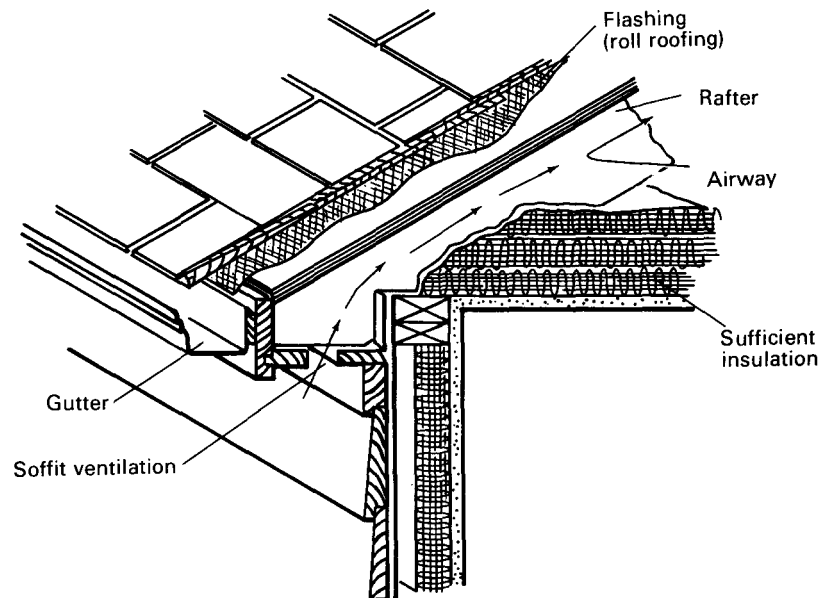


2. Two rust-resistant nails should be used in each shingle, spaced about  $\frac{3}{4}$  inch from the edge and  $1\frac{1}{2}$  inches above the butt line of the next course. Nails of 3d size should be used for 16-inch and 18-inch shingles, and 4d nails for 24-inch shingles in new construction. A ring-shank (threaded) nail is often recommended for plywood roof sheathing less than  $\frac{1}{2}$  inch thick.
3. The first course of shingles should be doubled. In all courses,  $\frac{1}{8}$ -inch to  $\frac{1}{4}$ -inch space between adjacent shingles should be allowed for expansion when wet. The joints between shingles should be offset at least  $1\frac{1}{2}$  inches from the joints between shingles in the course below so that they do not line up directly with joints in the second course below.

**Figure 80 – Snow and ice dams:**



**A, Ice dam forming at roof overhang causing melting snow water to back up under shingles and fascia board which damages ceilings inside and paint outside**



**B, Eave protection for snow and ice dams**

4. When valleys are present, shingling should proceed away from the valleys, wide valley shingles being selected and precut.
5. A metal edging along the gable end should be considered to aid in guiding water away from the side walls.
6. In laying No. 1 all-heartwood edge-grain shingles, no splitting of wide shingles is necessary.

Shakes are applied in much the same manner as wood shingles. Shakes are much thicker than shingles, with longer shakes having thicker butts, and long galvanized nails are therefore used. To create a rustic appearance, the butts are often laid unevenly.

Because shakes are longer than shingles, they are applied with greater exposure. Exposure distance is usually 7½ inches for 18-inch shakes, 10 inches for

Figure 81 – Installation of wood shingles.

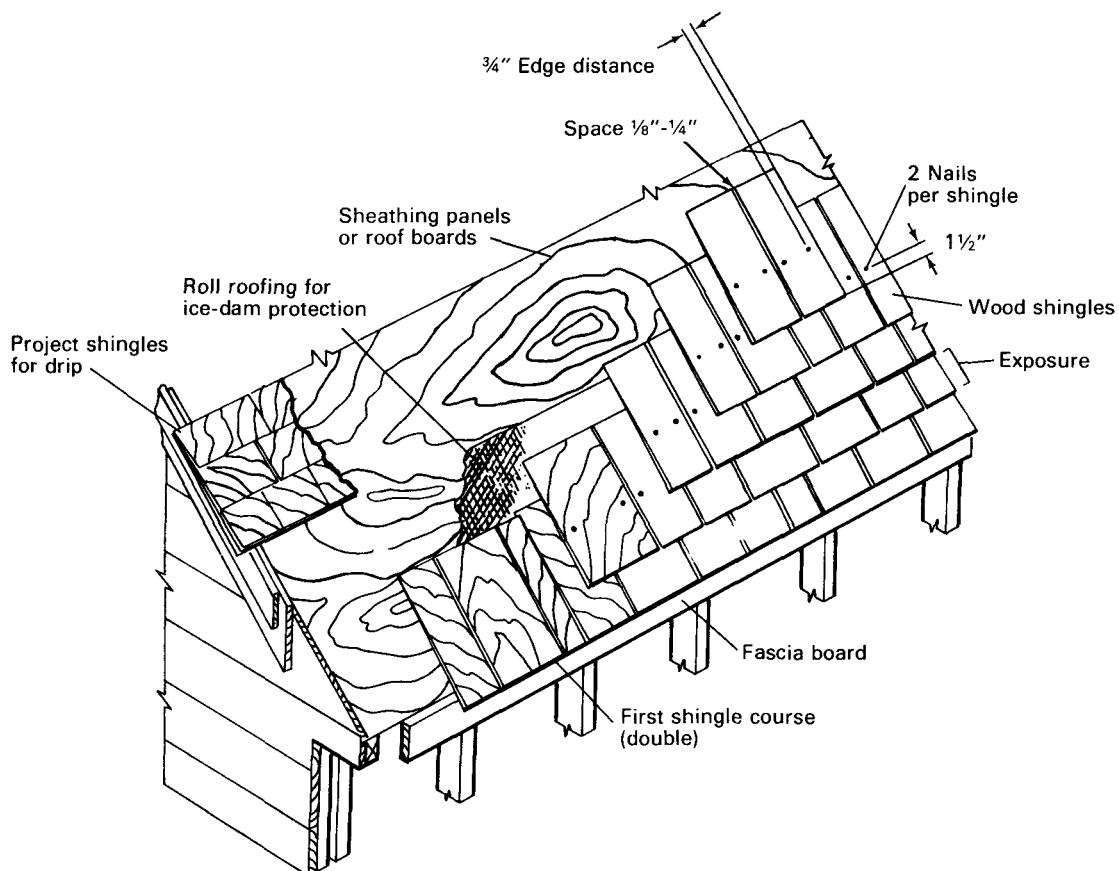


Table 11 – Recommended exposure for wood shingles

Shingle length (in.)	Shingle thickness (green)	Maximum exposure (in)	
		Slope less than 4 in 12	Slope 5 in 12 and over
16	5 butts in 2 inches	3¾	5
18	5 butts in 2¼ inches	4¼	5½
24	4 butts in 2 inches	5¾	7½

As recommended by the Red Cedar Shingle and Handsplit Shake Bureau  
Minimum slope for main roofs, 4 in 12; for porch roofs, 3 in 12.

24-inch shakes, and 13 inches for 32-inch shakes. Shakes are not smooth on both faces, and wind may drive snow beneath them. In areas where wind-driven snow occurs, it is essential to use an underlay between successive courses. An 18-inch-wide layer of 30-pound asphalt felt should be used, with the bottom edge positioned above the butt edge of the shakes at a distance double the exposure distance of the shakes. A 36-inch-wide starting strip of asphalt felt is used at the eave line. Solid sheathing should also be used to protect against wind-driven snow.

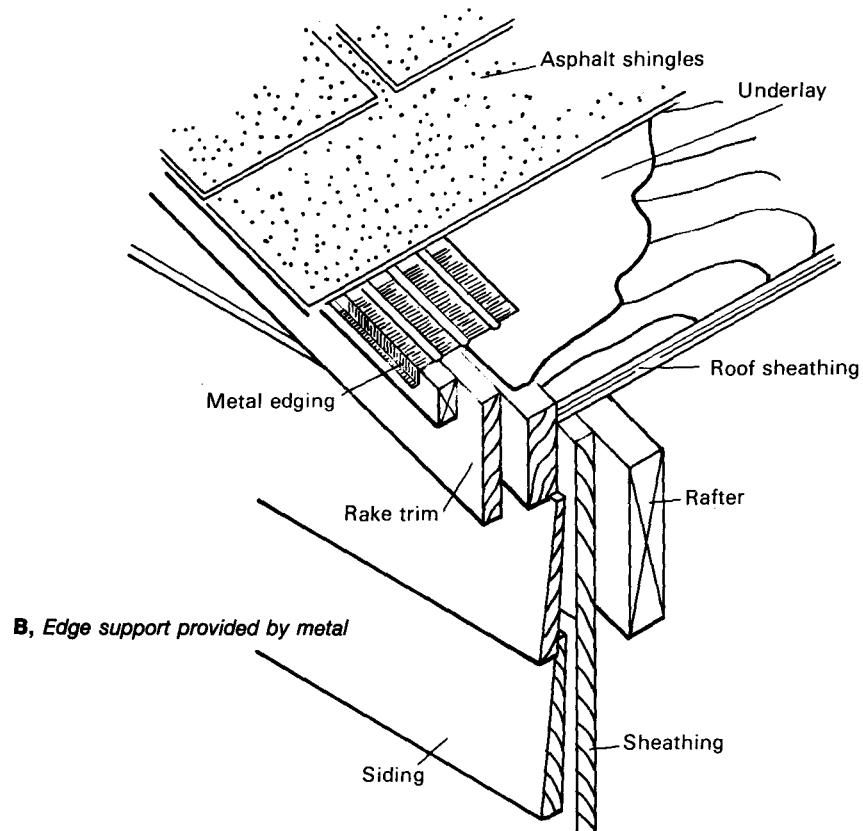
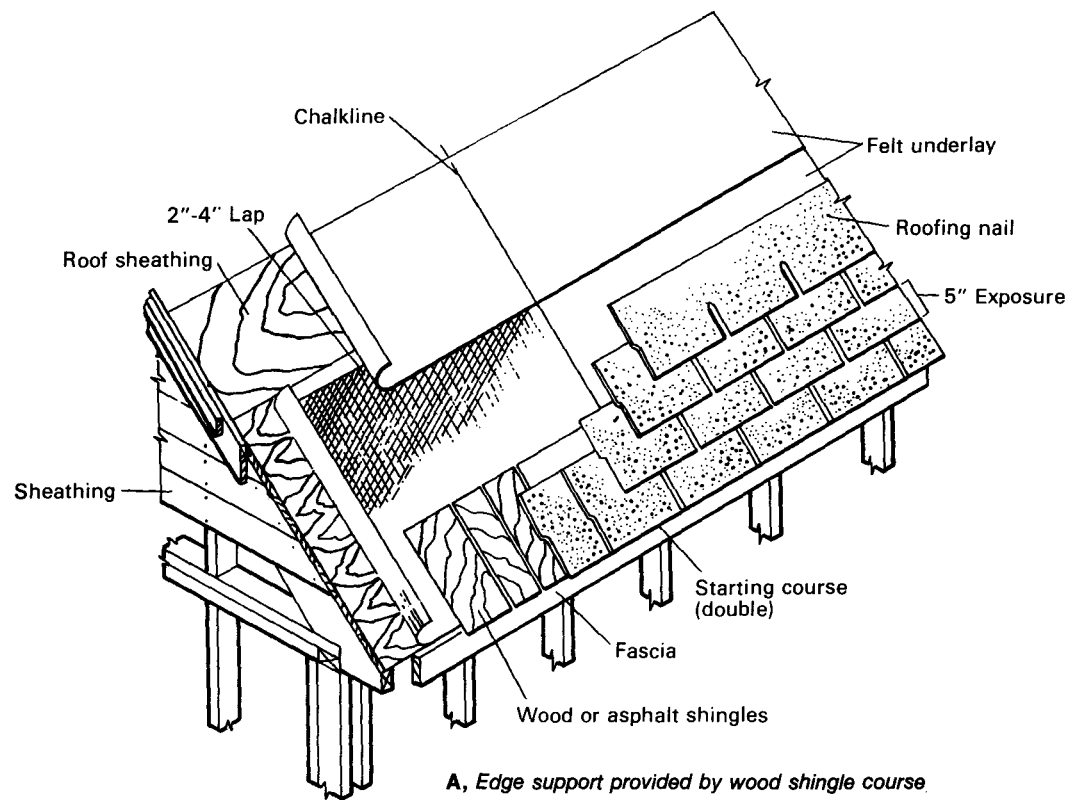
**Asphalt and fiberglass shingles.** The method of laying an asphalt or fiberglass shingle roof is shown in figure 82A. Manufacturers’ requirements for the underlayment beneath the shingles should be followed to insure protection under warranty. The underlayment normally recommended is 15-pound asphalt-saturated felt. In areas with moderate to severe snowfall, precautions should be taken with regard to ice dams, as discussed above.

Asphalt shingles consist of a felt base with asphalt coating. Concealed spots of adhesive called seal tabs glue the shingles together and thus provide greater wind resistance. Felt base square butt asphalt strip shingles should have a minimum weight of 240 pounds per square. (A square is the amount of shingles required to cover 100 ft² of roof.)

Fiberglass shingles are made of an inorganic fiberglass base coated with asphalt. The usual minimum weight recommended is 220 pounds per square. Fiberglass shingles are generally considered more durable and fire resistant than felt-based shingles. Application methods are the same for both types.

The square-butt strip shingle is 12 by 36 inches, has three tabs, and is usually laid with 5 inches exposed to

**Figure 82** – Installation of fiberglass or asphalt shingles:



the weather. There are 27 strips in a bundle, and 3 bundles cover a square. Bundles should be piled flat for storage so that strips do not curl when the bundles are opened.

Metal edging is often used around the entire perimeter of the roof. A starter course is used under the first shingle course. This starter course should extend downward about ½ inch beyond the metal or edging to provide a layer of roof covering under the tab cutouts and to provide uniform roof covering thickness. A ½-inch projection should also be used at the rake (fig. 82B).

Several chalk lines on the underlay help align the shingles so that tab notches are in a straight line for good appearance. Each shingle strip should be fastened securely according to the manufacturer's directions. It is good practice to use four 1 ¼-inch galvanized roofing nails for each 12- by 36-inch strip. The nails should be driven straight; they should not cut the shingle; and they should be driven to a depth that is flush with the surface of the shingle rather than below the surface. If a nail does not penetrate solid wood, another should be driven nearby.

Many builders use pneumatic staple guns rather than a hammer and nails to speed the process of fastening the shingles to the roof. If this method is chosen, wide crown staples 1 ⅝ inches long should be used, and they should be installed parallel to the roof ridge line for maximum wind resistance.

### ***Built-up roofs***

Built-up roof coverings are normally installed by roofing companies that specialize in this work. Such roofs may utilize three, four, or five layers of roofer's felt, each mopped down with tar or asphalt, with the final surface coated with asphalt and covered with gravel (fig. 83A). It is customary to refer to built-up roofs as 10-, 15-, or 20-year roofs, depending upon the method of application.

The cornice or eave line of projecting roofs is usually finished with metal edging or flashing, which acts as a drip. A metal gravel stop is used in conjunction with the flashing at the eaves when the roof is covered with gravel (fig. 83B). Where built-up roofing is finished against another wall, the roofing is turned up on the wall sheathing over a cant strip and is often flashed with metal (fig. 83C). This flashing generally extends about 4 inches above the bottom of the siding.

### ***Other roof coverings***

Other roof coverings, including slate, tile, and metal also require specialized applicators. They are less commonly used than wood, asphalt, or fiberglass shingles or built-up roofs. Several new materials, such as plastic

films and coatings, show promise as future moderate-cost roof coverings. Generally, however, they are currently more expensive than the materials now in use.

Roofs made of galvanized steel, copper, or aluminum are sometimes used on flat decks over dormers, porches, or entryways. Joints should be watertight and the deck properly flashed at the juncture with the house. Nails should be of the same metal as is used in covering the roof. Special nails manufactured with rubber or elastomeric gaskets should be driven through the metal to the point at which the gasket begins to expand in contact with the metal. This provides a watertight seal around the nail hole.

### ***Finish at the ridge and hip***

The most common type of ridge and hip finish for wood and asphalt shingles is called the Boston ridge. Asphalt or fiberglass cap shingle squares (one-third of a 12- by 36-in strip) are used over the ridge and blind-nailed (fig. 84A). Each cap shingle is lapped 5 to 6 inches to give double coverage, and the laps are turned away from the prevailing wind. In areas where driving rains occur, it is good to use metal flashing under the shingle ridge. The use of a ribbon of asphalt roofing cement under each lap will also reduce the chance of water penetration.

A wood-shingle roof (fig. 84B) can be finished in a Boston ridge with continuous flashing or roll roofing beneath the cap shingles. Flashing or roll roofing is first placed along the length of the ridge, as shown in the figure. Shingles 6 inches wide are alternately lapped, fitted, and blind-nailed. The shingles are nailed in place with exposed trimmed edges alternately lapped. Using preassembled hip and ridge units can save both time and money.

A metal ridge vent or ridge roll of copper, galvanized steel, or aluminum formed to the roof can also be used on asphalt or fiberglass shingle or wood-shingle roofs (fig. 84C). Some metal ridge vents provide an outlet ventilating area for letting warm, moist air out of the attic and are designed with louvers and interior baffles to prevent entry of rain or snow.

### ***Skylights***

Skylights have become popular because they provide natural light and a sense of outdoors inside the house. Some can be opened for ventilation while others are fixed. Ventilating skylights are usually operated manually although motorized units are available. Skylights have sometimes been promoted as a means for providing passive solar heating. However, under most conditions, skylights are inefficient for this purpose and can be net energy losers.

**Figure 83 – Built-up roof:**

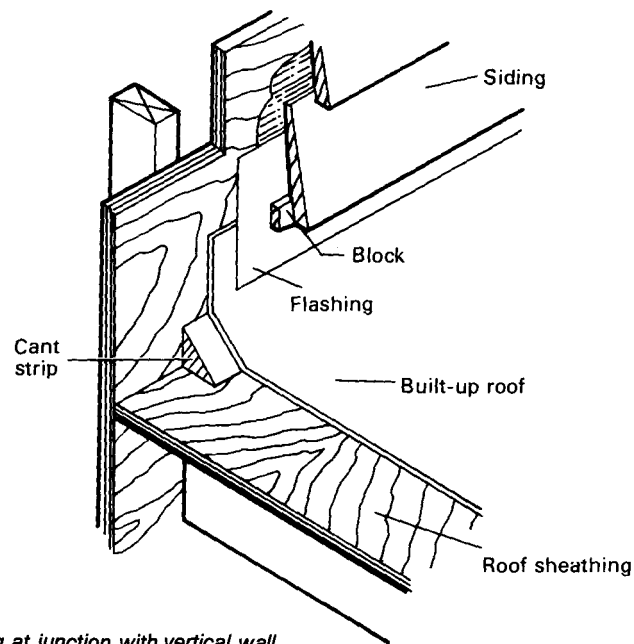
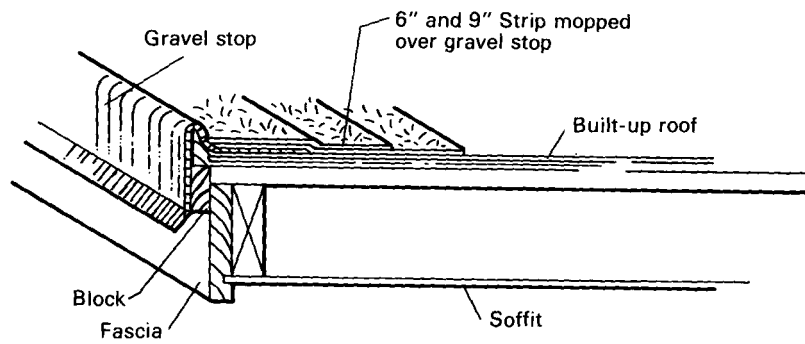
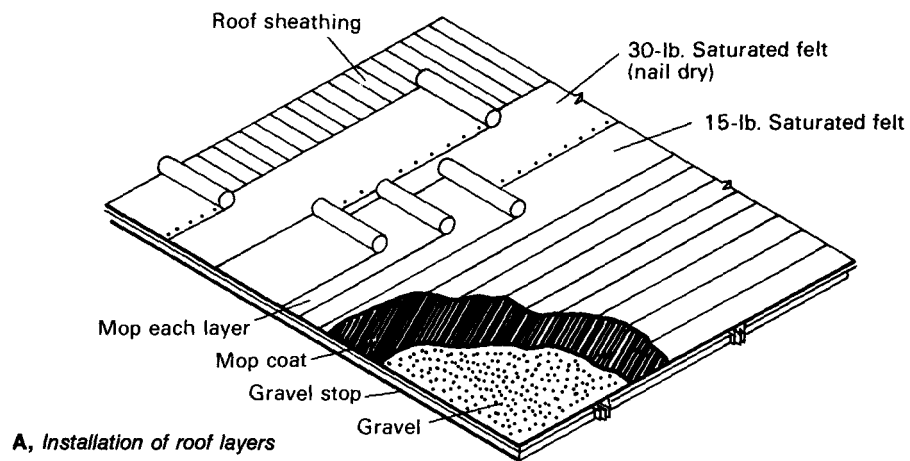
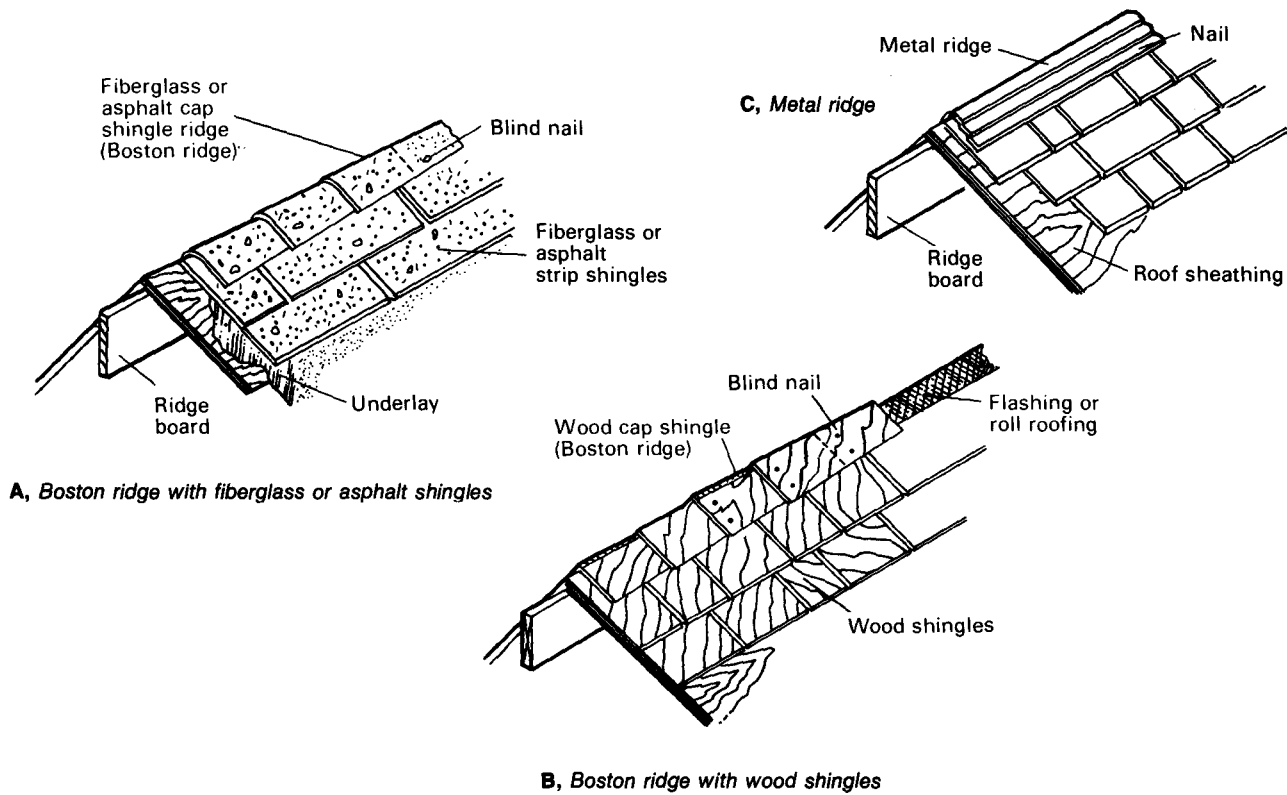


Figure 84 – Finishing shingled roof ridge:



Skylights are available in numerous shapes including flat, dome, and pyramid. They can have acrylic, plastic, or glass glazing, either clear or tinted, and can be single or double glazed. Skylight manufacturers provide installation specifications that should be followed to prevent leaks and to protect the warranty. The size of the hole in the roof sheathing to accommodate the skylight should conform to the mounting instructions.

There are three basic skylight frame types, as follows:

- **Surface-mounted skylights** (fig. 85) are fastened directly to the roof sheathing, usually with galvanized, aluminum, or stainless steel nails. Felt or aluminum flashing and flashing cement are required to make the skylight watertight.

- **Built-up curbs** are made by the installer in accordance with manufacturer specifications. The skylight is installed atop the curb. Gaskets and flashing are usually included with the skylight to provide a weatherproof seal.
- **Skylights with integral curbs** (fig. 86) are common. Most operable skylights have integral curbs. The curb, which is an extension of the frame, raises the skylight off the roof. The skylight is fastened to the roof by means of a flange at the bottom of the curb.

Condensation often occurs on the inside of skylights, especially in areas of high humidity such as kitchens and bathrooms. Some skylights have built-in condensate gutters with weep holes in the frame to reduce moisture accumulation.

Figure 85 – Surface-mounted skylight.

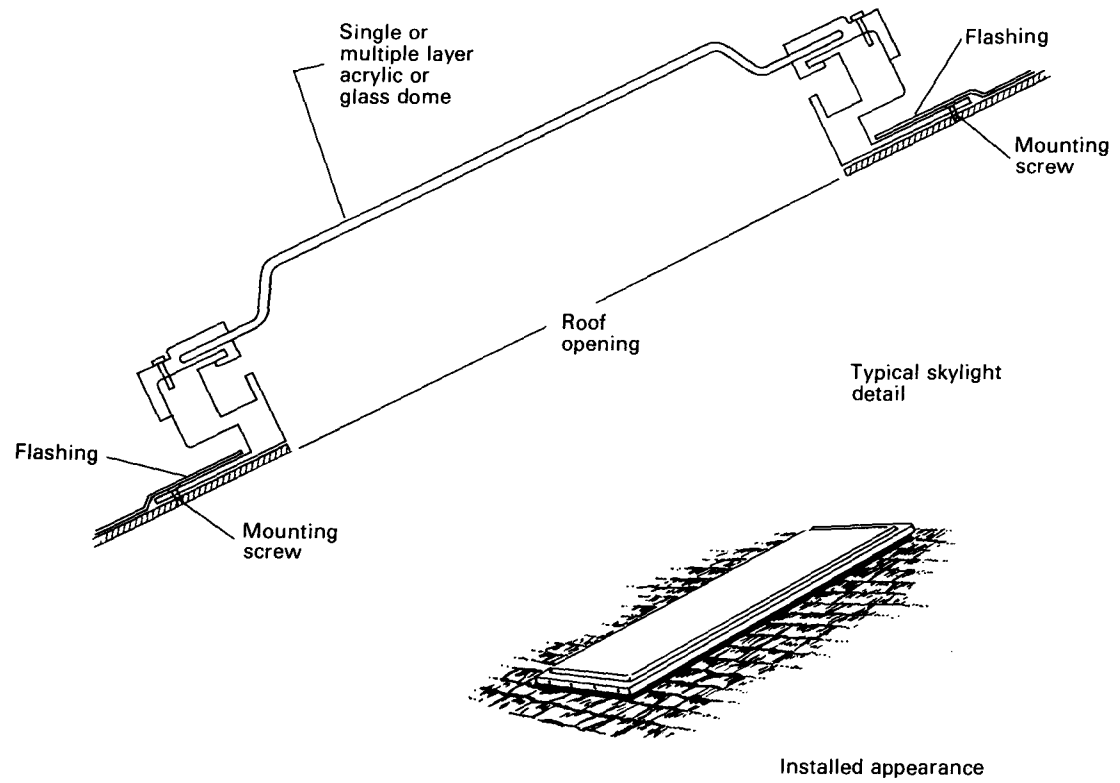
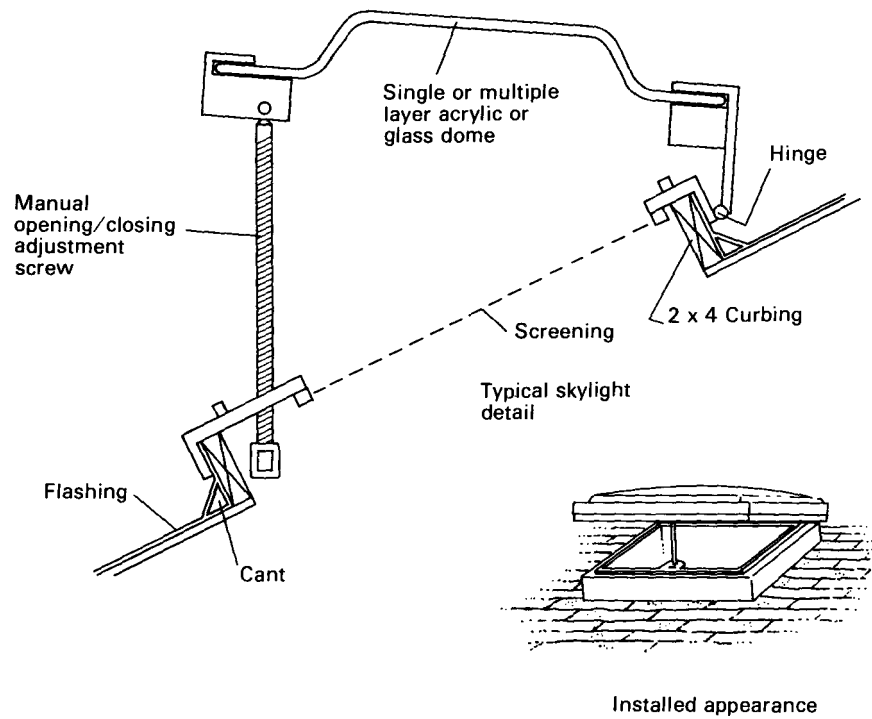


Figure 86 –Curb-mounted skylight.







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## Completing the Shell

The topics discussed in this chapter are specific tasks related to completing the construction of the shell of the house. Their order of presentation does not necessarily reflect the sequence of performance.

### Flashing and Other Sheet-Metal Work

Sheet metal work normally consists of installing flashing, gutters, downspouts, and sometimes attic ventilators. Flashing is often provided to prevent wicking action by joints between moisture-absorbent materials. It can also be used to provide protection from wind-driven rain or melting snow. As previously indicated, damage from ice dams is often the result of inadequate flashing.

Gutters are installed at the cornice line of a house with pitched roof, to carry the rain or melted snow to the downspouts and away from the foundation area. They are especially needed on houses with narrow roof overhangs where poor drainage away from the foundation wall is often the cause of wet basements.

### Materials

Aluminum is the material most commonly used for sheet-metal work; other materials commonly used include zinc-coated (galvanized) steel, copper, and vinyl plastic. Aluminum flashing for roof valleys should have a minimal thickness of 0.019 inch. Thickness for gutters should be 0.027 inch and for downspouts 0.020 inch. Copper for flashing and similar uses should have a minimal thickness of 0.020 inch. Aluminum is not normally used where it will come in contact with concrete or stucco, unless it is insulated against reaction with the alkali in the cement by a coat of asphaltum or other protection.

Galvanized (zinc-coated) sheet metal is also frequently used. Zinc coatings come in two weights, 1.25 and 1.50 ounces per square foot (total weight of coating on both sides). When 1.25-ounce sheet is used for exposed flashing and for gutters and downspouts, 26-gauge metal is required. With 1.50-ounce coating, a 28-gauge metal is satisfactory for most metal work, except that gutters should be 26 gauge.

In choosing accessory hardware such as nails, screws, hangers, and clips, it is important to avoid the potential for corrosion or deterioration that can occur when unlike metals are used together. For aluminum, only aluminum or stainless steel fasteners should be used. Galvanized sheet metal should be fastened with galvanized or stainless steel fasteners.

### Flashing

Flashing should be used at the junction of a roof and a wood or masonry wall, at chimneys, over exposed doors and windows, at changes of siding material, in roof valleys, and in other areas where rain or melted snow might penetrate into the house.

**Material changes.** Horizontal gaps formed at the intersection of two types of siding material often require Z-flashing (fig. 87). For example, a stucco-finish gable end and a wood-siding lower wall should be flashed at their juncture (fig. 87A).

An upper wall sided with vertical boards, with horizontal siding below, usually requires some type of flashing (fig. 87B). When the upper wall, such as a gable end, projects slightly beyond the lower wall (fig. 88), flashing is usually not required. The bottom edge of the siding is cut back at an angle to provide a drip edge, as shown in the figure.

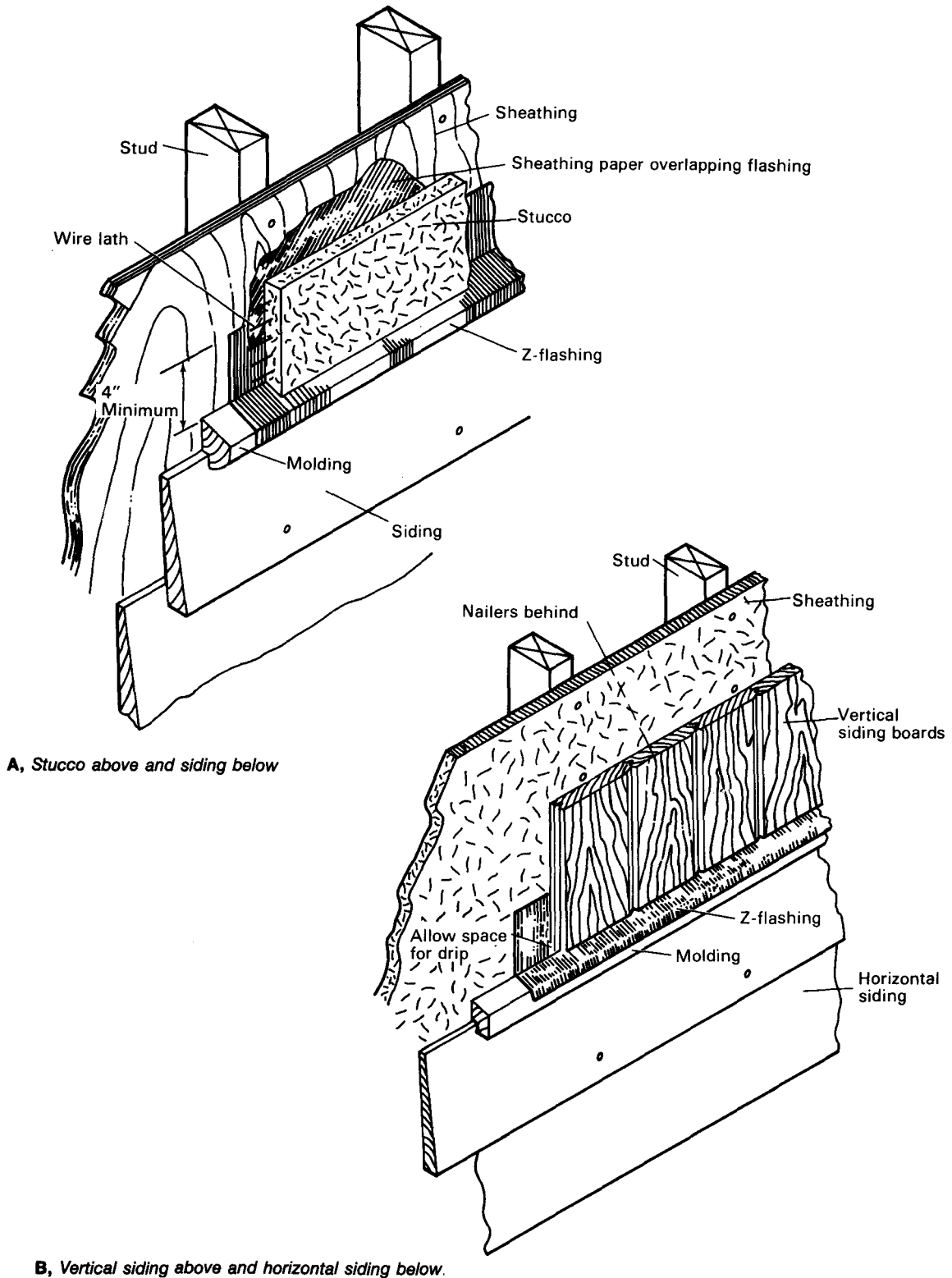
**Doors and windows.** Head flashing, which is similar to Z-flashing, should be used over door and window openings exposed to rain. Windows and doorheads protected by wide overhangs in a single-story house do not ordinarily require such flashing. Head flashing should be started behind the siding and should be bent out and down over the top molding over the window or door. When building paper is used on the side walls, it should lap the top edge of the flashing.

**Flat roofs.** Flashing is required at the junction of an exterior wall and a flat or low-pitched built-up roof (fig. 89). When a metal roof is used, the metal is turned up on the wall and covered by the siding. A clearance of 2 inches should be allowed at the bottom of the siding for protection from melted snow and water.

**Ridges and roofs.** Ridge flashing or roll roofing should be used under a Boston ridge on wood shingle or shake roofs to prevent water entry (fig. 90). The flashing should extend about 3 inches on each side of the ridge and be nailed in place only at the outer edges. Ridge shingles or shakes, which are 6 to 8 inches wide, cover the flashing.

**Vents.** Stack vents and roof ventilators are provided with flashing collars, which are lapped by the shingles on the upper side. The lower edge of the collar laps the shingles. Sides are nailed to the shingles and caulked with roofing mastic.

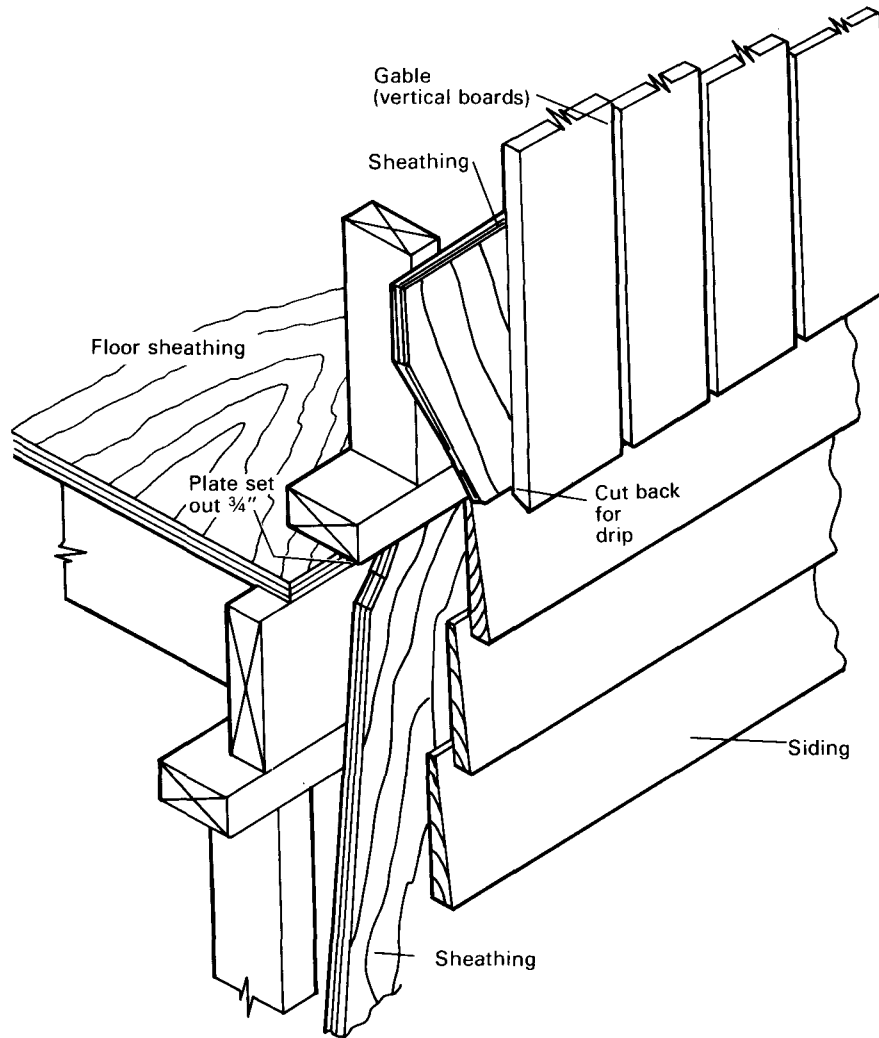
**Figure 87 – Z-flashing at material changes:**



**Valleys.** The valley formed by two intersecting roof planes is usually covered with metal flashing. Some building regulations allow the use of two thicknesses of

mineral-surfaced roll roofing in place of metal flashing. As an alternative, one strip of roll roofing 36 inches wide can be applied to the valley and covered with asphalt or

**Figure 88** – Gable end projection material transition without flashing.



fiberglass shingles applied continuously from one plane of the roof to the other. This type of valley is normally used only on roofs with a slope of 10 in 12 or steeper.

Widths of sheet-metal flashing for valleys should not be less than:

- 12 inches for roof slopes of 7 in 12 and steeper.
- 18 inches wide for roof slopes 4 in 12 to 7 in 12.
- 24 inches wide for slopes flatter than 4 in 12.

The width of the valley between shingles should increase from the top to the bottom (fig. 91A). The minimal open width at the top is 4 inches and should be increased at the rate of about  $\frac{1}{8}$  inch per foot. These widths can be marked on the flashing with a chalking string before shingles are applied.

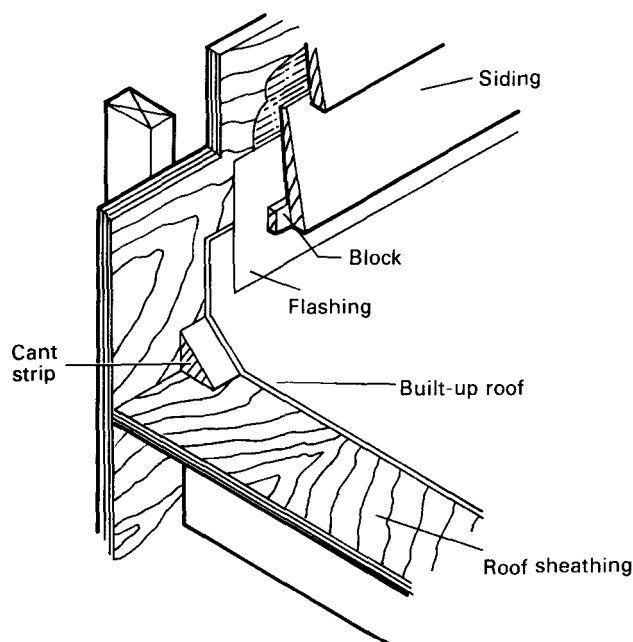
When adjacent roof slopes vary, for example, where a low-slope porch roof intersects a steeper main roof, a

1-inch-high crimped standing seam should be used (fig. 91B). This will keep heavy rains on the steeper slopes from overrunning the valley and being forced under the shingles on the adjoining slope. Nails for the shingles should be kept back as far as possible to eliminate holes in the flashing. A ribbon of asphalt-roofing mastic is often used under the edge of the shingles.

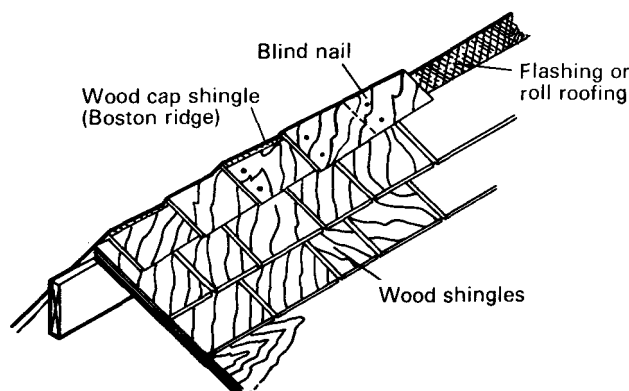
**Roof-wall intersections.** When shingles on a roof intersect a vertical wall, step flashing is used at the junction. Aluminum or galvanized steel is bent at a 90° angle and extended up the side of the wall a minimum of 4 inches over the sheathing (fig. 92A). When roofing felt is used under the shingles, it is turned up on the wall and covered by the flashing. The siding is then applied over the flashing, allowing about a 2-inch vertical space between the level edge of the siding and the roof.

If the roof intersects a brick wall or chimney, the same type of metal flashing is used as that described for the

**Figure 89** – Flashing at junction of built-up roof and vertical building wall.



**Figure 90** – Flashing at Boston ridge with wood shingles.



wood-sided wall. In addition, counterflashing or brick flashing is used to cover the step flashing (fig. 92B). This counterflashing is often preformed in sections and is inserted in open mortar joints. All flashing joints should overlap the next lower piece.

In laying up the chimney or brick wall, the mortar is usually raked out for a depth of about 1 inch at flashing locations. Lead wedges driven into the joint above the flashing hold it in place. The joint is then caulked to provide a watertight connection. In chimneys, this counterflashing is often preformed to cover one entire side.

Around small chimneys, flashing often consists of simple counterflashing applied over step flashing on each side. For single-flue chimneys, the shingle flashing on the high side should be carried up under the shingles. This flashing should extend up the chimney for a distance of about 4 inches above the roof sheathing (fig. 93A).

A saddle for better drainage is often constructed on the high side of wide chimneys. It is made of a ridge board and post and sheathed with plywood or boards (fig. 93B). It is then covered with metal that extends up on the brick and under the shingles. Counterflashing at the chimney is then used, as previously described, with lead plugging and caulking. A very wide chimney may have on the high side a partial gable that can be shingled in the same manner as the main roof.

**Roof drip edge.** Aluminum drip edge flashing is often used around the entire perimeter of the roof to protect the edge of the sheathing and to reduce the amount of rain-water running down the fascia or blowing under the roof covering (fig. 94).

### *Gutters and downspouts*

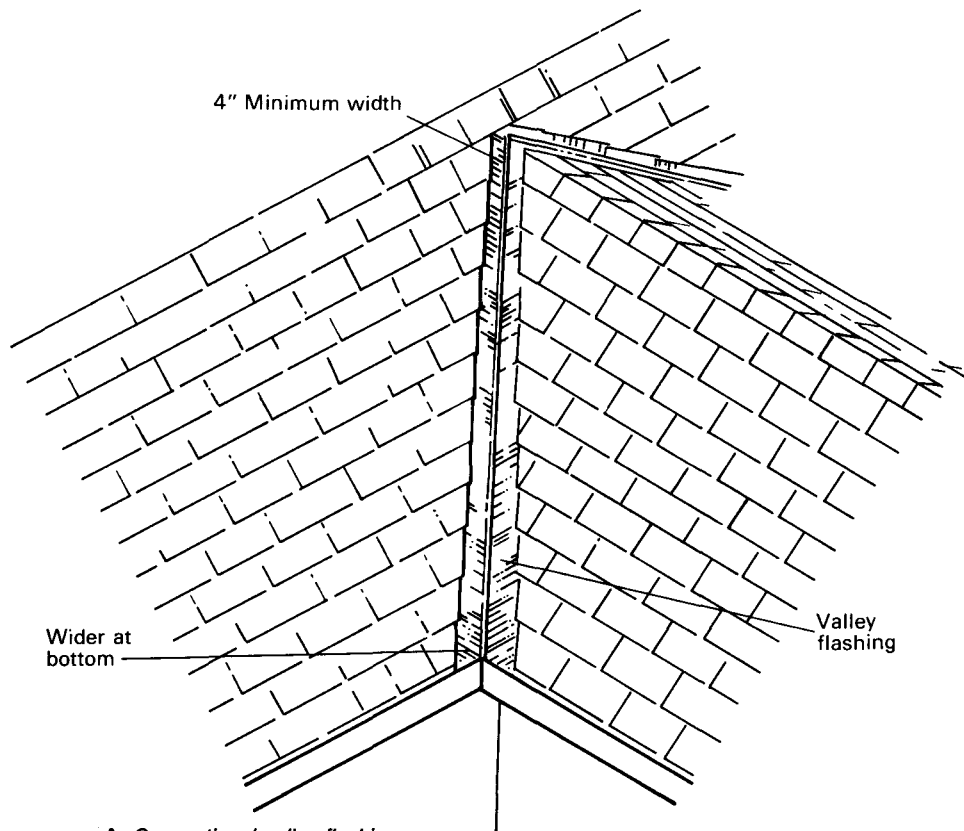
Several types of gutters are available to carry the rain-water to the downspouts and away from the foundation. The gutter most commonly used is the type hung from the edge of the roof or fastened to the edge of the cornice fascia. Gutters may be the half-round (fig. 95A) or the formed type (fig. 95B) and may be aluminum, galvanized steel, or vinyl. Some have a factory-applied enamel finish that minimizes maintenance.

Downspouts are round or rectangular (figs. 95C and 95D), the round type being used with the half-round gutters. They are usually corrugated to provide extra stiffness and strength. Corrugated patterns are less likely to burst when plugged with ice.

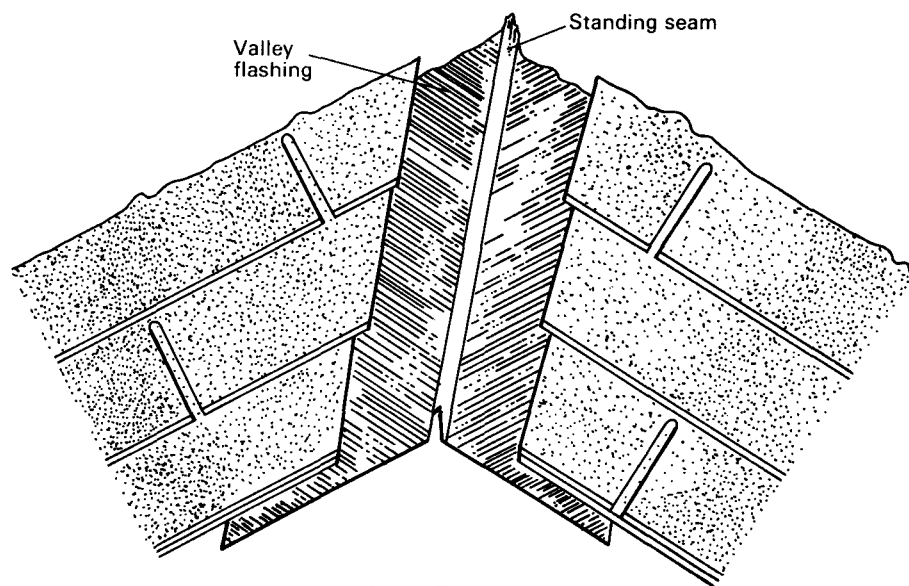
**Size.** An area of 1 square inch (in<sup>2</sup>) of downspout cross section is required for each 100 ft<sup>2</sup> of roof area. The size of gutters should be determined by the size and spacing of the downspouts used. When downspouts are spaced up to 40 feet apart, the cross-sectional area of the gutter should be the same as that of the downspout. For greater spacing, the size of the gutter should be increased. On long runs of gutters, such as would be required around a hip-roofed house, at least four downspouts are desirable.

**Installation.** Gutters should be installed with a slight pitch, such as ¼ inch in 10 feet, toward the downspouts. The points marking the ends of the gutter that produce the necessary slope should be established with a transit and marked on the fascia. A chalking string can be stretched tightly between the points and snapped. The

**Figure 91 – Flashing roof valley:**



**A, Conventional valley flashing**



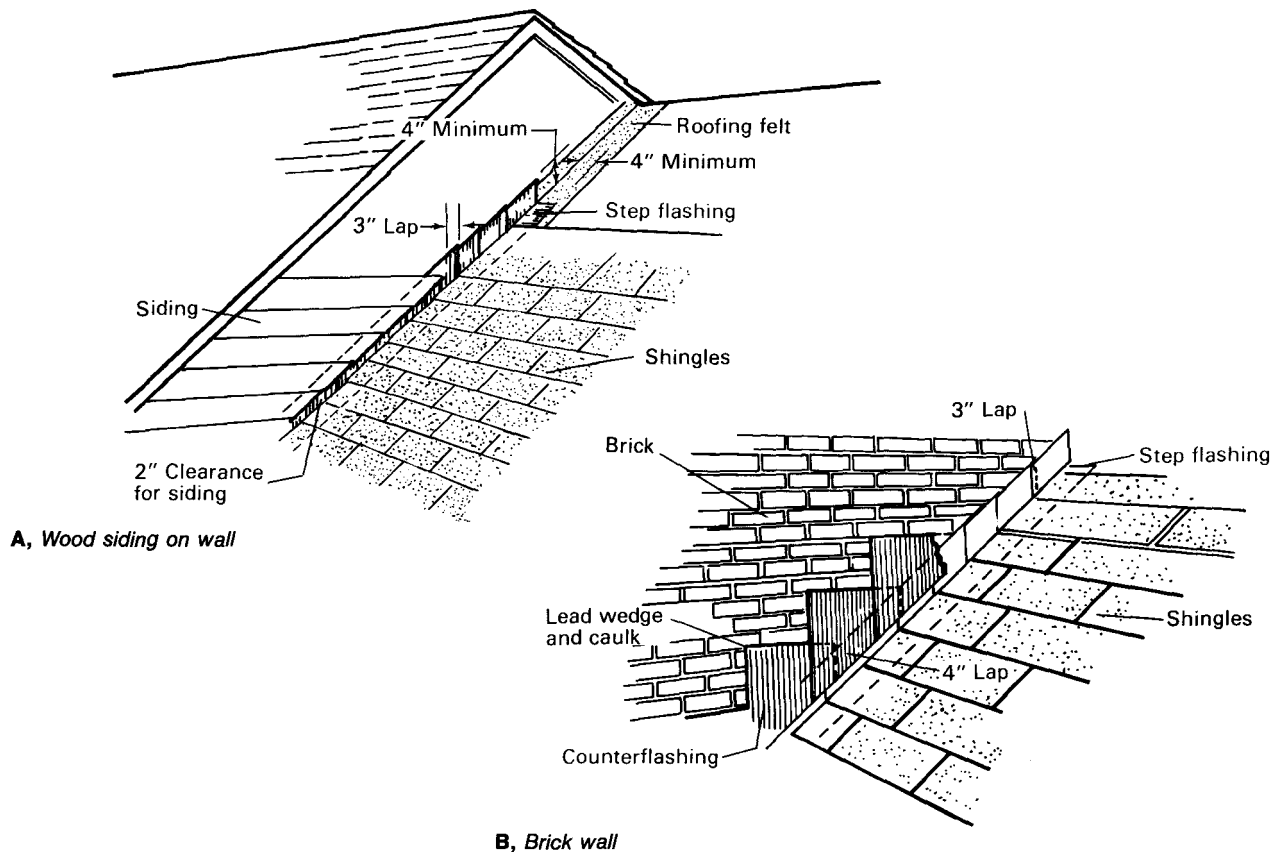
**B, Valley flashing with standing seam**

resulting line on the fascia can be used to guide the installation of the gutter.

Gutters are often suspended from the edge of the roof with hangers (fig. 96). Hangers should be spaced 48 inches apart when made of galvanized steel and 30 inches

apart when made of aluminum. Gutter splices, downspout connections, and corner joints should be soldered or sealed with an exterior silicone or latex caulk to provide watertight joints.

**Figure 92 – Flashing at roof-wall intersection:**



Downspouts, or conductor pipes, are fastened to the wall by straps (fig. 97A). Several patterns of fasteners allow a space between the wall and downspout. One common type consists of a metal strap with a spike and spacer collar. After the spike is driven through the collar and into the siding and backing stud, the strap is fastened around the pipe.

Downspouts should be fastened at top and bottom. For long downspouts, a strap or hook should be used for every 6 feet of length. An elbow should be used at the bottom of the downspout, as well as a splash block, to carry the water away from the wall (fig. 97A). Alternatively, the downspout may be directly connected to the sewer system if permitted by the local code (fig. 97B).

### **Attic Ventilation**

Ventilation is required in most attic areas to facilitate the removal of moisture vapor and condensate. During cold weather, the warm, moist air from the heated rooms can work its way into these spaces around penetrations of walls and ceilings for pipes and electrical fixtures, and other inadequately protected areas. The use of vapor retarders in building construction can reduce this vapor migration. Although the total amount of vapor might be

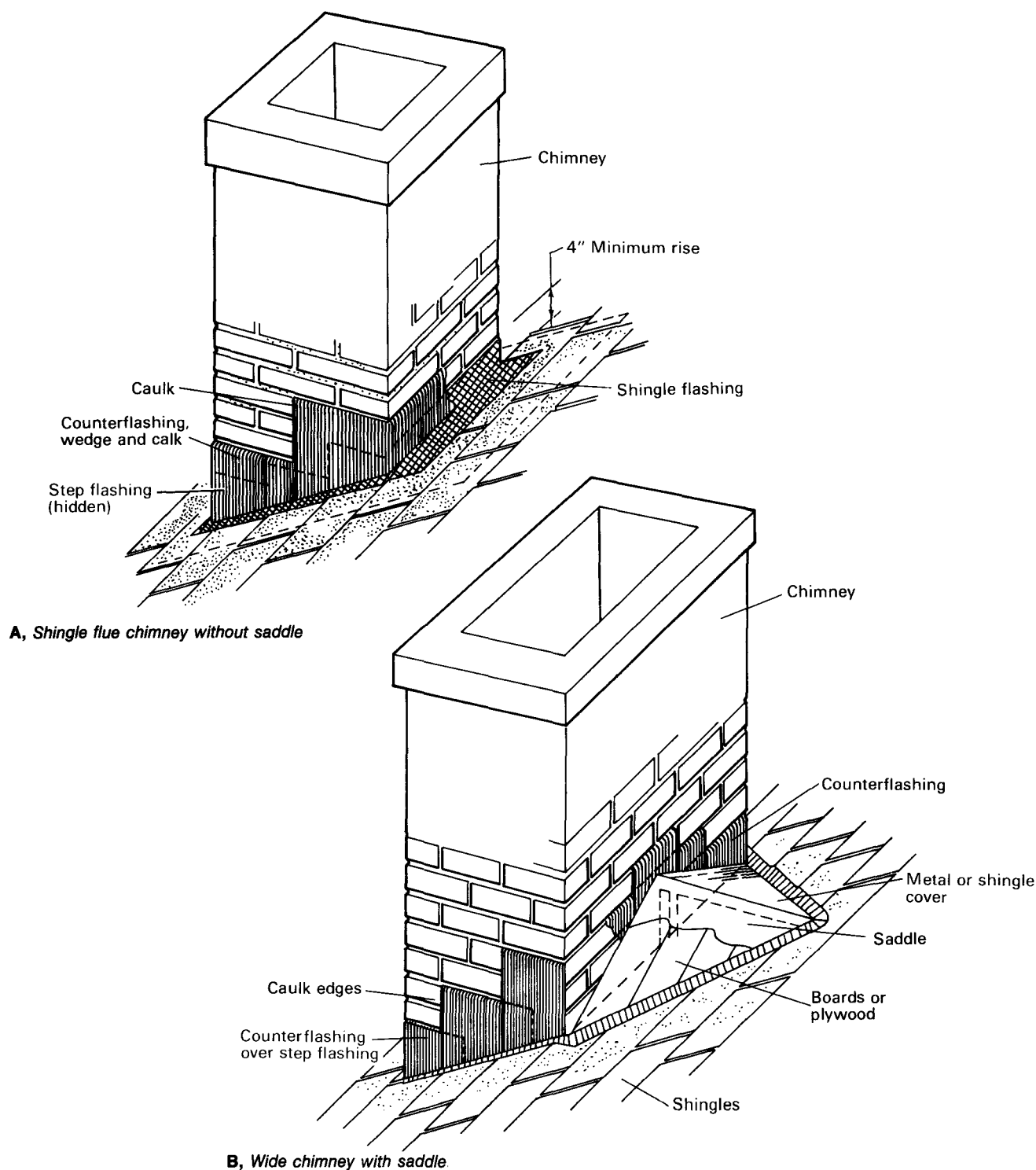
unimportant if it were equally distributed, it may be sufficiently concentrated in some cold spots to cause significant condensation and possibly damage. Although wood shingle and wood shake roofs do not resist vapor movement, such roofings as asphalt shingles and built-up roofs are highly resistant, and this can contribute to a buildup of vapor in the attic. The most practical method of removing the moisture is by adequate ventilation of the roof spaces.

During winter weather, a warm attic that is inadequately ventilated can foster the formation of ice dams at cornices or in roof valleys, as discussed previously in the section on roof coverings.

With a well-insulated attic floor and adequate ventilation, attic temperatures can be kept relatively low, and melting of snow over the attic space can be reduced.

In hot weather, ventilation of attic and roof spaces removes hot air and lowers temperatures in these spaces. Insulation should be used in the attic floor or in the roof structure if there is no attic to further retard heat flow into the rooms below.

**Figure 93 – Flashing at chimney:**



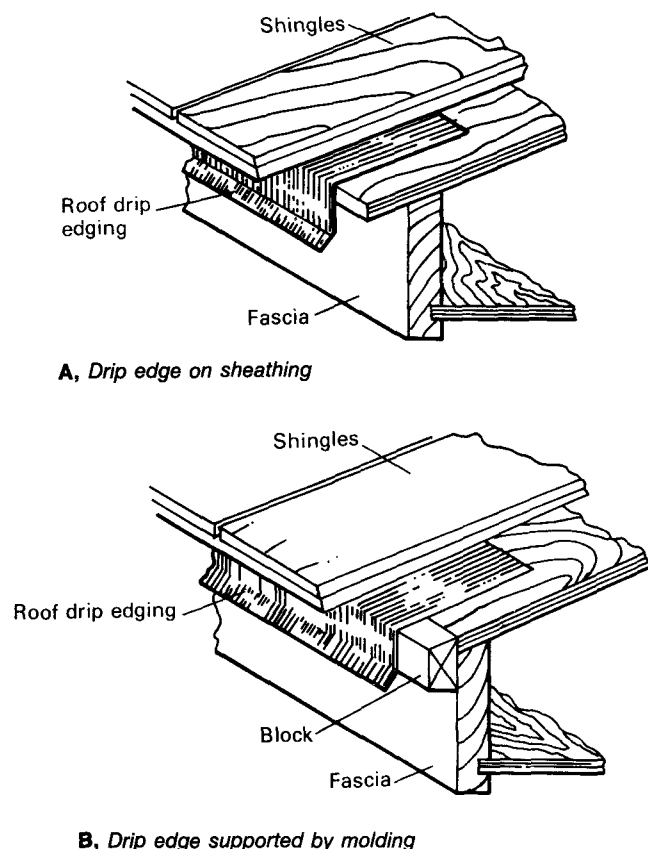
### *Types and location of roof ventilators*

Inlet ventilation is provided by small, well-distributed modular ventilators or a continuous slot in the soffit. Small vents for easy installation in appropriate locations

can be obtained in most lumberyards or hardware stores (fig. 98).

The small sections that must be cut out of the soffit can be removed before the soffit is installed. Aluminum vent covers can be purchased to fit into the holes cut in the

**Figure 94 – Roof drip edge:**



soffit or the holes can be covered with stapled screening. It is preferable to use a greater number of smaller, well-distributed ventilators rather than fewer large ones.

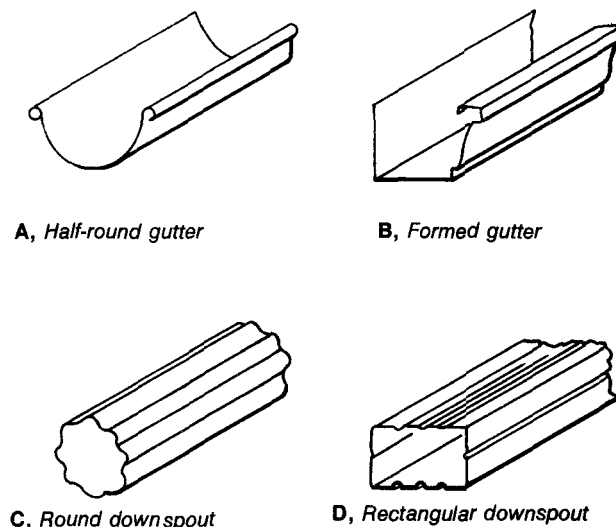
Blocking may be required between rafters at the wall line to leave an airway into the attic area above the soffit vents. This airway should not be blocked with insulation. To help ensure a free flow of air, cardboard or plastic baffles may be installed between the rafters at the wall line (fig. 98A), or the raised Fink truss design may be used.

When a continuous screened slot is used for ventilation, it should be located near the outer edge of the soffit close to the fascia (fig. 98B) to minimize snow entrance. This type of ventilator can also be used under the extension of flat roofs.

#### **Area of ventilators**

Minimal sizes recommended for ventilators have been generally established for various types of roofs and are required by most building codes. The minimal net vent area is determined as a given ratio of vent area to projected ceiling area of the rooms below. This ratio, discussed for various roof types below, determines the unob-

**Figure 95 – Gutters and downspouts:**



structed or “net free vent area.” When screening, louvers, or rain/snow shields cover the vents, the area of the vent opening should be increased to offset the area of the obstruction. Recognized conversion factors for determining the gross area of the vent opening related to the type of vent covering and the required net free ventilating area are given in table 12.

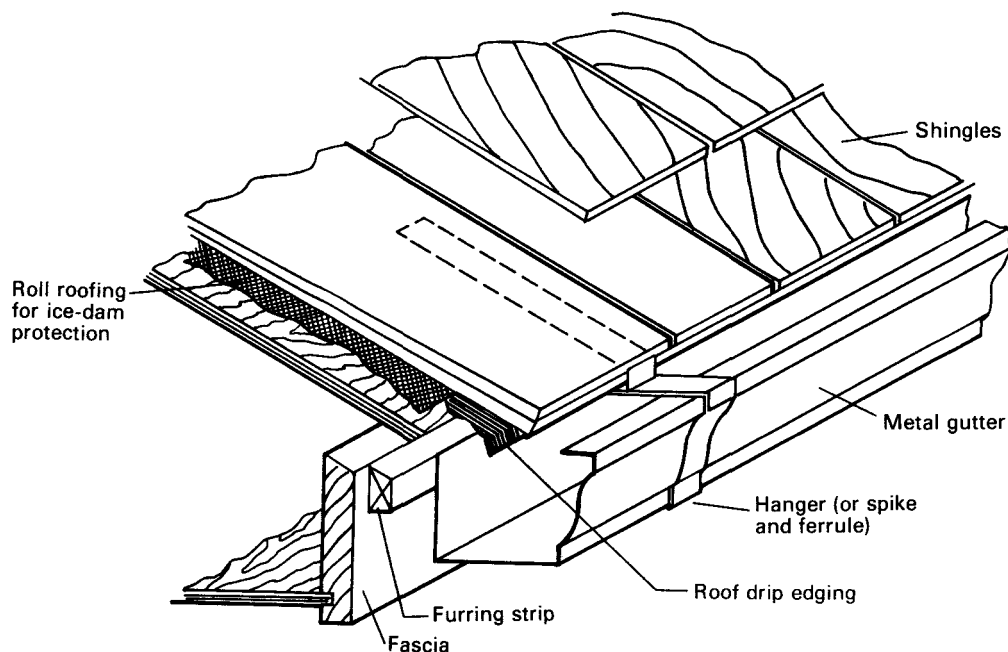
Louvered openings are generally provided in the end walls of gable roofs. These should be as close to the ridge as possible (fig. 99A). The net free area for the vent openings should be 1/300 of the ceiling area or as required by local code. For example, where the ceiling area equals 1,200 ft<sup>2</sup>, the minimal total net free area of the ventilators should be 4 ft<sup>2</sup>. Some building codes decrease the vent area requirements for ventilators located close to the ridge or cornice.

Various styles of gable end ventilators are available in metal and/or wood (fig. 100). One common type fits the slope of the roof and is located near the ridge (fig. 100A).

In metal, the vent is often adjustable to conform to the roof slope. In wood, it is enclosed in a frame and placed in the rough opening, much like a window frame (fig. 100B).

Houses with a wide roof overhang at the gable end can use an attic ventilation system consisting of a series of small vents or a continuous slot on the underside of the soffit areas, in lieu of gable vents (fig. 100F). Several large openings located near the ridge can also be used. This system is especially desirable on low-pitched roofs where standard gable ventilators may not be suitable.

**Figure 96 – Gutter installation.**



The roof framing at the wall line should not block ventilation to the attic area. Blockage can be avoided by use of a “ladder” frame extension (see fig. 126).

Air movement through gable vent openings depends primarily on wind direction and velocity. No appreciable movement can occur when there is no wind or when openings do not face the wind. Greater air movement can be obtained by providing openings in the soffit areas of the roof overhang in addition to openings at the gable ends or roof ridge. Minimum ventilation areas for this method are shown in figure 99B.

Where there are rooms in the attic with sloping ceilings under the roof, the insulation should follow the roof slope and be placed so that there is a free opening of at least 1½ inches between the roof sheathing and insulation for air movement (fig. 99C).

### ***Hip roofs***

Hip roofs should have air inlet openings in the soffit area of the eaves, and outlet openings at or near the peak. The differences in temperature between the attic and the outside will create an air movement independent of the wind, and more positive movement when there is wind.

As shown in figure 101A, minimum net free areas of vent openings are: 1 ft² at the ridge for each 300 ft² of ceiling; and 0.5 ft² of vent area in each soffit or at each eave for each 300 ft² of ceiling, provided the required

ridge venting area is at least 3 feet above the eave or cornice vent.

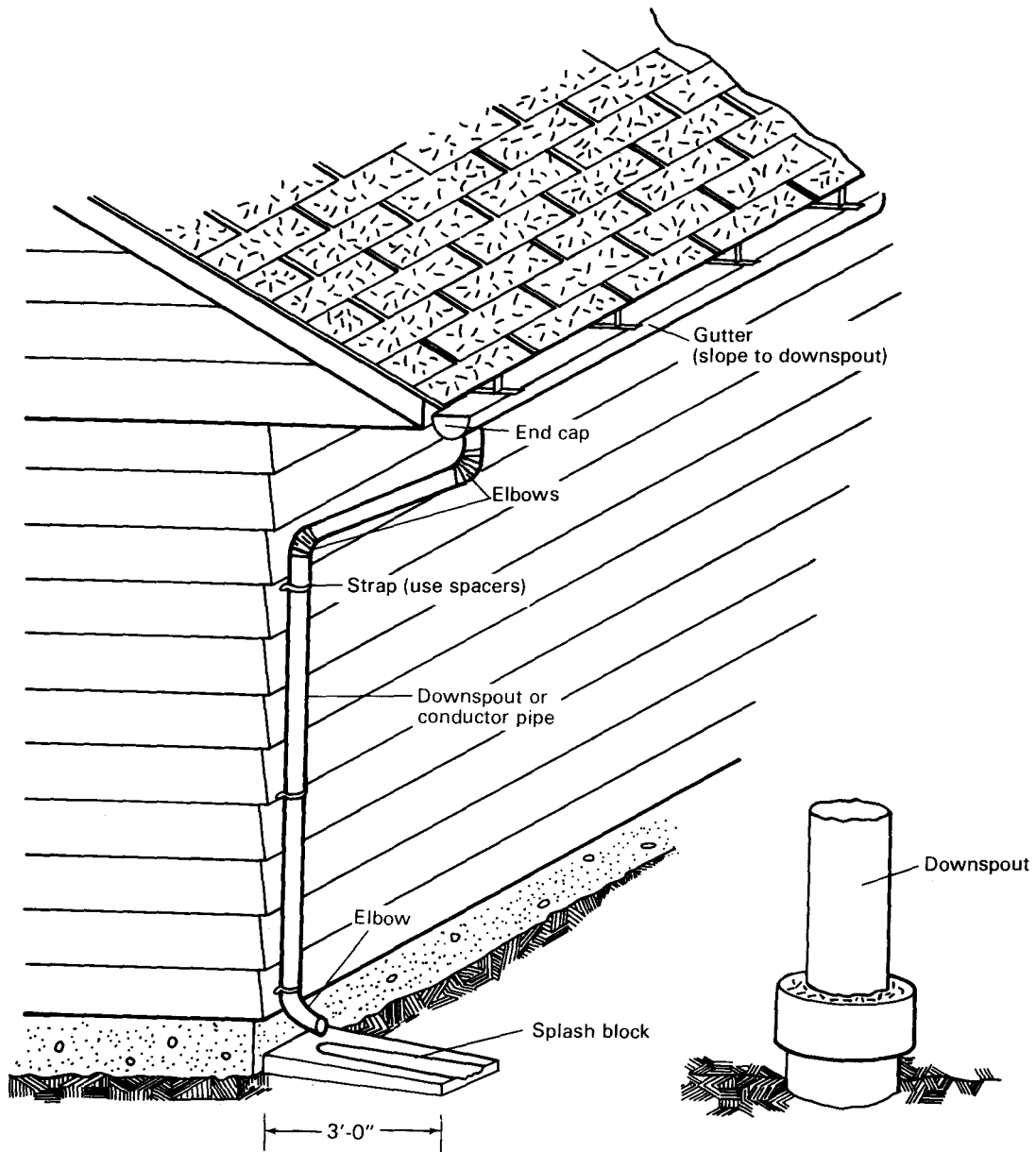
The most efficient type of inlet is the continuous slot, which should be at least ¾ inch wide. The air outlet opening near the peak can be a globe-type metal ventilator or several smaller roof ventilators near the ridge. These can be located below the peak on the rear slope of the roof, so they will not be visible from the front of the house. Gabled extensions of a hip roof house are sometimes used to provide efficient outlet ventilators (fig. 101B).

### ***Flat roofs***

A greater ratio of ventilating area is required in some types of flat roofs than in pitched roofs because air movement is less positive. There should be a clear open space above the ceiling insulation and below the roof sheathing to permit free air movement from inlet to outlet openings. Solid blocking should not be used for bridging or for bracing over bearing partitions if its use prevents air circulation.

A common type of flat or low-pitched roof is one in which the rafters extend beyond the wall, forming an overhang (fig. 102A). When soffits are used, this area can contain the combined inlet-outlet ventilators, preferably a continuous slot. When single ventilators are used, they should be distributed evenly along the overhang.

**Figure 97 – Downspout installation:**



**A, Downspout with splash block**

**B, Downspout connected directly to storm sewer**

The combination of a parapet-type wall and flat roof may be constructed with the ceiling joists separate from or combined with the roof joists. When members are separate, the space between can be used as an airway (fig. 102B). Inlet and outlet are then located as shown, or a series of outlet stack vents are used along the centerline of the roof in combination with the inlet vents. When ceiling joists and roof joists are served by one member in parapet construction, vents may be located as shown in figure 102C.

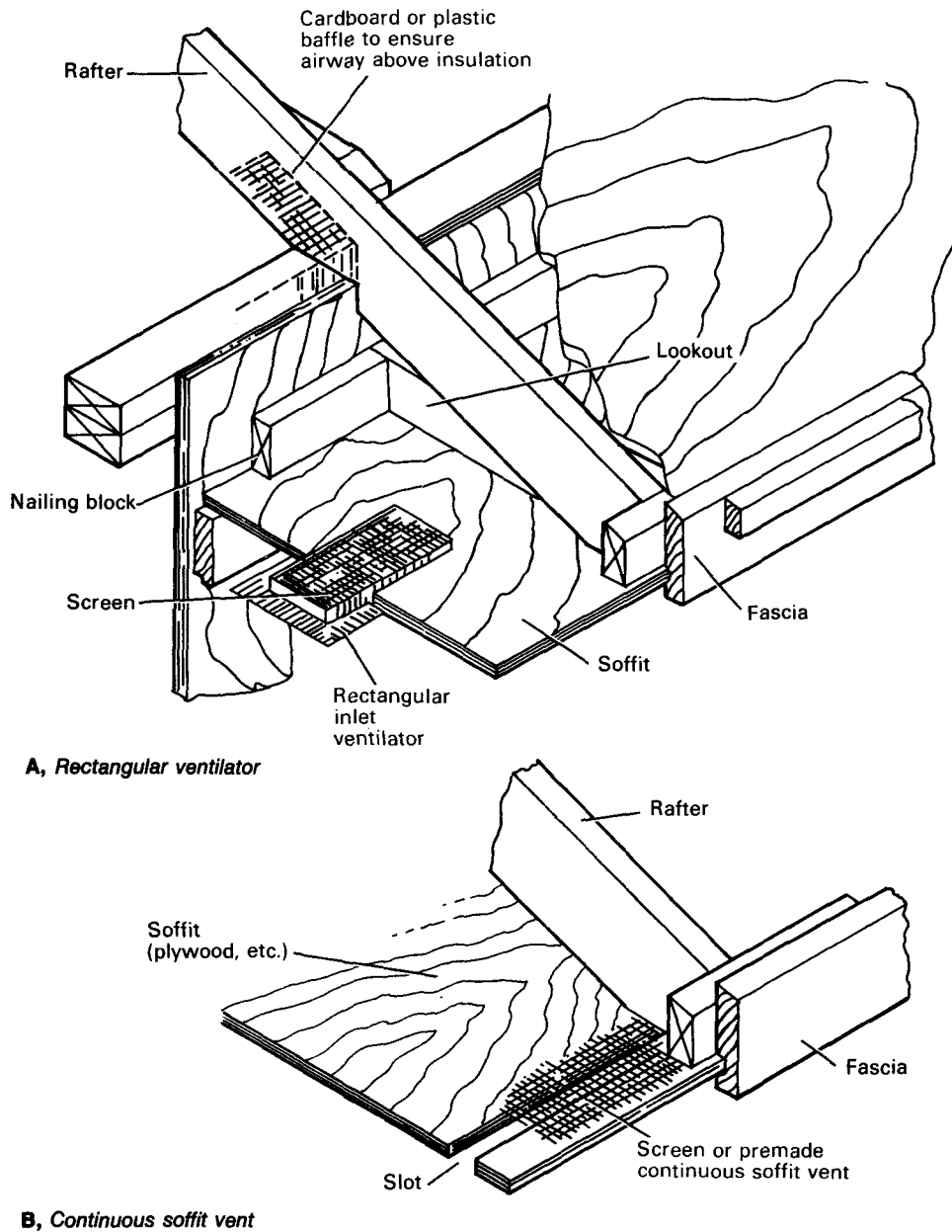
## Windows and Exterior Doors

Windows, exterior doors, and their frames are millwork items that are fully assembled and delivered to the building site ready for installation. Neither windows nor doors serve as structural elements of the house.

### Window materials and styles

Windows are available in many styles including single- or double-hung, casement, stationary (fixed), awning, and horizontal sliding (fig. 103). They can be made of wood,

**Figure 98 – Soffit inlet ventilators:**



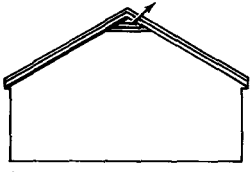
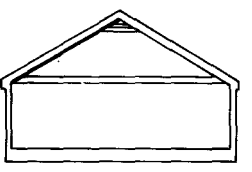
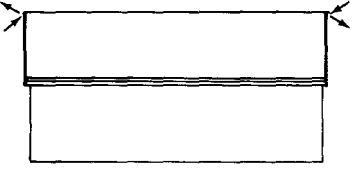
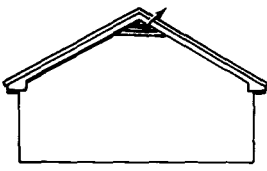
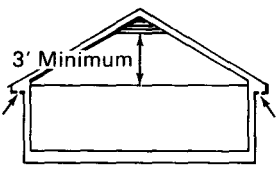
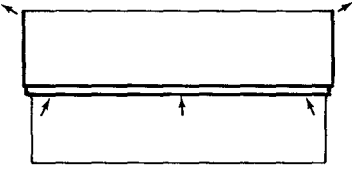
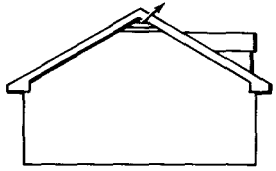
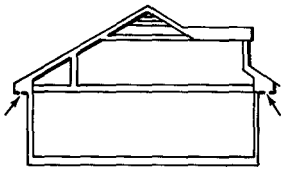
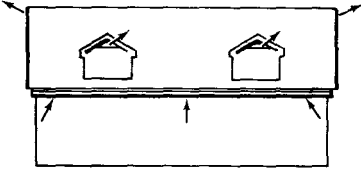
metal, or vinyl, or of wood or metal clad with vinyl. The window units may be purchased with either interior or exterior storm windows.

Glazing can consist of a single layer of glass or double- or triple-layer insulating glass. With insulating glass, the sheets of glass are separated by a space which is evacuated and hermetically sealed. This type of glass offers better resistance to the flow of heat out of the house in the winter and into the house in the summer. Glass may be tinted or coated to reduce the amount of heat from the sun that enters the house.

Wood window and door frames should be made from a clear grade of all-heartwood stock of a decay-resistant wood species. Such species include ponderosa and other pines, cedar, cypress, redwood, and spruce. Most manufacturers pretreat wood window and door frames with a water-repellent preservative for temporary protection.

Local suppliers of building products have manufacturers' catalogs, in which the various window styles, sizes, and glass types are specified. Catalog descriptions include the rough dimensions for the wall opening required to install each window unit and installation instructions.

Figure 99 – Ventilator areas for gable roofs:

			Ratio of total minimum net ventilator area to ceiling area	
			Inlet	Outlet
<p><b>End elevations</b></p>  <p><b>Cross sections</b></p>  <p><b>Side elevations</b></p> 			0	$\frac{1}{300}$
			(Combined)	
<p><b>End elevations</b></p>  <p><b>Cross sections</b></p>  <p><b>Side elevations</b></p> 			$\frac{1}{600}$	$\frac{1}{600}$
<p><b>End elevations</b></p>  <p><b>Cross sections</b></p>  <p><b>Side elevations</b></p> 			$\frac{1}{600}$	$\frac{1}{600}$

**A, Louvers in end walls**

**B, Louvers in end walls with additional openings in eaves and soffit.**

**C, Louvers at end walls with additional openings at eaves and dormers. Ratios of total minimum net ventilator area to ceiling area may be specified in local building codes**

Figure 100 – Outlet ventilators:

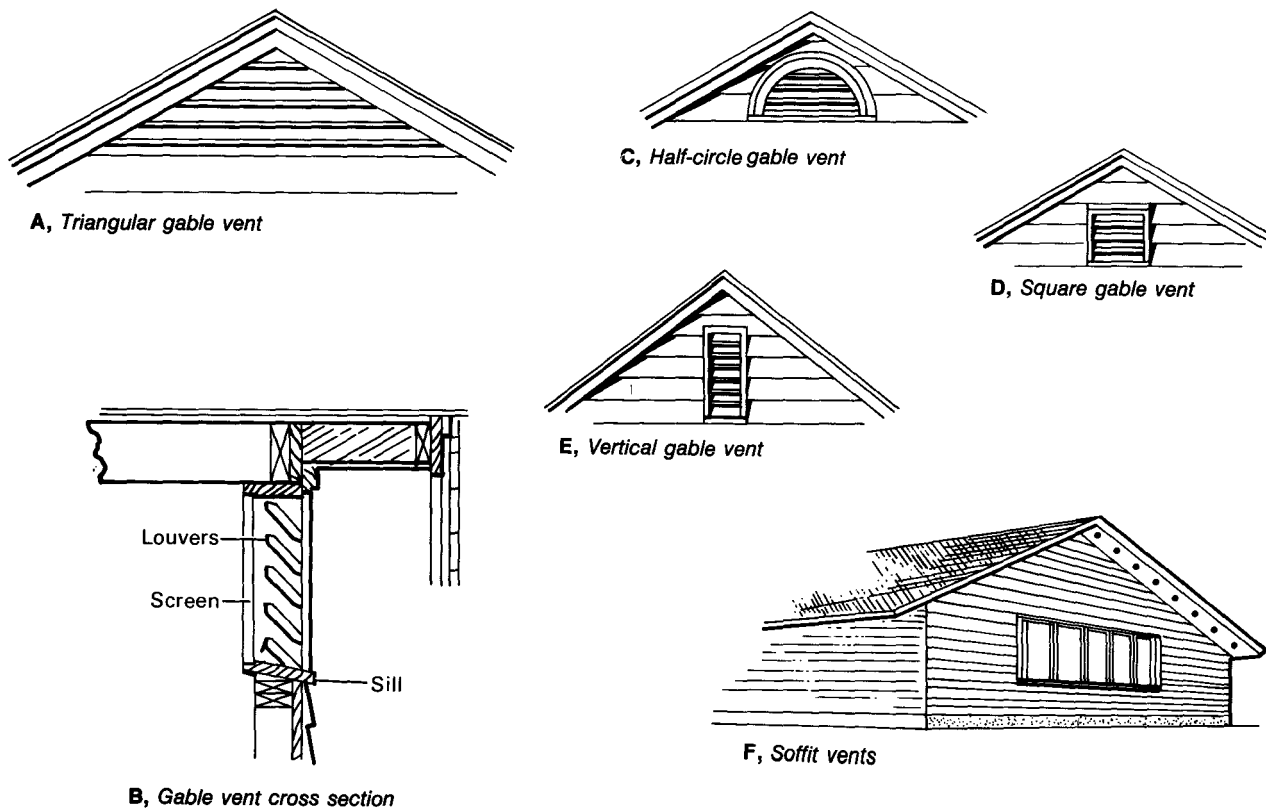


Figure 101 –Ventilator areas for hip roofs:

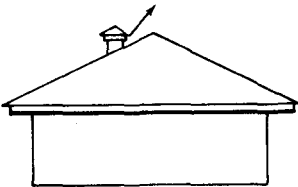
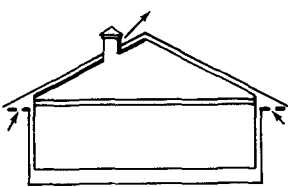
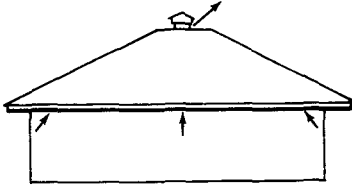
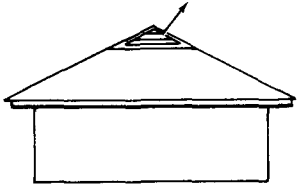
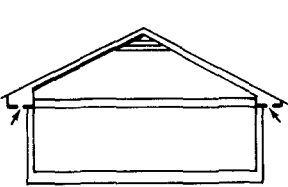
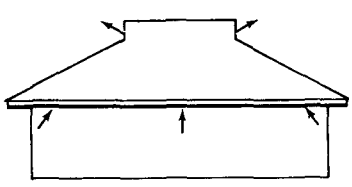

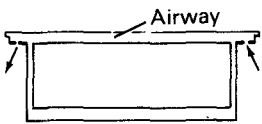
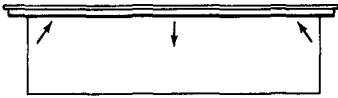
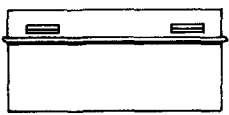
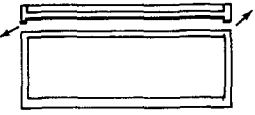
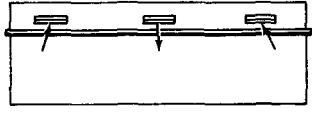
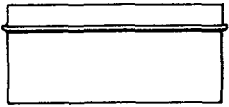
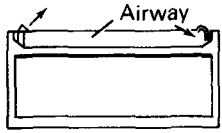
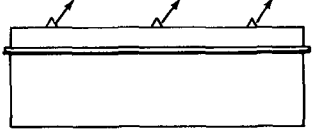
			Ratio of total minimum net ventilator area to ceiling area	
End elevations	Cross sections	Side elevations	Inlet	Outlet
			$\frac{1}{600}$	$\frac{1}{300}$
A, Inlet openings in eave soffit and outlet vent near peak.				
			$\frac{1}{600}$	$\frac{1}{600}$
B, Inlet openings in eave soffit and outlet vent at ridge. Ratios of total minimum net ventilator area to ceiling area may be specified in local building codes				

Figure 102 – Ventilator areas for flat roofs:

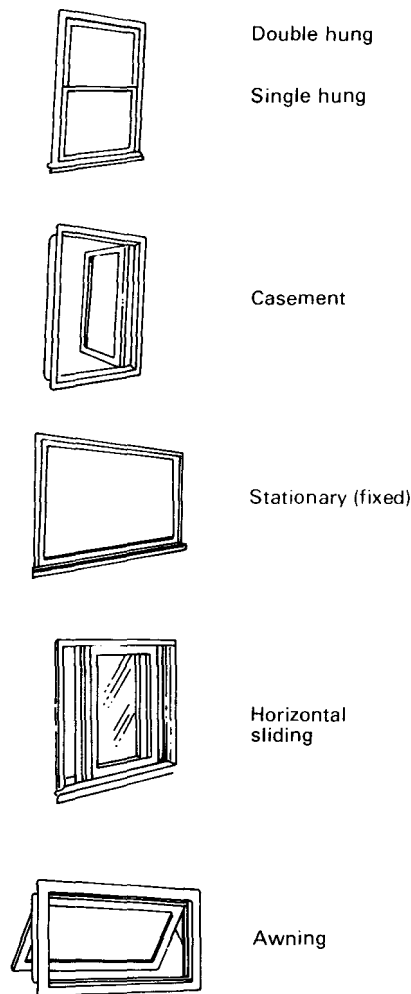
			Ratio of total minimum net ventilator area to ceiling area	
End elevations	Cross sections	Side elevations	Inlet	Outlet
			0 (Combined)	$\frac{1}{250}$
A, Vent openings in overhang soffit				
			0 (Combined)	$\frac{1}{300}$
B, Vent openings for roof with parapet where roof and ceiling joists are separate				
			$\frac{1}{600}$	$\frac{1}{600}$
C, Vent openings for roof with parapet where roof and ceiling joist are the same member				

Single- and double-hung windows

Single- and double-hung windows are the most common. In the single-hung style the upper sash does not

move; in the double-hung style both the upper and lower sash are free to slide vertically. In both styles, movable sashes are controlled by springs, balances or compression

**Figure 103 – Common window styles.**



**Table 12 – Multipliers for various vent coverings to determine net free-vent area**

Type of covering	Area of opening
¼-inch hardware cloth	1 x required net free area
¼-inch hardware cloth and rain louvers	2 x required net free area
⅛-inch mesh screen	1.25 x required net free area
⅛-inch mesh screen and rain louvers	2.25 x required net free area
⅛-inch mesh screen	2 x required net free area
⅛-inch mesh screen and rain louvers	3 x required net free area

weatherstripping to hold them at any position. Compression weatherstripping offers the added benefit of reducing air infiltration. Several manufacturers offer units that permit removal of movable sashes for easy painting, cleaning, and repair.

The glass in window sashes may be divided into two or more smaller sections by small wood members called

muntins. These smaller sections, or panes, of glass are called “lights.” A ranch-type house may look best with top and bottom sash divided into two horizontal lights. A colonial or Cape Code house may have each sash divided into six or eight lights. Some manufacturers provide preassembled dividers that snap into place over a single light, dividing it into two or more lights. These dividers may be made of plastic, wood, or metal. They give the appearance of muntins but can be removed for easier window cleaning.

Assembled frames are placed in the rough opening with the sash closed to maintain window unit squareness. The window unit should be leveled and plumbed before being nailed in place. Wedge-shape strips of wood shingles may be used as shims to hold the window unit in place during leveling and plumbing. The shims should be positioned under each point where nails will be driven so that the nails do not cause the window casing to bend (fig. 104).

Hardware consists of sash locks or fasteners located at the meeting rail. They lock the window and draw the sash together to provide a tight fit.

### *Casement windows*

Casement windows consist of side-hinged sashes, usually designed to swing outward because this type can be made more weathertight than the inswinging style. An advantage of the casement window over the double-hung type is that the entire window area can be opened for ventilation.

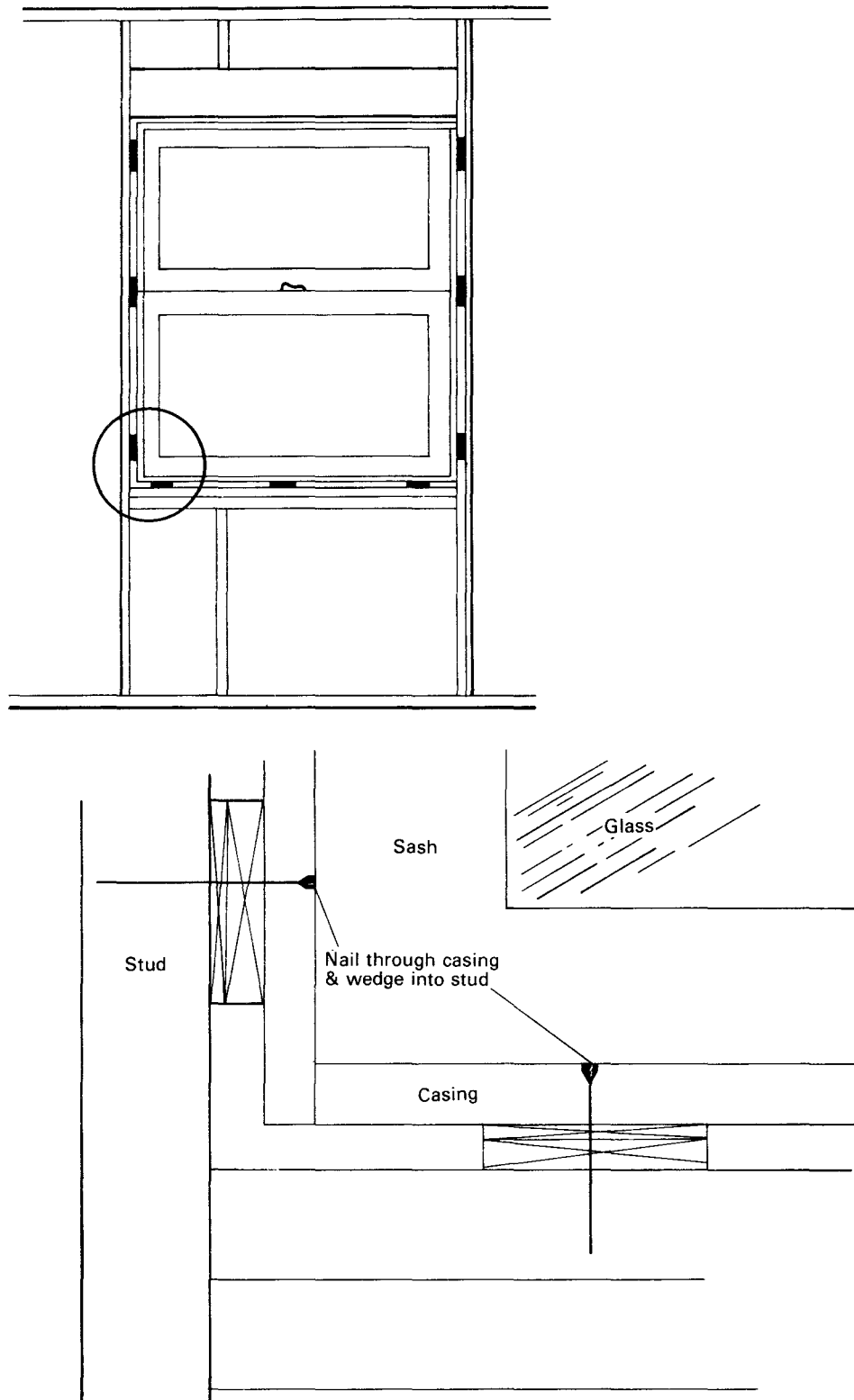
Units are usually received from the factory entirely assembled, with hardware (including weatherstripping) in place. Closing hardware consists of a rotary operator and sash lock. Style can be varied by divided lights. Snap-in muntins provide a small, multiple-pane appearance for traditional styling. Screens are located inside outswinging windows. Winter protection may be provided by storm sashes or by insulated glass in the sash.

Metal sashes are sometimes used in casements. Because of the low insulating value of the metal, condensation and frosting on the interior surfaces may occur during cold weather. A full storm window unit is sometimes necessary to eliminate this problem.

### *Stationary (fixed) windows*

Stationary windows, used alone in combination with vertical opening or casement windows, usually consist of a wood sash with a large single light of insulating glass, fastened permanently into the frame. Because their size may range up to 6 or 8 feet in width and because of the thickness of the insulating glass, 1¾-inch-thick sash is used to provide strength.

**Figure 104** – Installation of window unit in rough opening with detail at corner showing nailing.



In some instances, stationary glazing is installed without a sash. The glass is set directly into rabbeted frame members and held in place with stops. As with window sash

units, back puttying and face puttying of the glass provide resistance to moisture.

### *Awning windows*

An awning window unit consists of a frame that may contain one or more fixed sash, including sashes of the awning type that swing outward at the bottom. A similar unit, called the hopper type, is one in which the top of the sash swings inward. Both types provide protection from rain when open.

Operable sashes are provided with hinges, pivots, and sash-supporting arms. Weatherstripping, storm sashes, and screens may be provided. The storm sash is omitted when the windows are glazed with insulating glass. Jambs are usually  $1\frac{1}{16}$  inches thick, or more, because they are rabbeted, whereas the sill is at least  $1\frac{5}{16}$  inches thick when two or more sashes are used in a complete frame. Each sash may also be provided with an individual frame, so that any combination in width and height can be used.

### *Horizontal sliding window units*

With horizontal sliding windows, the sashes, in pairs, slide horizontally in separate tracks or guides located in the sill and head jambs. Multiple window openings, consisting of two or more single units, can be used when the effect desired is a wall of windows. The fully factory-assembled units include weatherstripping, water-repellent preservative treatments, and hardware.

### *Specialty windows*

Windows of various sizes and types may be grouped or ganged together to produce a pleasing effect architecturally. A common practice is to install a large stationary bay window with one smaller window unit at each side with movable sash. A wall of windows may be created by arranging awning window units three across and three high.

Certain specialty window designs protrude from the wall of the house. Installation may require special floor framing as shown in figure 39. Bow windows consist of four or five individual window units that form a curve. The box bay is formed with three window units. The side units are installed perpendicular to the plane of the wall and the third unit is installed parallel to the wall. The angled bay is similar to the box bay except the two side window units are installed at either  $45^\circ$  or  $30^\circ$  to the plane of the wall.

### *Sliding glass doors*

Sliding glass doors are similar to sliding windows in design and manufacture but are made from heavier material. They can be made with insulating glass, and frames can be made of wood or aluminum. The units can be used for architectural effect for rear or side doors when space is at a premium and/or more light is desired in a room.

### *Exterior doors and frames*

Exterior doors are manufactured products that can be ordered prehung in frames and fully weatherstripped from local building product suppliers. Exterior doors are commonly made of solid wood or metal skin. Metal skin doors are foam filled or contain a solid wood core. Most doors are equipped with compression weatherstripping similar to that used on refrigerator doors.

Detailed dimensions, rough opening requirements, and installation instructions are shown in catalogs available from local building product suppliers. Residential exterior doors are typically 6 feet 8 inches high. Main entrance doors are usually 3 feet wide; rear doors and service doors are usually 2 feet 8 inches wide. The most common exterior door thickness is  $1\frac{3}{4}$  inches. All exterior residential doors should open by swinging inward.

The two major door styles are flush and panel (fig. 105). The flush door has a smooth surface to which decorative molding can be applied and may have one or more glass areas called doorlights.

The panel door and its components are shown in figure 106. Panels may be replaced by glass to form doorlights.

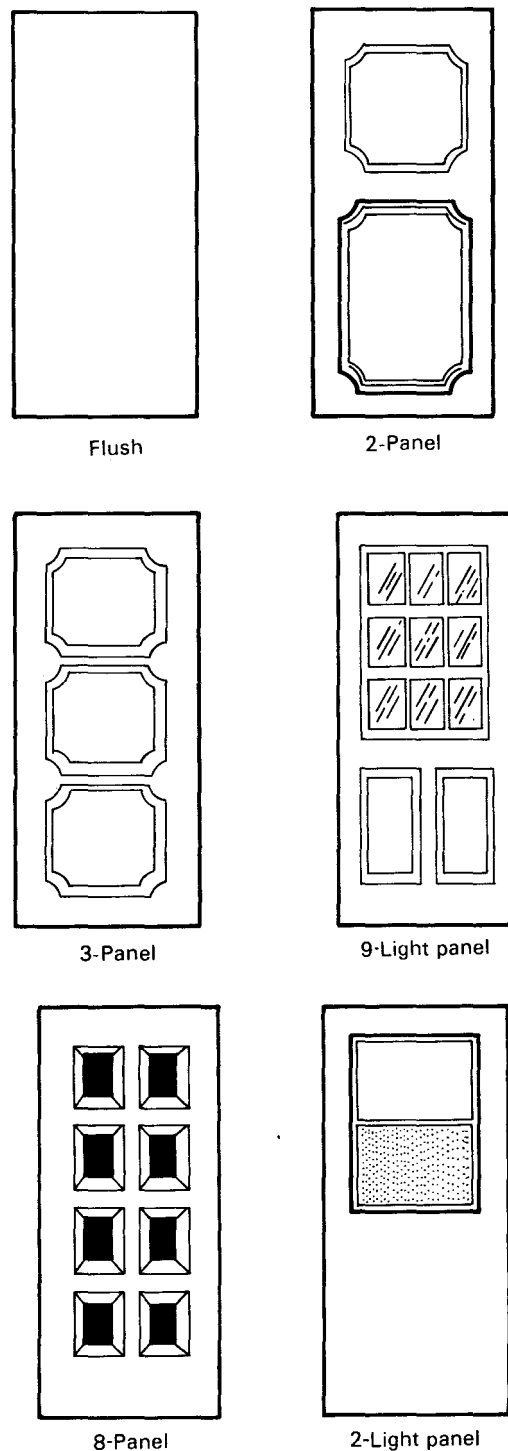
An option available with either type is a fixed pane window unit adjacent to the door, called a sidelight.

Installation of exterior doors begins with the setting of the unit (door, frame, and sill) in the rough opening. Space for the sill may have to be cut out of the floor sheathing and joists so that the top of the sill will be the correct distance above the rough floor to accommodate the finished floor covering. Once placed in the opening, the unit is centered and secured with a temporary brace. Blocks or wedges should be used to level the sill and to bring it to the proper height. A nail should be driven through the two side jambs near the bottom of the frame. Blocks or shingle wedges should then be used at the top of the side jambs to plumb and square the door frame. The frame should be secured by nailing through the side jambs and wedges. Additional blocks or wedges should then be nailed between the side jambs and studs to support the door frame and keep it straight.

### *Exterior Covering Materials*

Builders and homeowners have a wide choice of wood-base materials, masonry veneers, and metal or plastic sidings to cover exterior walls. Wood siding can be obtained in several different patterns and can be finished naturally, stained, or painted. Wood shingle, plywood, and hard-board are other types of wood and wood-based exterior siding. Coatings and films applied to base materials, or

Figure 105 – Common door styles.



certain base materials themselves (e.g., vinyl), postpone the need to refinish for many years.

**Wood siding**

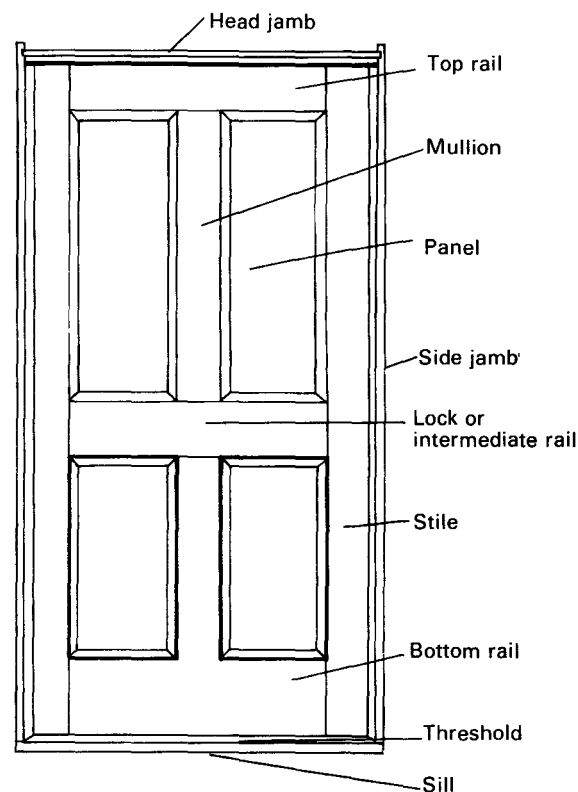
Important properties for wood siding include good painting characteristics, easy working qualities, and free-

dom from warp. Such properties are present to a high degree in cedars, eastern white pine, sugar pine, western white pine, cypress, and redwood; to a good degree in western hemlock, ponderosa pine, the spruces, and yellow-poplar; and to a fair degree in Douglas-fir, western larch, and southern pine.

Preferably, exterior siding that is to be painted should be of a high grade, and free from knots, pitch pockets, and waney edges. Edge grain (vertical grain) and mixed grain (in which some boards have edge grain and some have flat grain) are available in some species such as redwood and western redcedar. Siding is subject to seasonal movement caused by changes in moisture content. There is less movement in edge grain siding than in flat grain siding, and edge grain is therefore to be preferred. When the siding is to be painted, use of edge grain results in longer paint life.

Moisture content of the siding at the time of application should match the general level that is to be experienced in service. This is approximately 10 to 12 percent except in the dry southwestern states, where the moisture content averages about 8 to 9 percent.

Figure 106 – Panel door components.



### *Horizontal siding*

Several types of horizontal siding are shown in figure 107. They are described below.

**Bevel siding.** Plain bevel siding can be obtained from 4 to 8 inches wide  $\frac{1}{2}$ -inch butt thickness, or from 8 to 10 inches wide with  $\frac{3}{4}$ -inch butt thickness. "Anzac" siding is  $\frac{3}{4}$  inch thick by 12 inches wide. The finished width of bevel siding is usually about  $\frac{1}{2}$  inch less than the nominal size.

One side of bevel siding has a smooth planed surface while the other has a rough resawn surface. For a stained finish the rough or sawn side is exposed, because wood stain penetrates rough wood surfaces more fully and the staining therefore lasts longer.

**Drop siding.** Obtainable in several patterns, this siding, with tongue-and-groove or shiplap edges, can be obtained in 1- by 6-inch and 1- by 8-inch sizes. It is commonly used, usually without sheathing, for buildings without air-conditioning or heating and for garages. Tests conducted at the Forest Products Laboratory have shown that the tongue-and-groove patterns have greater resistance to the penetration of wind-driven rain than shiplap patterns.

**Hardboard lap siding.** This also is available, both primed and prefinished, in various widths. Installation should be performed in accordance with manufacturer's instructions regarding spacing, nailing, and finishing.

**Plywood and flakeboard.** These also are available as 6-, 8-, and 12-inch horizontal lap siding in thickness from  $\frac{1}{2}$  to  $\frac{5}{8}$  inch.

### *Siding for horizontal, vertical, and diagonal applications*

A number of sidings can be used horizontally, vertically, or diagonally. These are manufactured in nominal 1-inch thickness and in widths from 4 inches to 12 inches. Both matched and shiplap edges are available. The narrow and medium widths are likely to be more satisfactory where moisture content changes are moderate. When wide siding is used, vertical grain is desirable to reduce shrinkage. With tongue-and-groove siding, correct moisture content at the time of installation is particularly important because of possible shrinkage to a point where the tongue is exposed or even totally withdrawn from the groove.

Treating the edges of drop siding with water-repellent preservative usually prevents moisture penetration of the wood. In areas under wide overhang, or in porches or other protected sections, this treatment is less important.

### *Siding for vertical application*

A method of siding application popular for some architectural styles utilizes rough-sawn boards and battens applied vertically. These can be arranged in several ways: (a) board and batten, (b) batten and board, and (c) board and board (fig. 108). Nail vertical sidings to 2 by 4 horizontal wood blocking installed 16 to 24 inches on center between the studs.

### *Siding with sheet materials*

Sheet materials available for siding include plywood in a variety of face treatments and species, paper-overlaid plywood, and hardboard. Plywood or paper-overlaid plywood is often used without sheathing. Exterior grade particle-board and waferboard are also available for panel siding.

Sheets of these materials are usually 4 by 8 feet or longer. They are usually applied vertically, with intermediate and perimeter nailing to provide the desired rigidity. Some can be applied horizontally with appropriate vertical joint treatment. Most other methods of applying sheet materials require some type of sheathing beneath. Horizontal joints should be protected by a Z-flashing.

Exterior-type plywood should be used for siding. It can be obtained in such surfaces as grooved, brushed, or saw-textured. These surfaces are usually finished with some type of stain. If shiplap or matched edges are not provided, some method of providing a waterproof joint should be used. This often consists of applying caulking and a batten at each joint. A batten at each stud may be applied if closer spacing is desired for appearance. Another alternative is to install Z-flashing along the joint (see fig. 87). An edge treatment of water-repellent preservative also aids in reducing moisture absorption. A minimum  $\frac{1}{16}$ -inch edge and end spacing should be allowed for expansion when installing plywood in sheet form.

Paper-overlaid plywood provides a very satisfactory base for paint. A medium-density overlaid plywood is most commonly used.

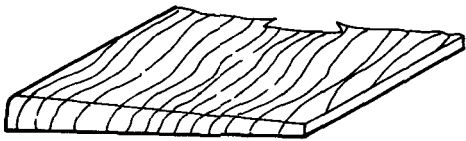
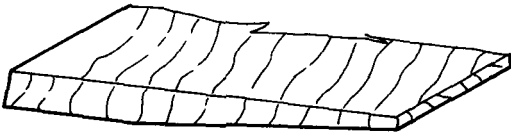
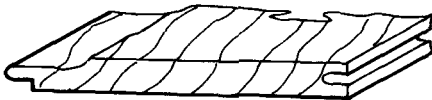

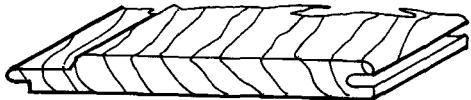

Hardboard sheets are applied in much the same way as plywood. Manufacturer's recommendations for installation should be followed.

Many of these materials resist the passage of water vapor. A well-installed vapor retarder should be applied on the warm side of the insulated walls when sheet materials are used for siding.

### *Wood shingles and shakes*

Wood shingles and shakes, discussed in the section on roof covering in chapter 3, can be used for siding on

Figure 107 – Common wood siding patterns.

	Type	Nominal sizes
	Bevel	$\frac{1}{2}$ x 4 to $\frac{3}{4}$ x 10
	"Anzac" (bevel)	$\frac{3}{4}$ x 12
	Drop (pattern 106)	1 x 6 to 1 x 8
	Drop (pattern 124)	1 x 6 to 1 x 8
<u>Horizontal application</u>		
	Paneling (WC 130)	1 x 4 to 1 x 12
	Paneling (WC 140)	1 x 4 to 1 x 12
<u>Horizontal or vertical application</u>		

many styles of house. In Cape Cod or colonial houses, shingles can be painted or stained. For ranch or contemporary designs, wide exposures of shingles or shakes often add a desired effect. They are easily stained.

**Grades and species.** Western redcedar, northern white-cedar, bald cypress, and redwood are commonly used for shingles. The heartwood of these species has a natural resistance to decay that is desirable, particularly if shingles are to remain unpainted or unstained.

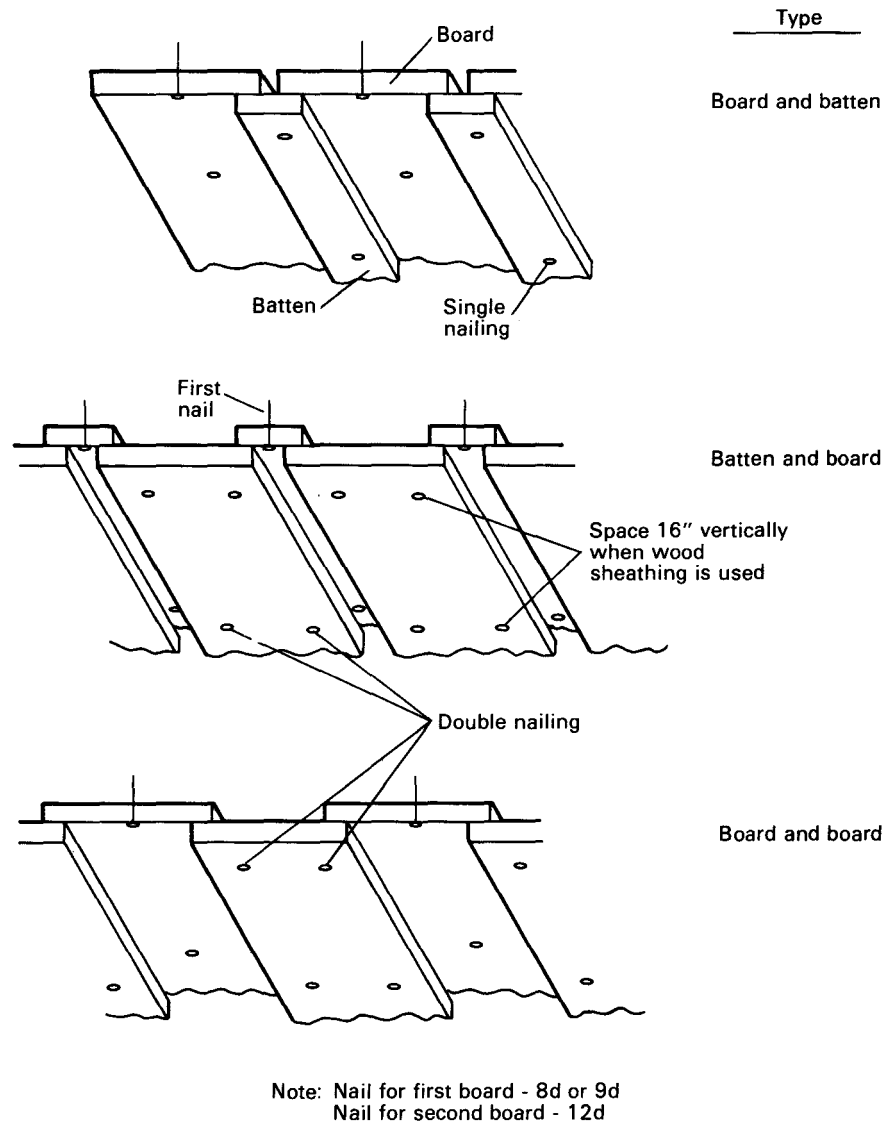
Western redcedar shingles can be obtained in three grades. The first grade (No. 1) is all heartwood, edge grain, and knot-free. It is primarily intended for roofs but is desirable in double-course side wall application where much of the face is exposed.

With second grade shingles (No. 2), three-fourths of the shingle length is blemish free. A 1-inch width of sapwood and mixed vertical and flat grain are permissible in this grade. No. 2 shingles are most often used in single-course application for side walls.

Third grade shingles (No. 3) are clear for 6 inches from the butt. Flat grain and greater widths of sapwood are permissible. No. 3 shingles are likely to be somewhat thinner than the first and second grades. They are used for secondary buildings, and sometimes as undercourse in double-course application.

A lower grade than the third grade, known as under-coursing shingles, is used only as the completely covered undercourse in double-course side wall applications.

**Figure 108** – Common vertical board siding patterns.



**Shingle sizes.** Wood shingles are available in three standard lengths—16, 18, and 24 inches. The thickness of 16-inch-length shingle is five butt thicknesses per 2 inches when green (designated a 5/2). These shingles are usually packed in bundles with 20 courses on each side. Four such bundles cover 100 ft<sup>2</sup> (one square) of wall or roof with an exposure of 5 inches. The 18-inch and 24-inch-length shingles have thicker butts, five in 2¼ inches for the 18-inch shingles and four in 2 inches for the 24-inch lengths.

Shakes are usually available in several types, the most popular being split and resawn. The sawed face is used as the back face. Butt thickness varies from ¾ inch to 1½ inches. They are usually packed in bundles of 20 ft<sup>2</sup> so that five bundles cover one square.

### *Other exterior finishes*

Nonwood materials such as vinyl and metal sidings are used in some types of architectural design. Stucco or cement plaster, preferably over a wire mesh base, are most often seen in the southwest and on the West Coast. Masonry veneers can be used in combination with wood siding in various finishes to enhance the appearance of both materials.

### **Exterior Covering Installation**

Corrosion-resistant nails made, for example, of galvanized steel, stainless steel, or aluminum, should be used to install siding. Ordinary steel-wire nails tend to rust in a short time and can cause disfiguring stains on the face of the siding. In some cases, small-head nails will show rust spots through putty and paint.

Two types of nails are commonly used with siding: finishing nails with small heads and siding nails with moderate-sized flat heads. Finishing nails should be set (driven with a nail set) about  $\frac{1}{16}$  inch below the face of the siding and the hole filled with putty after the prime coat of paint is applied. Flathead nails should be driven flush with the face of the siding and the head later covered with paint.

In some types of prefinished sidings, nails with color-matched heads are supplied.

Nails with modified shanks can be used. These include annularly threaded shank (ring shank) nails and helically threaded shank nails. Both have greater withdrawal resistance than smooth shank nails and, for this reason, a shorter nail can be employed.

Exposed nails should be driven just flush with the surface of the wood. Overdriving may produce hammer marks and may split and crush the wood. In sidings with prefinished surfaces or overlays, the nails should be driven so as not to damage the finished surface.

### *Bevel siding*

The lap for bevel siding should not be less than 1 inch. Average exposure distance is usually determined by the distance from the underside of the window sill to the top of the drip cap (fig. 109). For weather resistance and appearance, the butt edge of the first course of siding above the window should coincide with the top of the window drip cap. In many one-story houses with an overhang, this course of siding is often replaced with a frieze board. It is also desirable that the bottom of a siding course be flush with the underside of the window sill. However, this may not always be possible because of varying window heights and types.

One system for determining siding exposure width so that it is about equal above and below the window sill is as follows. Divide the overall height of the window frame by the approximate, recommended exposure distance for the siding used (4 for 6-in siding, 6 for 8-in siding, 8 for 10-in siding, and 10 for 12-in siding). This gives the number of courses between the top and bottom of the window. For example, if the overall height of a window from the top of the drip cap to the bottom of the sill is 61 inches, and 12-inch siding is used, the number of courses would be  $61/10 = 6.1$  or slightly more than six courses. To obtain the exact exposure distance, divide 61 by 6 =  $10\frac{1}{6}$  inches. The next step is to determine the exposure distance from the bottom of the sill to just below the top of the foundation wall. If this is 31 inches, three courses at  $10\frac{1}{3}$  inches each would be used, and the exposure distance above and below the window would be about the same.

When this system is not satisfactory because of large differences in the two areas, an equal exposure distance for the entire wall height should be used and the siding at the window sill notched. The fit should be tight to prevent moisture entry.

Installation should begin at the bottom course. It is normally blocked out with a starting strip of the same thickness as the top of the siding board. Each succeeding course should overlap the upper edge of the lower course. Siding should be nailed to each stud with a  $1\frac{1}{2}$  inch minimum stud penetration. When plywood or wood is used over nonwood sheathing, 7d or 8d nails ( $2\frac{1}{4}$  in and  $2\frac{1}{2}$  in long) may be used when siding is  $\frac{3}{4}$  inch thick and nails  $\frac{1}{4}$  inch shorter when siding is  $\frac{1}{2}$  inch thick.

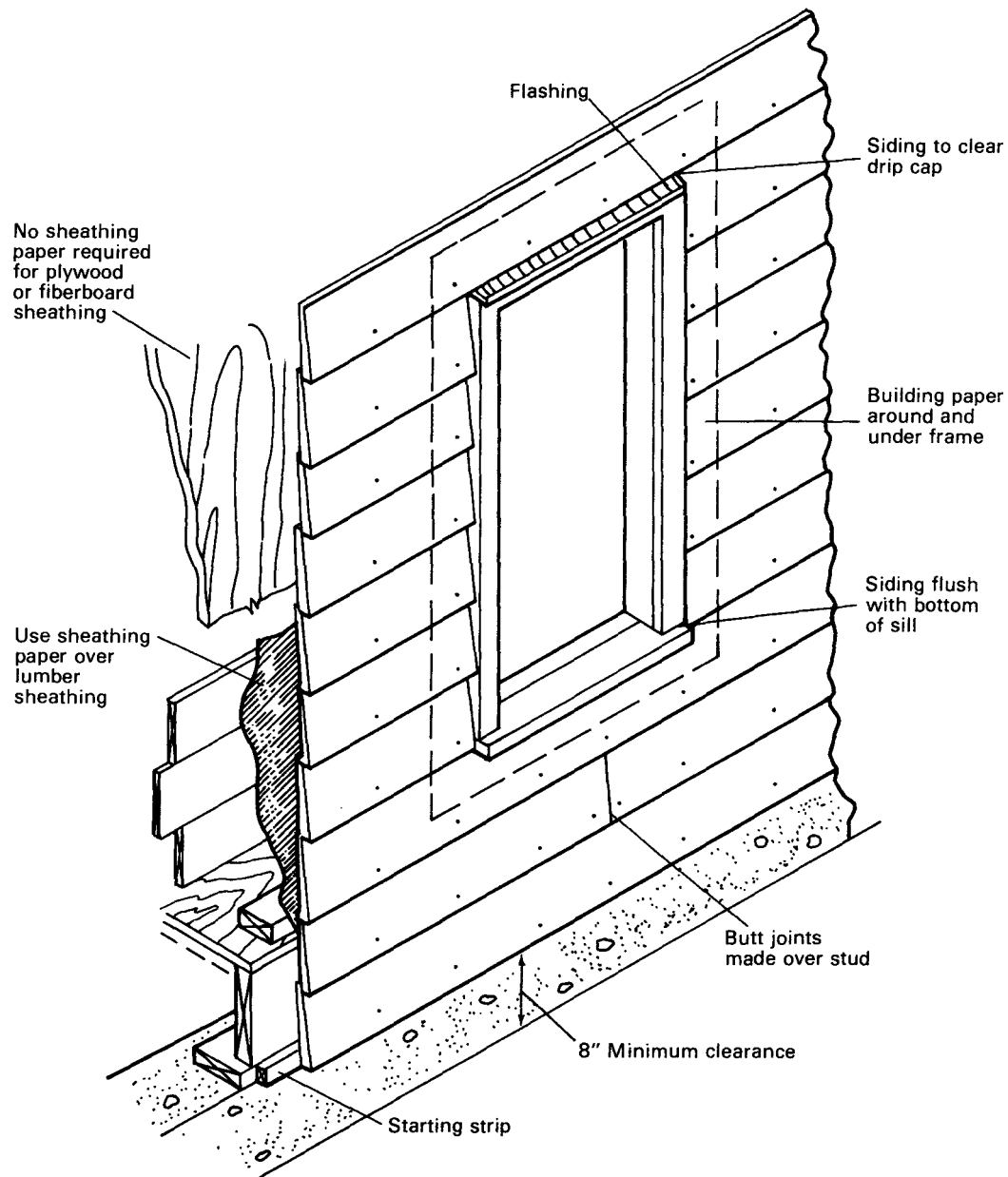
If rigid foam, gypsum, or non-nail-base fiberboard sheathing is used, the nail lengths must be adjusted to account for the thickness of the sheathing. Guidelines have been issued by the National Forest Products Association that deal with the nailing of wood bevel siding and hardboard lap siding over rigid foam sheathing. For  $\frac{1}{2}$ -inch wood bevel siding installed over  $\frac{1}{2}$ -inch rigid foam sheathing, a 9d ( $2\frac{3}{4}$ -in) smooth shank or a 7d ( $2\frac{1}{4}$ -in) ring shank wood siding nail is recommended. If  $\frac{3}{4}$ -inch rigid foam sheathing is used the nail sizes should be increased to a 10d (3-in) smooth shank or 8d ( $2\frac{1}{2}$ -in) ring shank. When  $\frac{3}{4}$ -inch wood bevel siding is installed over  $\frac{1}{2}$ -inch rigid foam sheathing the wood siding nail sizes recommended are 10d smooth shank or 8d ring shank. If  $\frac{3}{4}$ -inch rigid foam sheathing is used, the nail sizes should be increased to 12d ( $3\frac{1}{4}$ -in) smooth shank or 9d ring shank. The recommendation for  $\frac{7}{16}$ -inch hardboard lap siding installed over either  $\frac{1}{2}$ -inch or  $\frac{3}{4}$ -inch rigid foam sheathing is to use a 10d smooth shank hardboard siding nail.

Nails should be located far enough up from the bottom edge of the siding to miss the top edge of the lower siding course (fig. 110A). The clearance distance is usually  $\frac{1}{8}$  inch. This will permit slight movement of the siding resulting from moisture changes without causing splitting. Such an allowance is particularly important for the wider sidings of 8 inches to 12 inches.

It is good practice to avoid butt joints whenever possible. Longer sections of siding should be used under windows and for other long stretches. Shorter lengths should be used for areas between windows and doors. Where butt joints are unavoidable, they should be made over a stud and staggered between courses as much as possible.

Siding should be square-cut to provide good joints at windows and door casings and at butt joints. Open joints permit moisture to enter, often leading to paint deterioration. It is good practice to brush or dip the fresh-cut ends of the siding in a water-repellent preservative before

**Figure 109** – Installation of bevel pattern wood siding.



boards are nailed in place. Water-repellent preservative can be applied to end and butt joints after siding is in place by use of a small finger-actuated oil can.

#### ***Drop and similar sidings***

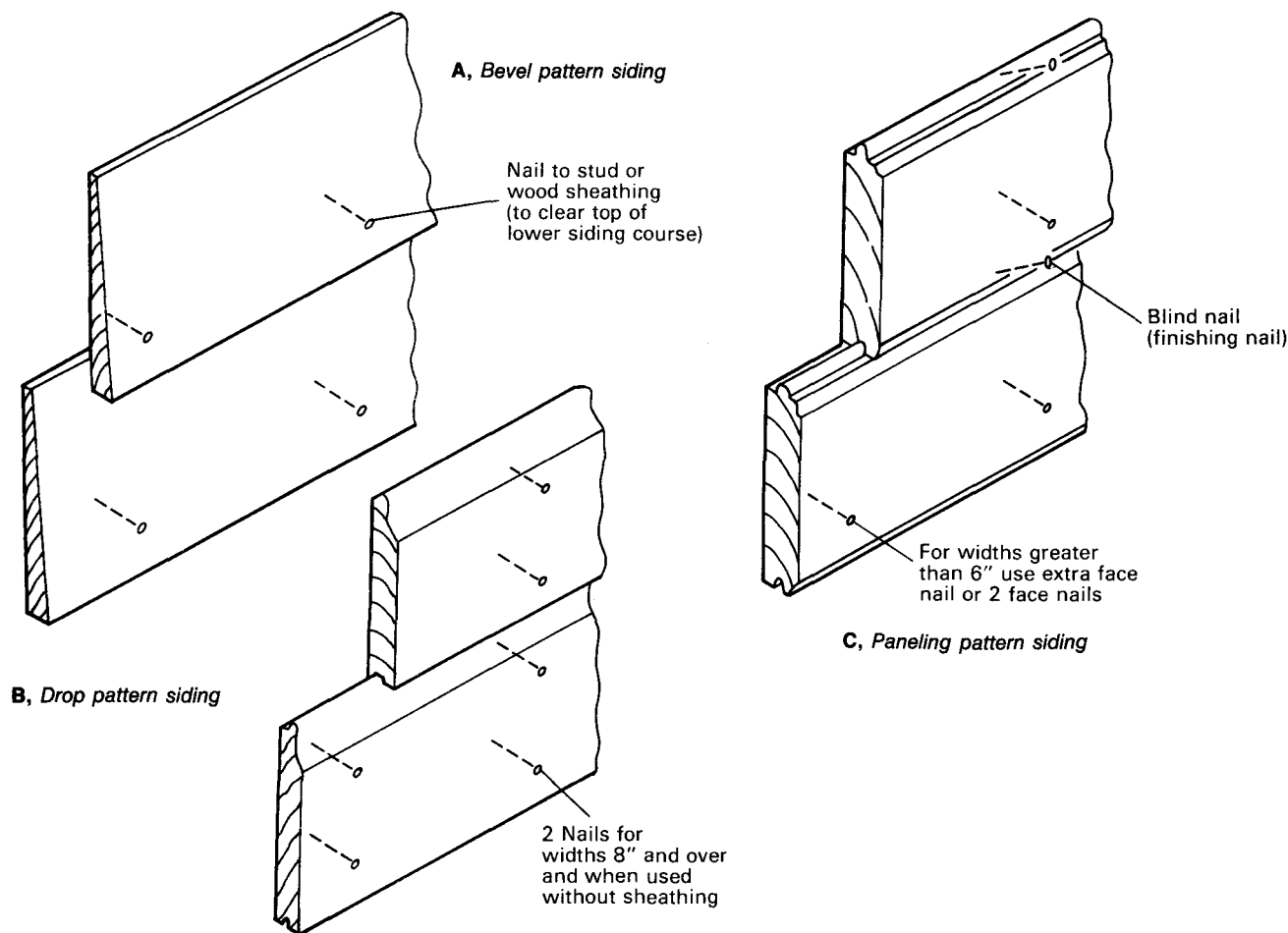
Drop siding is installed in much the same fashion as lap siding except for spacing and nailing. Drop sidings have a constant exposure distance. Face width is normally  $5\frac{1}{4}$  inches for 1- by 6-inch siding and  $7\frac{1}{4}$  inches for 1- by 8-inch siding. One or two 8d nails should be used at each stud crossing, depending on the width (fig. 110B and C). Two nails are used for widths greater than 6 inches.

Other materials that are used horizontally in widths up to 12 inches, such as plywood, hardboard, or medium-density fiberboard, should be applied in the same manner as lap or drop siding, depending on the pattern. Prepackaged siding should be applied according to manufacturer's instructions.

#### ***Vertical and diagonal siding***

Diagonally applied matched and similar siding having shiplap or tongue-and-groove joints is nailed to the studs in the same manner as when such materials are applied horizontally. When applied vertically, these sidings should

Figure 110 – Nailing of wood siding:



be nailed to blocking inserted between studs. Blocking is installed horizontally between studs and spaced from 16 inches to 24 inches apart.

When various combinations of boards and battens are used, they also should be nailed to horizontal blocking spaced from 16 to 24 inches apart between studs. The first boards or battens should be fastened with one 8d or 9d nail at each block to provide at least 1½-inch penetration. For wide underboards, two nails spaced about 2 inches apart may be used rather than a single row along the center. The second or top boards or battens should be nailed with 12d nails. Nails in the top board or batten should miss the underboards and not be nailed through them. Double nails should be spaced closely to prevent splitting if the board shrinks.

#### *Plywood and other sheet sidings*

Exterior-type plywood, paper-overlaid plywood, structural flakeboard, hardboard, and similar sheet materials used for siding are usually applied vertically, although some plywood siding may be applied horizontally. All

nailing should be over studs and effective penetration into wood should be at least 1½ inches.

Plywood should be nailed at 6-inch intervals around the perimeter and at 12-inch intervals at intermediate members. All types of sheet material should have joints caulked unless the joints are of the overlapping or matched type or unless battens are installed. For all sheet siding materials, manufacturer's recommended installation and finishing procedures should be followed.

#### *Corner treatment*

The method of finishing wood siding or other materials at exterior corners is often influenced by the overall design of the house. The ends of the siding can be mitered as in figure 111A.

A mitered corner effect (fig. 111B) on horizontal siding can be obtained by using metal comers at each course. Metal comers are easily placed over each corner as the siding is installed. They should fit tightly without openings and should be nailed on each side to the sheathing or

comer stud beneath. Most metal comers are made of aluminum and need no added treatment before painting. Those made of galvanized steel should be cleaned with a mild acid wash and primed with a metal primer before the house is painted, to prevent early peeling of the paint. Weathering of the metal also prepares it for the prime paint coat.

Comer boards of various types and sizes can be used for horizontal sidings of all types (fig. 111C) They also provide a satisfactory termination for plywood and similar sheet materials. Comer boards are usually nominal 1-inch material and for purposes of appearance can be quite narrow.

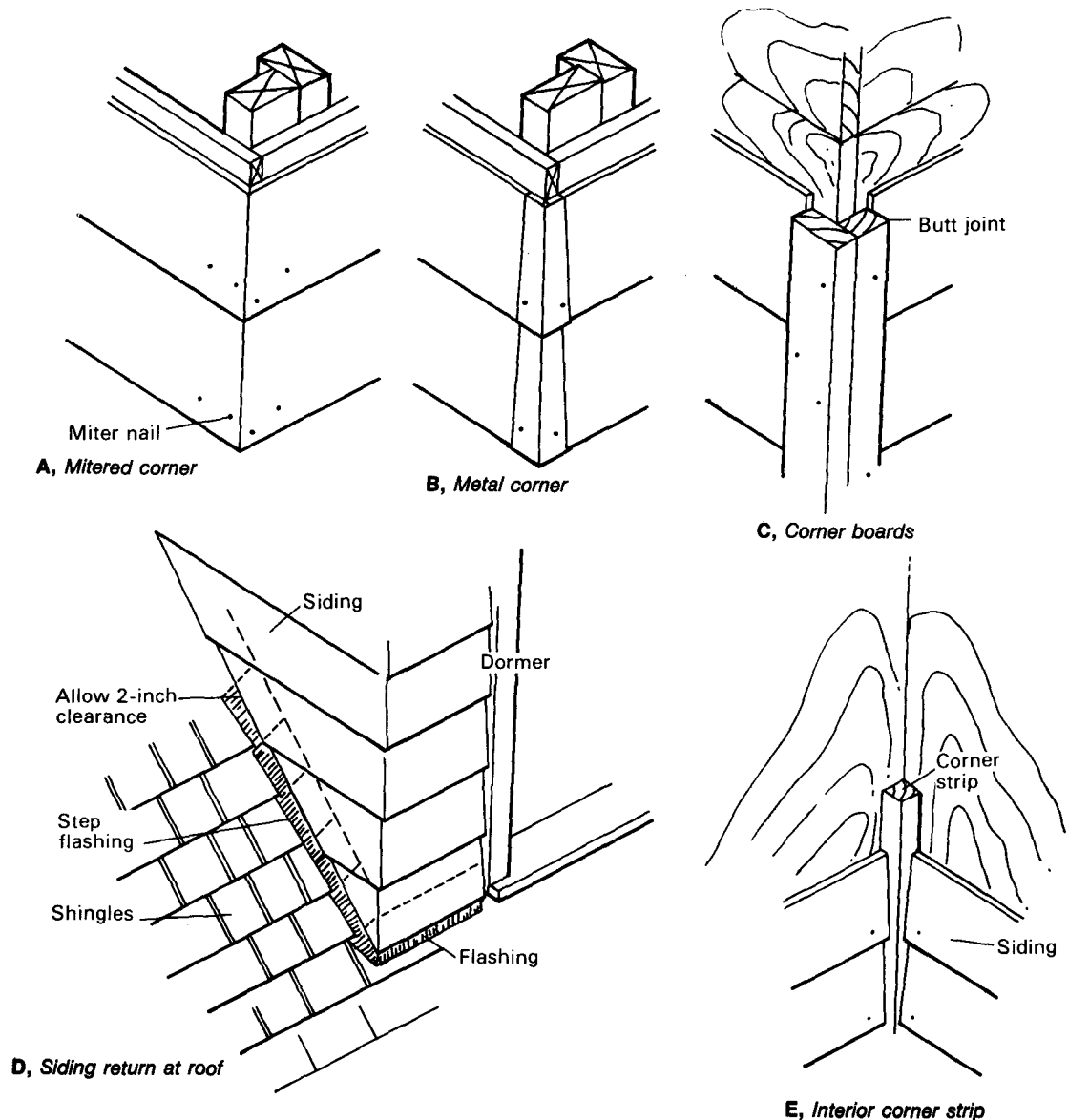
Color-matched metal comers can be used with prefinished shingle or shake exteriors. Such comers can also be

lapped over the adjacent comer shingle, alternating each course. This is called "lacing." This type of comer treatment usually requires that flashing be used beneath.

When siding returns against a roof surface, as at a dormer, there should be a clearance of about 2 inches (fig. 111D). Siding cut and installed tightly against the shingles retains moisture after rains and usually results in paint peeling. Shingle flashing extending well up on the dormer wall provides the necessary resistance to entry of rain. A water-repellent preservative should be used on the ends of the siding at the roofline.

Interior comers (fig. 111E) are butted against a square comer board of nominal 1¼-inch or 1⅜-inch size, depending on the thickness of the siding.

**Figure 111—Siding installation details:**



### ***Material transition***

Different materials may be used involving different methods of application in the gable ends and in the walls below. Good drainage should be assured at the juncture of the two materials. For example, if vertical boards and battens are used at the gable end and horizontal siding below, a drip cap or similar molding could be used (fig. 112). Flashing should be used over and above the drip cap so that dropping moisture clears the gable material. Alternatively, good drainage can be provided by extending the plate and studs of the gable end out from the wall a short distance, or by the use of furring strips to project the gable siding beyond the wall siding (fig. 113).

### ***Wood shingles and shakes***

Wood shingles and shakes are applied in a single-course or double-course pattern. They can be used over wood or plywood sheathing. If sheathing is  $\frac{3}{8}$ -inch plywood, threaded nails should be used. For nonwood sheathing, 1- by 3-inch or 1- by 4-inch wood nailing strips should be used as a base.

In the single-course application pattern, one course is laid over the other in a manner similar to siding. The shingles can be second grade because only half or less of the butt

portion is exposed (fig. 114). Shingles should not be soaked before application but should generally be laid up with about  $\frac{1}{8}$ -inch to  $\frac{1}{4}$ -inch space between adjacent shingles to allow for expansion during rainy weather. To obtain an effect similar to siding, the shingles should be laid up so that the edges are lightly in contact. Prestained or pretreated shingles provide the best results for this system.

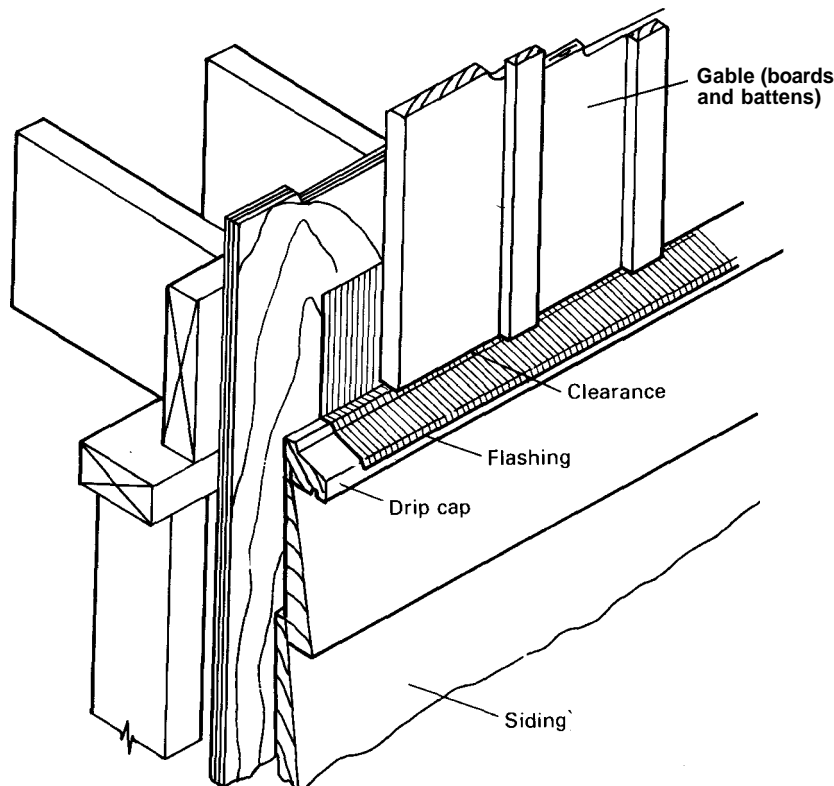
In the double-course pattern, the undercourse is applied over the wall, and the top course is nailed directly over the undercourse, with a  $\frac{1}{4}$ -inch to  $\frac{1}{2}$ -inch projection of the butt below the butt of the undercourse (fig. 115). The first course should be nailed only enough to hold it in place while the outer course is being applied. The first shingles can be third grade or undercourse grade. The top course should be first grade.

Exposure distance for various length shingles and shakes can be guided by the recommendations in table 13.

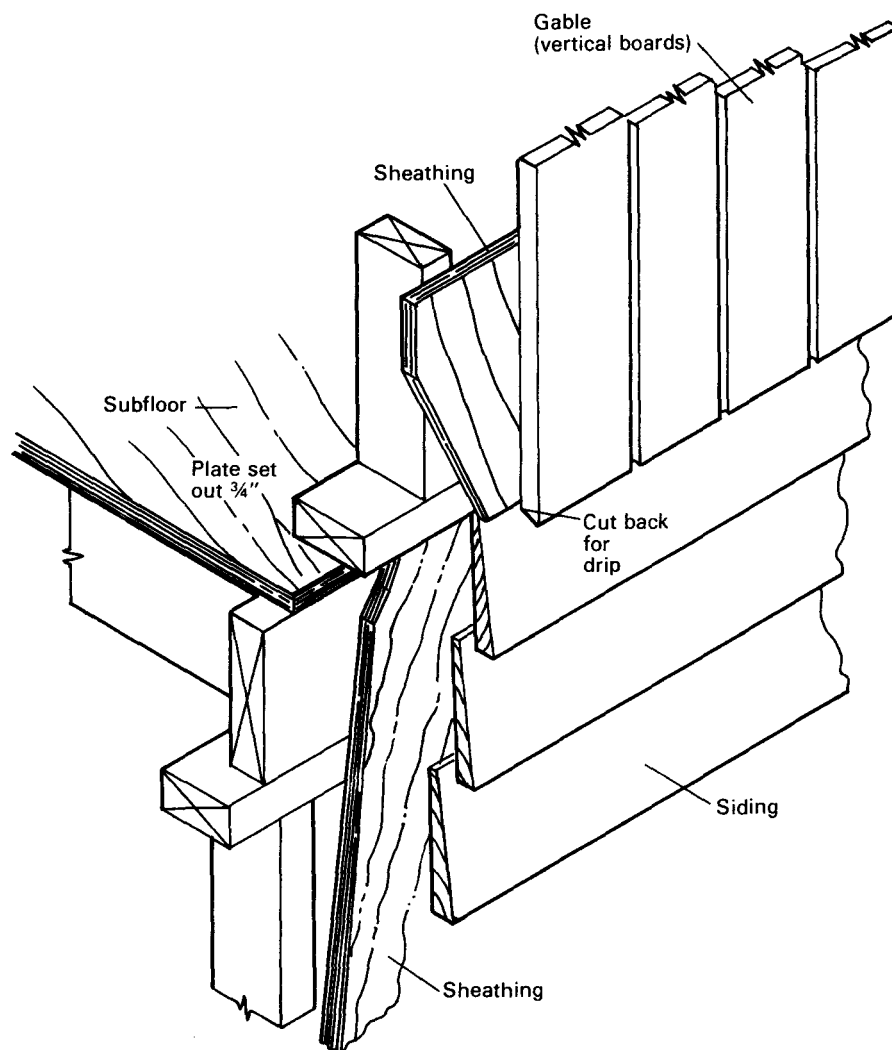
As with roof shingles, joints in the upper and lower course should be arranged so that edge joints of the upper shingles are at least  $1\frac{1}{2}$  inches from those of the shingles beneath.

Closed or open joints can be used in the application of shingles to side walls at the discretion of the builder. Spacing of  $\frac{1}{4}$  inch to  $\frac{3}{8}$  inch produces an individual

**Figure 112** – Siding transition at gable end.



**Figure 113** – Gable end siding projected to form drip edge without flashing.



effect, while close spacing produces a shadow line similar to bevel siding.

Shingles and shakes should be applied with rust-resistant nails long enough to penetrate into the wood backing strips or sheathing. In single coursing, a 3d or 4d galvanized “shingle” nail is commonly used. In double coursing, where nails are exposed, a 5d galvanized nail with a small flat head should be used for the top course and 3d or 4d size for the undercourse.

Nails should be placed  $\frac{3}{4}$  inch from the edge of the shingle. Two nails should be used for shingles up to 8 inches wide and three nails for shingles over 8 inches. In single-course applications, nails should be placed 1 inch above the butt line of the next higher course (fig. 114). In double coursing, the use of a piece of shiplap sheathing as a guide allows the upper course to extend  $\frac{1}{2}$  inch below the undercourse, producing a shadow line (fig. 115).

Nails should be placed 2 inches above the bottom of the shingle or shake. Rived or fluted processed shakes, usually factory-stained, produce a distinct effect when laid with closely fitted edges in a double-course pattern.

### *Stucco finish*

Stucco finishes are applied over a coated, expanded metal lath and, usually, over some type of sheathing. In some areas where local building regulations permit, such a finish can be applied to metal lath fastened directly to the braced wall framework. Waterproof paper should be used over the studs before the metal lath is applied.

When stucco is applied to platform-framed two-story houses, shrinkage of joists and sills may cause unsightly bulges or breaks in the stucco unless joists have reached moisture equilibrium. Proper moisture content of the framing members is important when this type of finish is used.

Figure 114 – Single-course application of wood shingles or shakes on side wall.

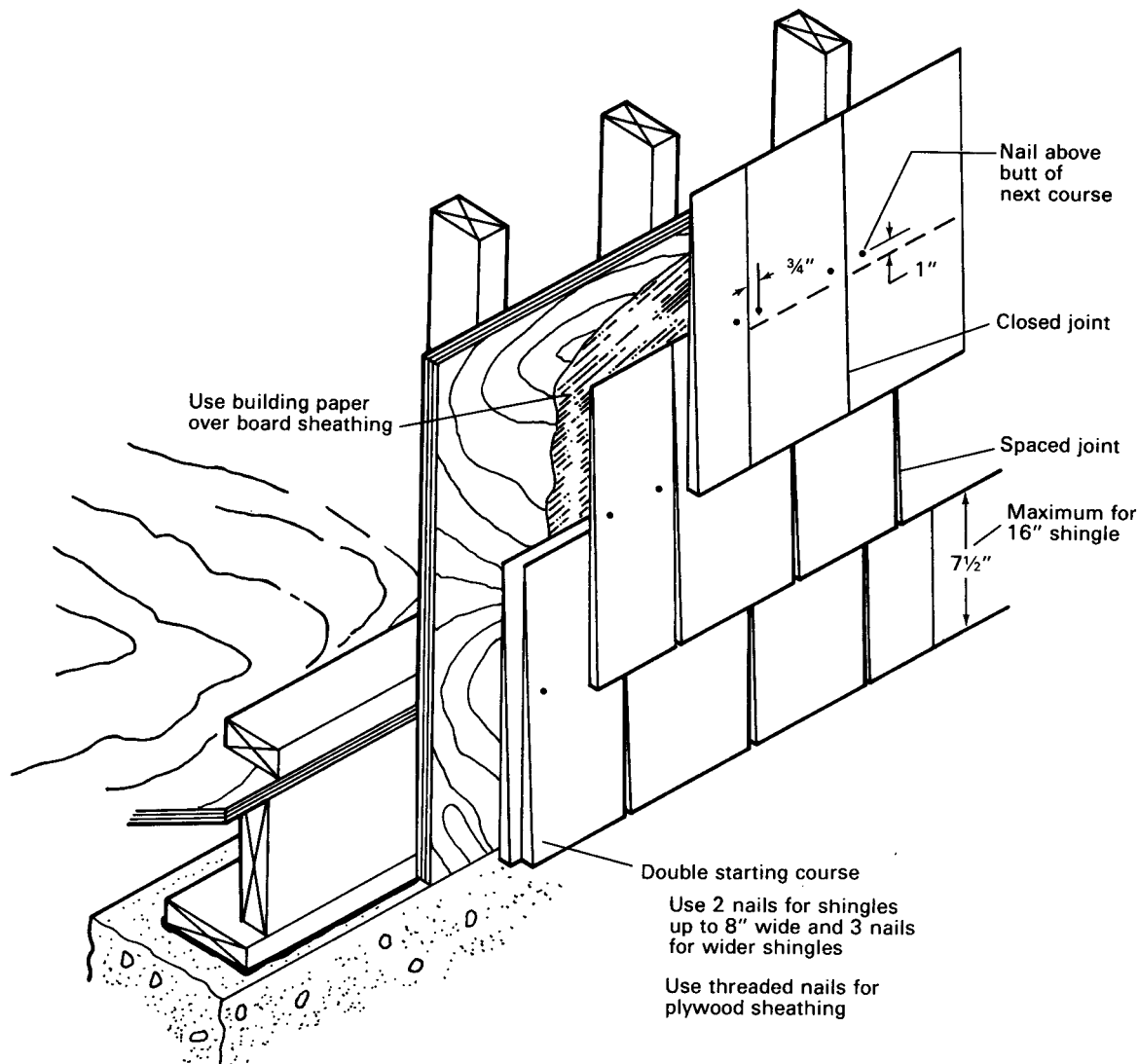


Table 13—Exposure distances for wood shingles and shakes on side walls

Material	Length (in)	Maximum exposure (in)		
		Single coursing	Double coursing	
			No. 1 grade	No. 2 grade
Shingles	16	7½	12	10
	18	8%	14	11
	24	11½	16	14
Shakes (hand split and resawn)	18	8%	14	—
	24	11½	20	—
	32	15	—	—

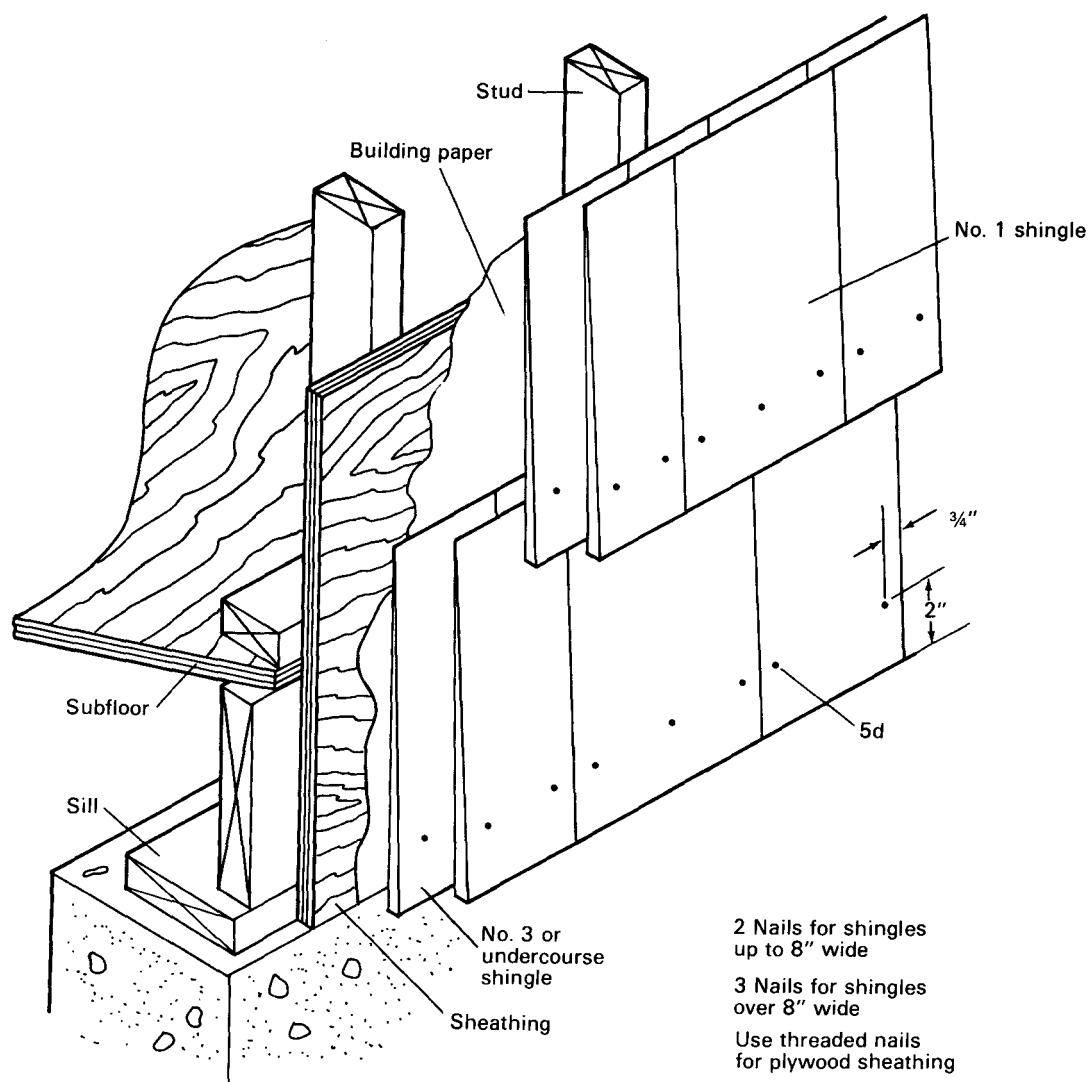
Masonry veneer

In some styles of architecture, brick or stone veneer is used for all or part of the exterior wall finish. It is good practice, when possible, to delay applying the masonry finish over platform framing until the joists and other members reach moisture equilibrium. Waterproof paper backing and sufficient wall ties should be used. Details of the installation of masonry veneer are shown in figure 116. It is normal practice to install the masonry veneer with a ¼-inch space between the veneer and the wall sheathing. This space provides room for the bricklayer's fingers when setting the brick.

Aluminum and vinyl

Aluminum and vinyl can be purchased in a variety of qualities. They require little maintenance beyond periodic

**Figure 115** – Double-course application of wood shingles or shakes on side wall.



cleaning. Installation should be performed in compliance with the instructions provided by the manufacturers.

### Exterior Trim

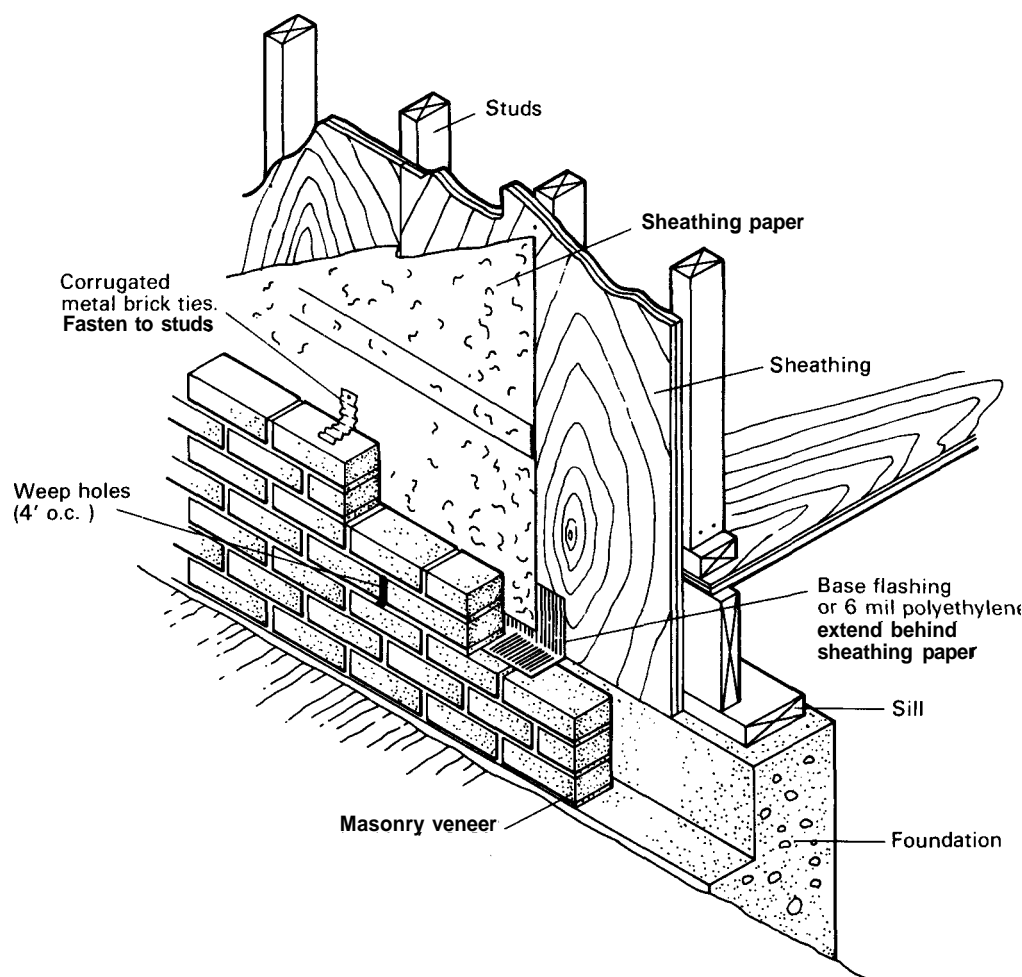
Exterior trim includes materials and products used for exterior finish other than siding or brick veneer. The term includes cornice trim, such as moldings, fascia boards and soffits; rake or gable-end trim; porch trim and molding (covered in section on porches); and window and door trim (supplied with prefabricated units). Some exterior trim, in the form of finish lumber and moldings, is cut and fitted on the job. Other materials or assemblies such as shutters, louvers, railings, and posts are shop-fabricated and are delivered ready for installation.

### Material used for trim

The properties desired in materials used for trim are good painting and weathering characteristics, easy working qualities, and maximum freedom from warp. Decay resistance is also desirable in such areas as the caps and the bases of porch columns, rails, and shutters where materials may absorb moisture. Pressure-treated lumber and the heartwood of cedars, cypress, and redwood have high decay resistance. Columns, shutters, and louvers are also available in aluminum and/or vinyl.

Many wood trim manufacturers predip such materials as siding, window sash, window and door frames, and trim, using a water-repellent preservative. On-the-job dipping of end joints or miters is recommended for water resistance and decay protection.

**Figure 116** – Masonry veneer siding installation.



Nails or screws used for fastening trim should be rust-resistant, that is, aluminum or galvanized or stainless steel, to reduce staining and discoloration. With a natural finish, only aluminum or stainless steel should be used. Cement-coated nails are not rust-resistant.

Installation of trim is like installation of siding, previously discussed. Trim is normally attached with standard nails; finish or casing nails can also be used. Most of the trim along the shingle line (e.g., at gable ends and cornices) is installed before the roof shingles are applied.

Lumber used for exterior trim should be grade No. 1 or No. 2, and should have a moisture content of approximately 12 percent at the time of installation.

#### ***Cornice construction and types***

The cornice or eave of a building is the lower portion of the roof that overhangs the wall. In gable roofs the cornice is formed on the long sides of a house; with hip roofs it is continuous around the perimeter.

Three common cornice types are the box, the closed (no overhang), and the open (no soffit). The box cornice is the most widely used. Box and open cornices overhang and protect the side walls, windows, and foundation from rain. Properly sized overhangs can shade south-facing windows in summer when the sun is at a high angle, but allow passive solar heating in winter when the sun is low in the sky. The closed cornice, with little overhang, does not serve these functions. Exposed-beam roofs with wood roof decking and wide overhangs in contemporary or rustic designs commonly use the open cornice.

**Narrow box cornice.** With a narrow box cornice, the projection of a rafter is cut to serve as a horizontal nailing surface for the soffit and fascia (fig. 117A). The truss roof version has a small horizontal return wedge to which the soffit is nailed (fig. 117B). The soffit provides a desirable area for inlet ventilators, which allow good attic insulation and ventilation, keep the house and attic cooler in the summer, and minimize ice dams in winter. (See the section on attic ventilation.)

Soffit molding, often  $\frac{3}{4}$ -inch cove, is used to cover the crack between the siding and soffit. Metal roof drip edge is often used to cover the crack between the roof sheathing and fascia, and to reduce the chance of water penetrating and rotting the wood.

**Wide box cornice with returns.** A wide box cornice normally requires an additional horizontal member, attached to each truss, to which the soffit is nailed. Trusses can be ordered with these returns attached (fig. 118A). When rafters are used, lookouts are toenailed to the wall and facenailed to the ends of the rafter overhang (fig. 118B).

Soffits can be made of lumber, plywood, paper-overlaid plywood, hardboard, medium-density fiberboard, or other sheet material. Maintenance-free soffits are made of prefinished aluminum and vinyl and have built-in ventilation holes. Thicknesses of wood soffit materials should be

based on the distance between supports;  $\frac{3}{8}$ -inch plywood and  $\frac{1}{2}$ -inch fiberboard are often used for 24-inch truss spacing. Fascias are normally made of No. 1 wood boards but may also be aluminum or vinyl. Expansion of aluminum and vinyl fascia with high temperatures can give them a wavy look. A fascia backer at the ends of the trusses or rafters is sometimes used to provide additional nailing and support area for soffit and fascia (fig. 118A and 118B). The fascia backer is normally omitted in cornice extensions when a rabbeted fascia is used.

The projection of the cornice beyond the wall should not be so great as to prevent the use of a molding above the top casing of the windows. A combination of steep slope and wide projection brings the soffit in this type of cornice too low. Alternatives include a box cornice without horizontal returns or lookouts or use of a raised Fink roof truss, as discussed below.

**Figure 117** – *Narrow box cornice:*

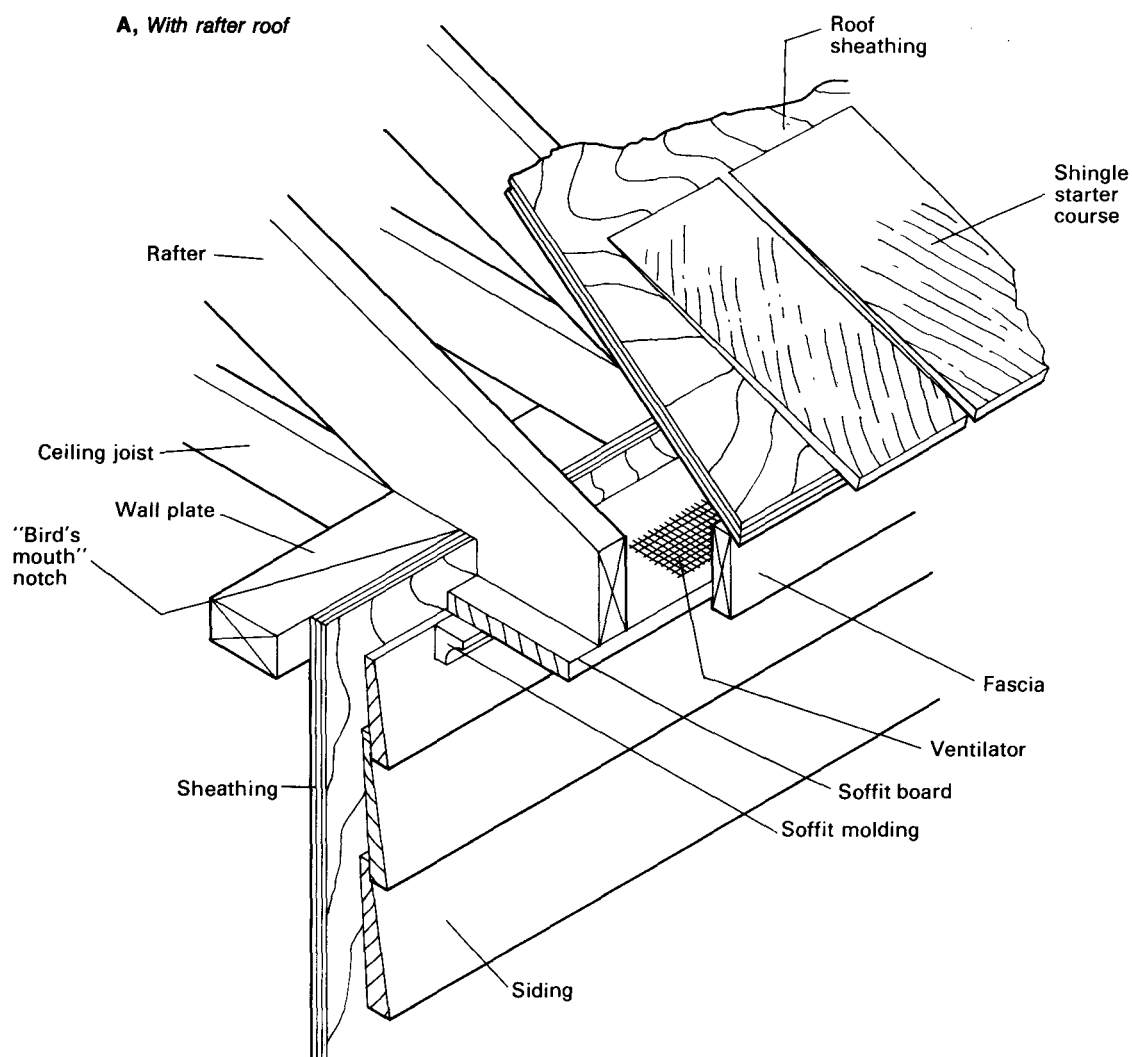
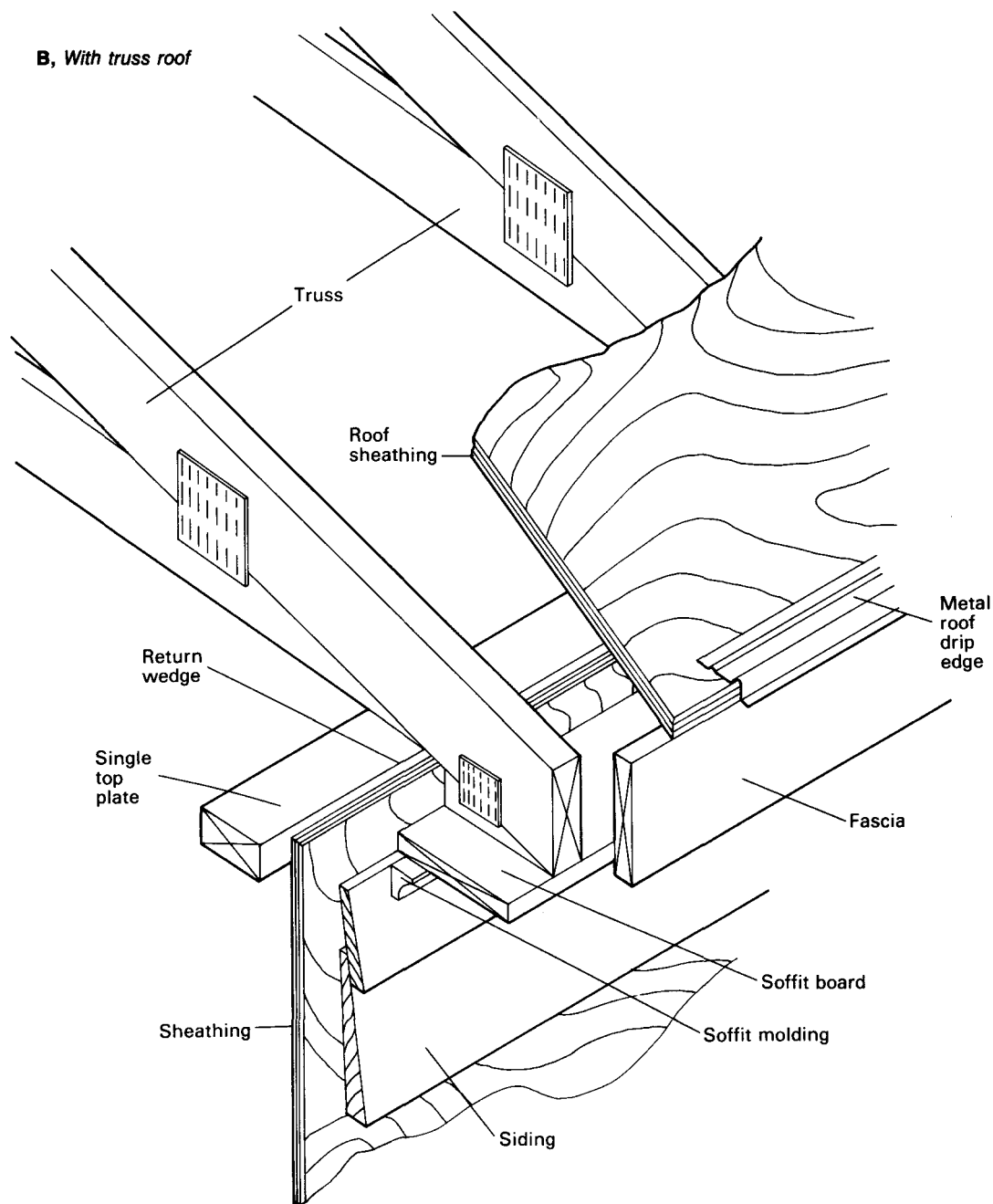


Figure 117 – Narrow box cornice (continued):

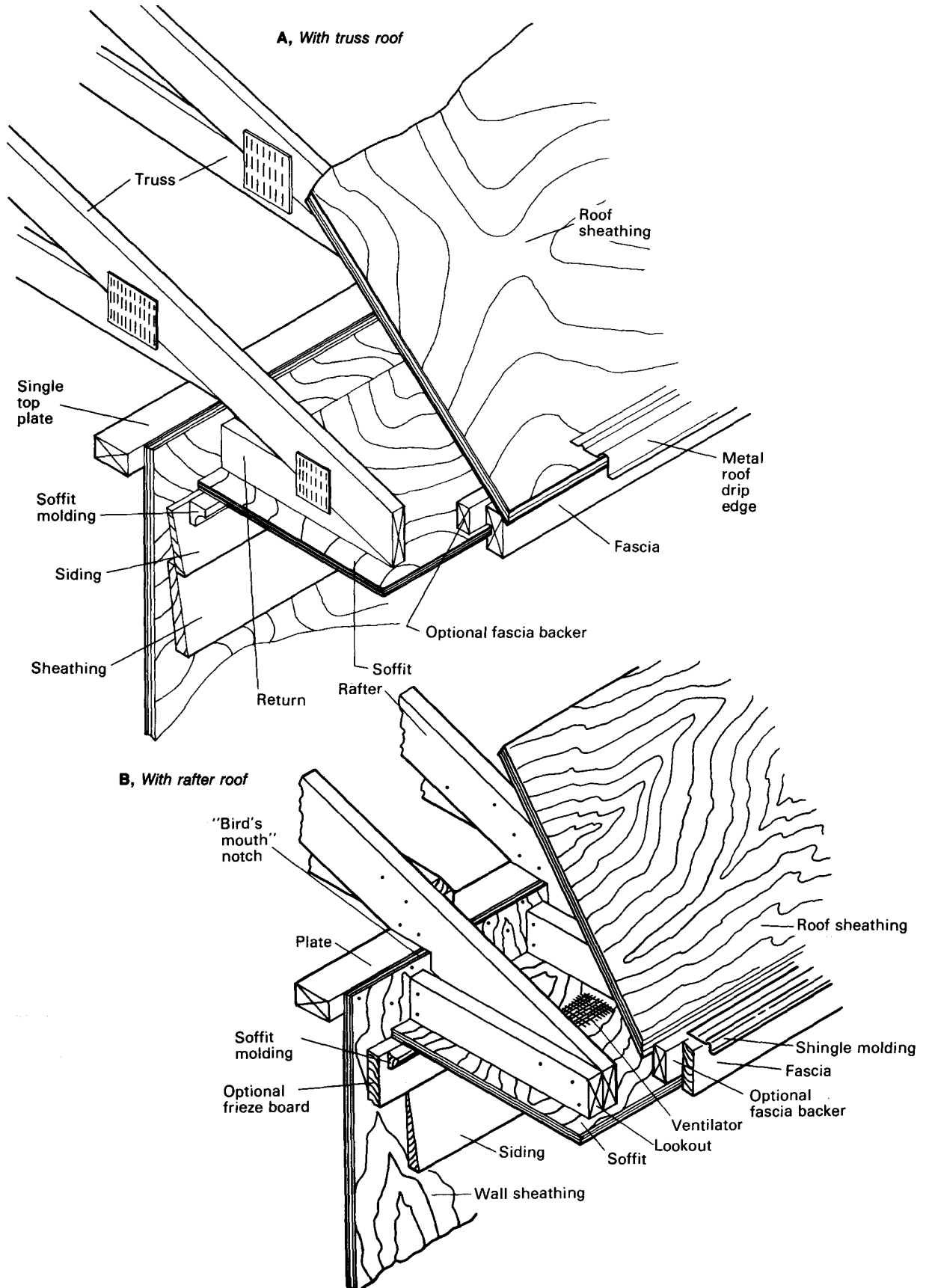


**Box cornice without returns.** A wide boxed cornice without horizontal returns or lookouts, providing a sloped soffit, is sometimes used for houses with wide overhangs (figs. 119A and 119B). The soffit material is nailed directly to the underside of the rafter extensions. Inlet ventilators, singly or in a continuous strip, are installed in the soffit area.

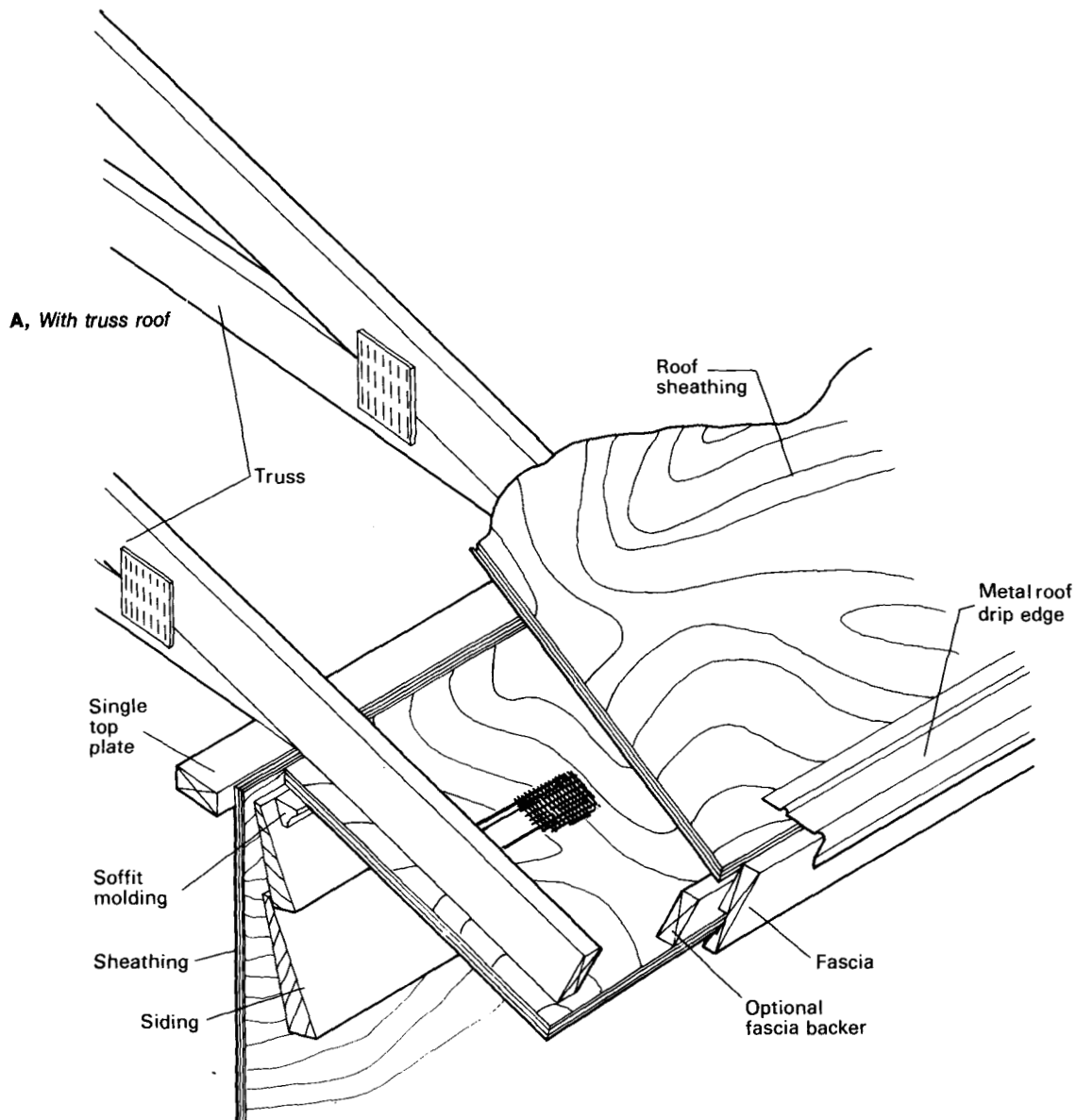
**Raised Fink truss box cornice.** The raised Fink truss roof allows thick ceiling insulation, with an air space above it, to extend to the outer edge of the exterior wall

(fig. 120). It also permits construction of a steeply sloped roof with wide overhangs, without interfering with windows and doors. The soffit remains the same height as the interior ceiling regardless of the roof slope or projection of the cornice. The soffit is attached to the horizontal bottom truss chord, which extends to the end of the rafter projection. A compression wedge carries the weight of the roof from the top truss chord to the bottom chord directly over the wall.

**Figure 118** – *Wide box cornice with horizontal returns:*



**Figure 119 – Wide box cornice without returns:**

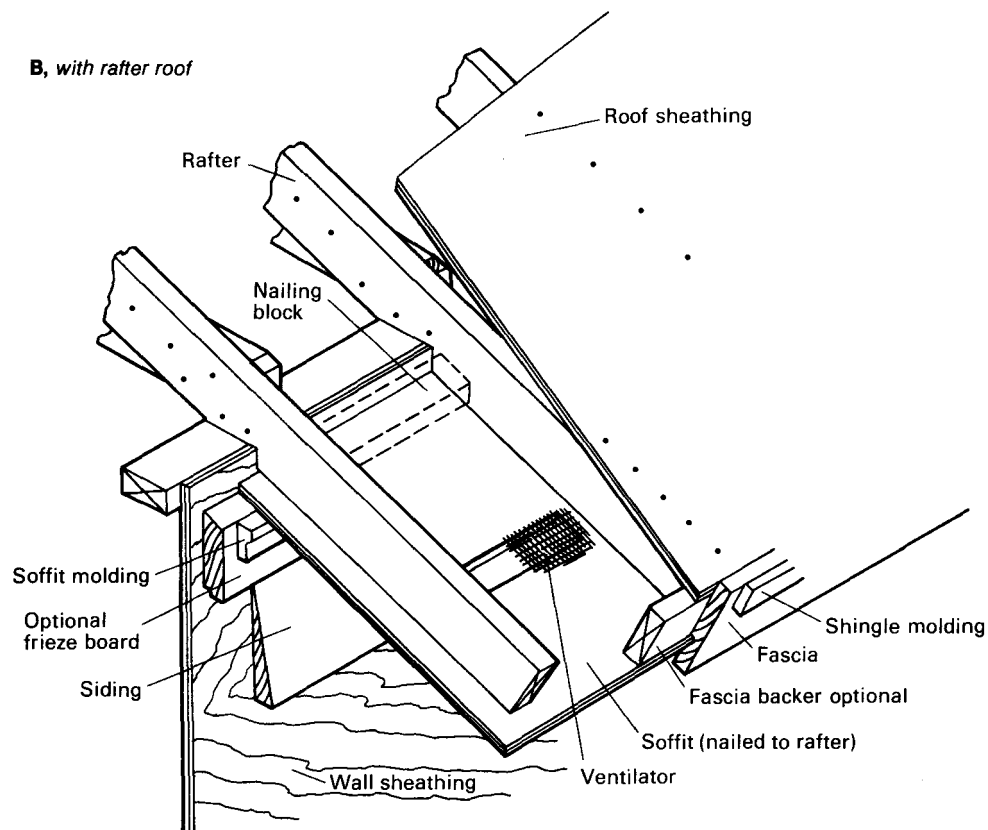


**Open cornice.** An open cornice is structurally the same as a wide box cornice without returns or lookouts except that soffit is eliminated (fig. 121). Open cornices are often used in post and beam construction with large, widely spaced rafters and with 2- by 4-inch or 2- by 6-inch tongue-and-groove decking used for roof sheathing. When rafters are more closely spaced, paper-overlaid plywood or V-grooved boards can be used for roof sheathing at the overhanging section. This might require, for the rest of the roof, sheathing thicker than would normally be used. This type of cornice can also be used for conventionally framed houses, utility buildings, or cottages, with or without a fascia board.

The open cornice requires that blocking be toenailed in place between the rafters or trusses to close the space between the top of the wall and the bottom of the roof sheathing (fig. 121). If trim is desired, blocking is best placed vertically. The trim board must then be carefully notched to fit around the rafters. Roofing nails protruding through the exposed sheathing can be clipped with large bull-nosed snips, and a higher grade roof sheathing can be used around the perimeter of the roof to enhance the appearance of the underside of the overhang.

**Closed cornice.** A closed cornice is one in which there is no rafter or truss projection beyond the wall (fig. 122). Wall sheathing or sheet siding (plywood or hard-board) extends upward past the ends of the trusses or

Figure 119 – Wide box cornice without returns (continued):



rafters to the bottom of the roof sheathing. The roof is terminated only by the fascia, siding, and sometimes a shingle molding. While this cornice is simple to build, it is not pleasing in appearance, and it provides little weather protection to the side walls and no space for inlet ventilators. Appearance can be improved and siding somewhat protected by the use of a gutter.

### ***Rake or gable-end finish***

A rake or gable overhang is the extension of a gable roof beyond the end wall of the house. The rake might be classed as (a) closed, with little projection, (b) box or open, supported by the roof sheathing, and (c) wide box supported by special ladder-like roof framing. It is essentially nonfunctional since it provides little shade or protection from rain. Such overhangs are normally too high to shade windows, and wind renders their protection from rain ineffective. In addition, no portion of the roof drains toward the gable overhang.

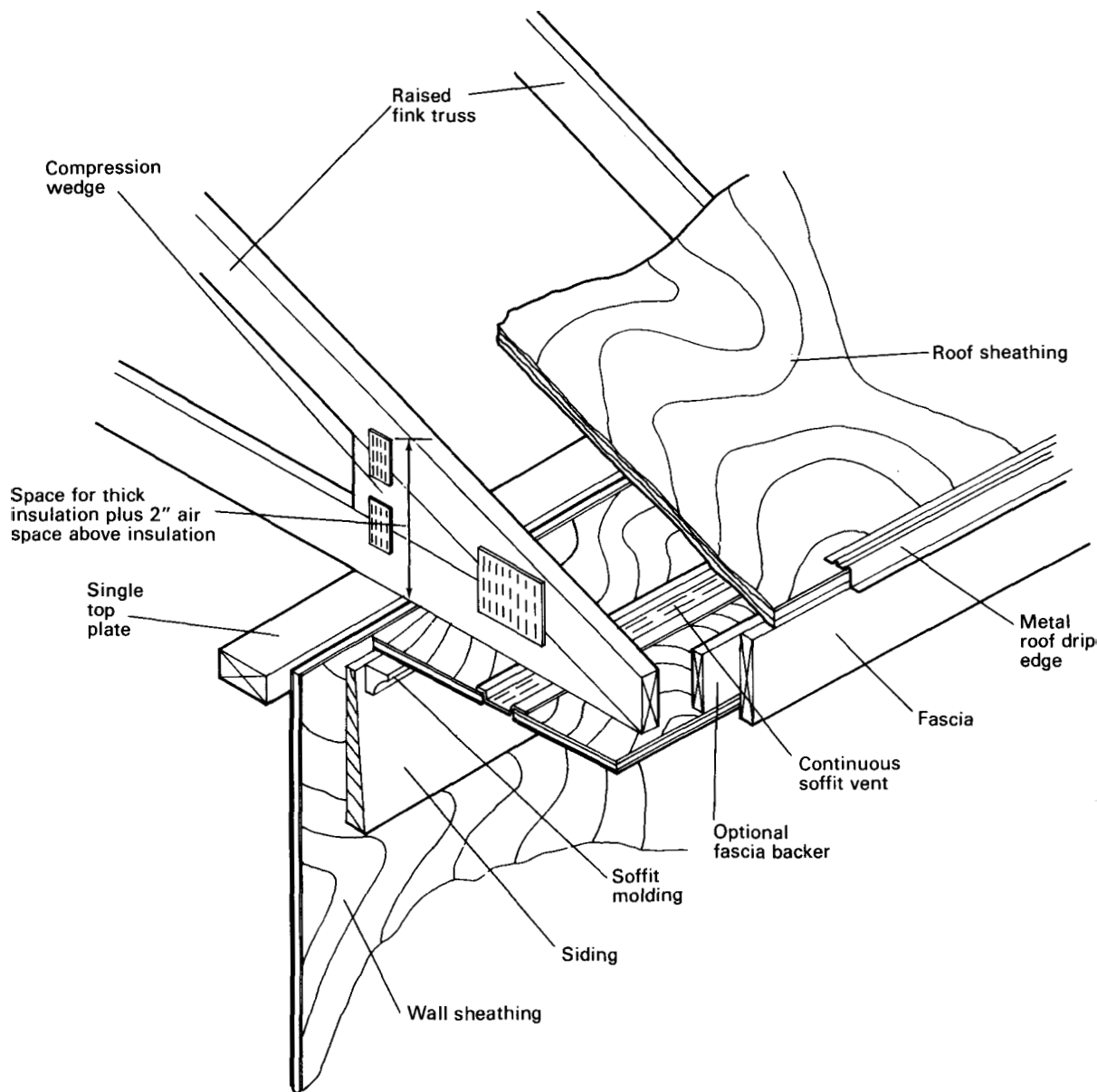
If no overhang is desired, the siding can be brought up to the underside of the roof sheathing and the crack covered by a metal roof drip edge. A small overhang can be provided by installing a fascia board (fig. 123B). Slightly greater overhang can be provided by attaching the fascia

to a fascia block (fig. 123C). Siding can be terminated beneath the fascia block. When the rake extension is supported by the roof sheathing and is 6 to 8 inches wide, the fascia and soffit can be nailed to a series of short lookout blocks (fig. 124).

With an overhang of up to 12 inches, the extended sheathing supports the overhang, and a fly rafter (rake board) keeps the sheathing straight (fig. 125). Additional support for the fly rafter can be provided by extending the rafter ridge board and the fascia backers and fascia at the eaves. The roof sheathing boards or plywood should extend from inner rafters to the end of the gable projection to provide rigidity and strength. The roof sheathing is nailed to the fly rafter and to the lookout blocks, which aid in supporting the rake section and also serve as a nailing area for the soffit.

Gable extensions of more than 12 inches require rigid framing to resist roof loads and to prevent sagging of the rake section. This is usually provided by a series of purlins or lookout members nailed to a fly rafter at the outside edge. The purlins pass over and are supported by the gable wall and are nailed to an interior truss (fig. 126). This framing can be constructed in place or constructed on the ground and hoisted into place. For ease of

**Figure 120** – Wide box cornice with horizontal return and raised Fink trusses.



construction, lookouts are often nailed between two rafters, giving the appearance of a ladder. One side of the ladder is nailed to the interior truss. This practice wastes a rafter but saves labor.

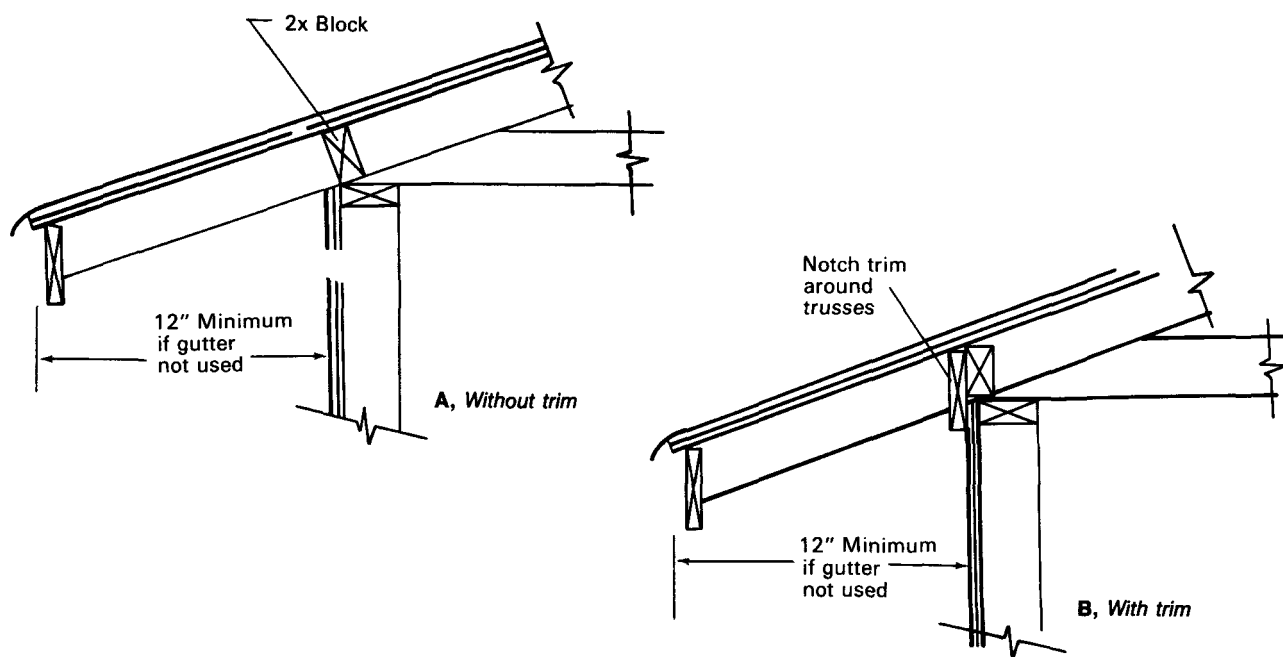
When ladder framing is used with a rafter roof, the rafter serving as the side of the ladder attached to the roof framing should be cut with a “bird’s mouth” notch in the same fashion as the other rafters, to fit the wall plate. The lookouts should be spaced 16 to 24 inches apart, depending on the thickness of the soffit material.

### *Cornice return*

In hip roofs, the cornice is usually continuous around the entire house. In a gable house, it must be terminated or joined with the gable ends. The cornice return is the finish where the cornice meets the rake on a gable roof.

Cornices with horizontal soffits are usually changed to the angle of the roof by use of a cornice return. A horizontal lookout is attached to the fly rafter, and a vertical block connects the rafter with the lookout at a point in line with the house wall. Nailers are fastened from the lookout to the house and between the fly rafter and the gable (fig. 127). Fascia boards are nailed to vertical portions, and the soffit is nailed to the horizontal portions.

**Figure 121** – *Open cornice detail:*

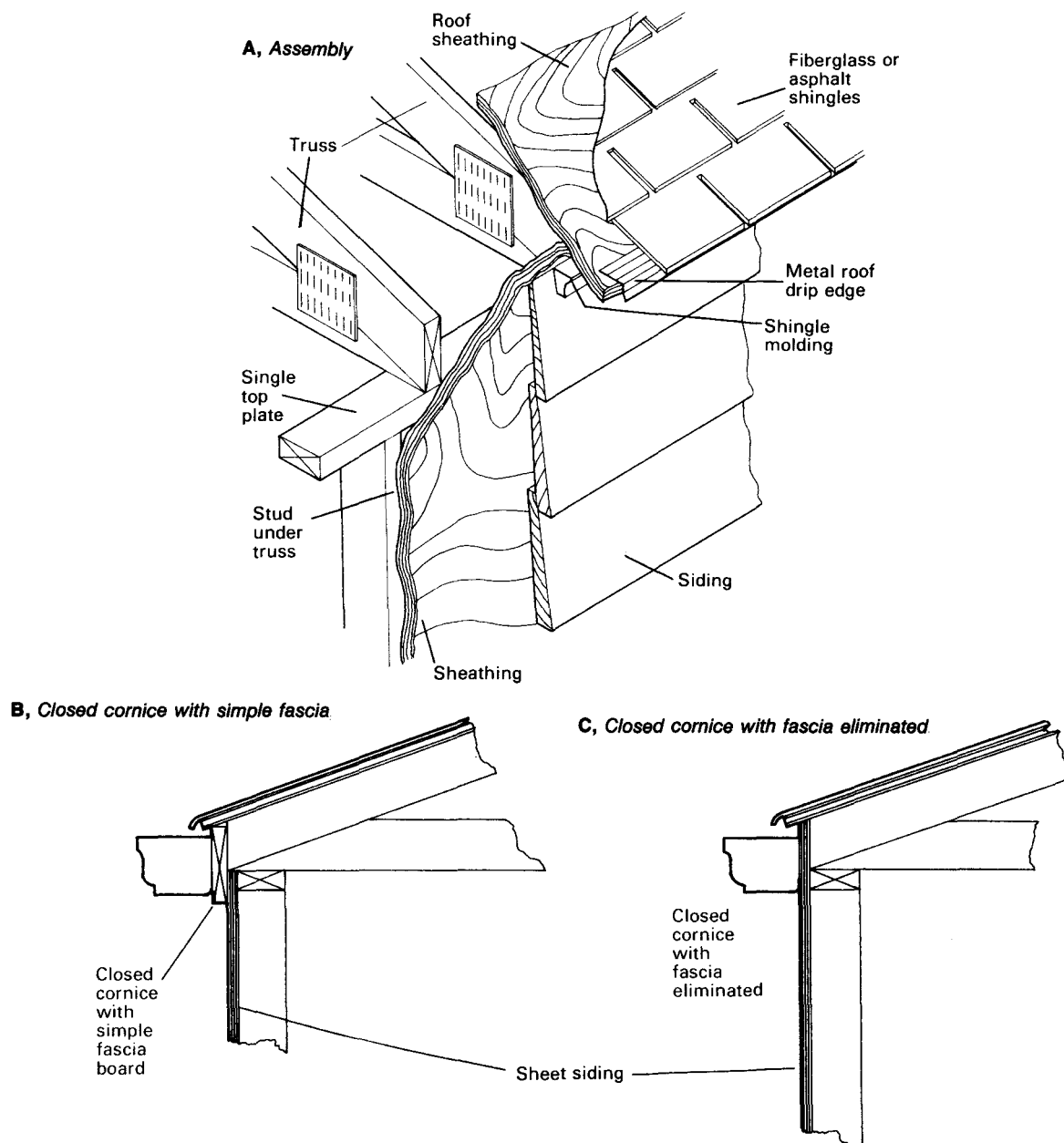


The fascia board and shingle molding of the cornice are carried around the corners and up to the slope of the rake.

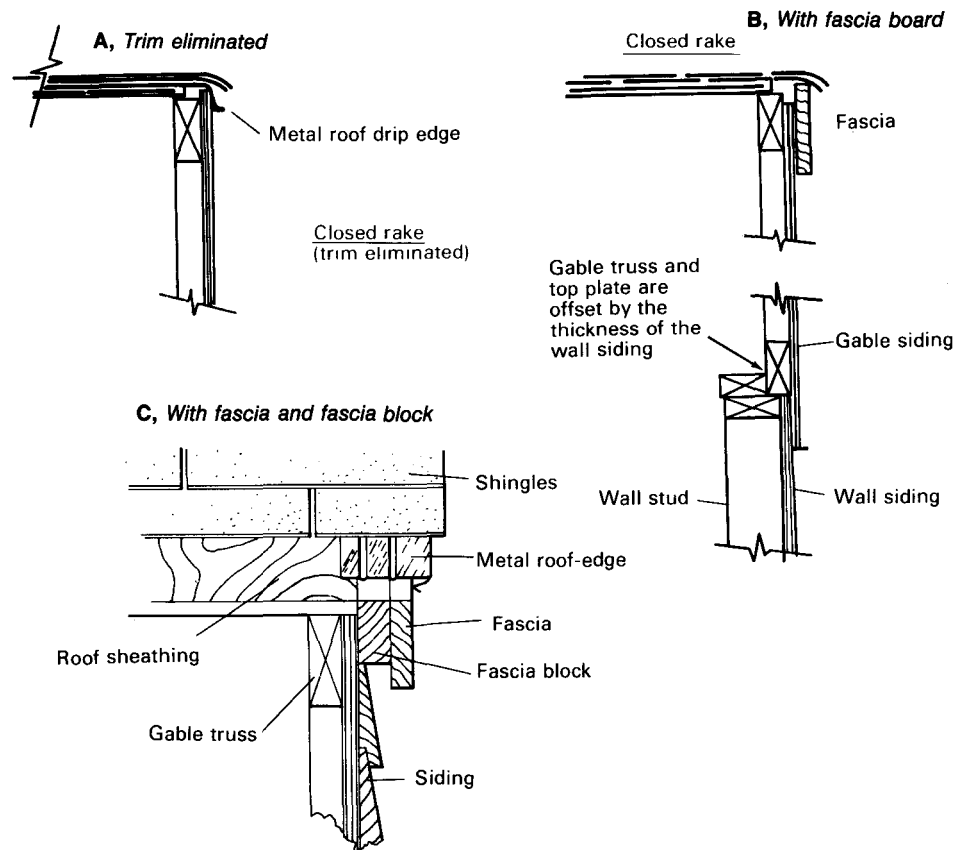
On cornices without horizontal lookout members, the soffit continues its slope up the rake overhang (fig. 128).

The extra material and labor required for good cornice overhangs are usually justified by achieving better protection of side wall and foundation, lower paint maintenance costs, and, if soffit vents are used, a cooler house in summer and smaller ice dams in winter.

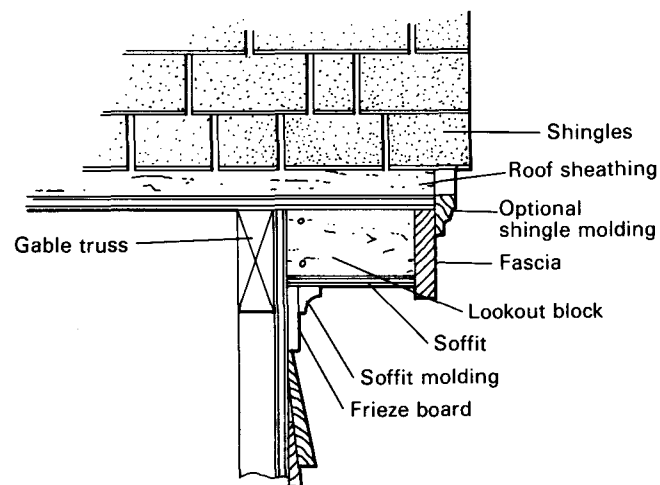
Figure 122 – Closed cornice detail:



**Figure 123 – Closed rake finish:**



**Figure 124 —short rake extension with lookout blocks.**



**Figure 125** – Moderate rake extension with fly rafter:

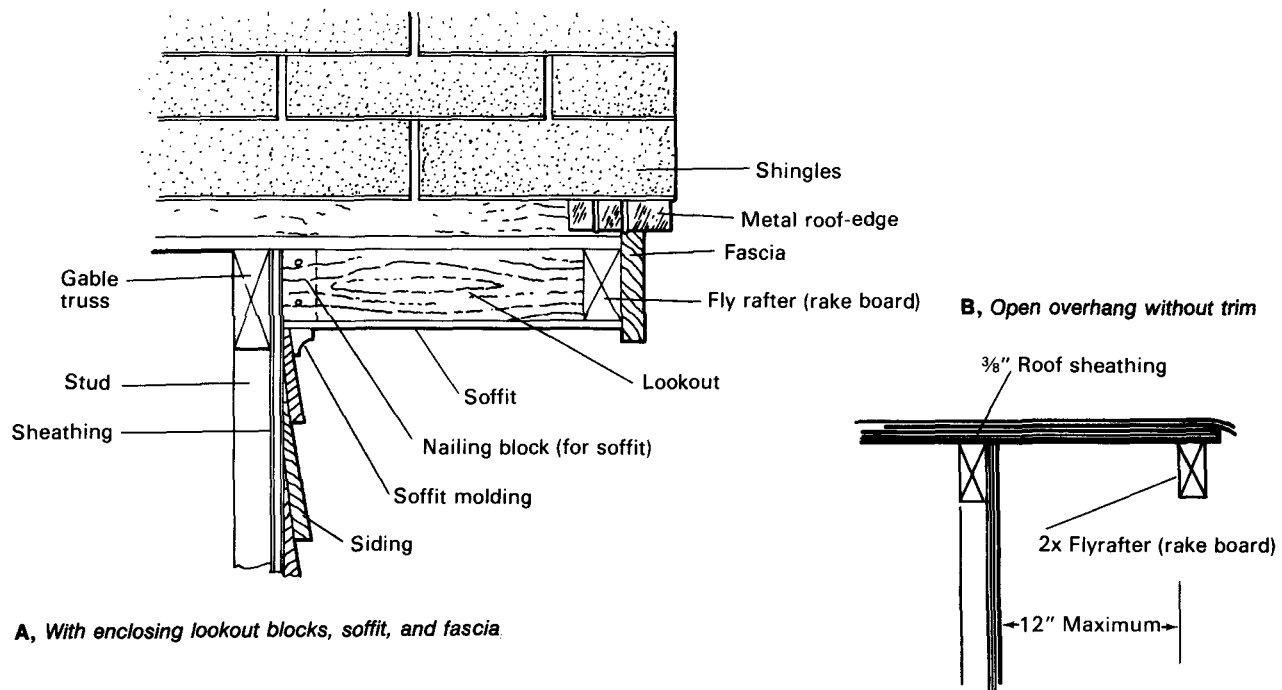


Figure 126 – Wide rake extension:

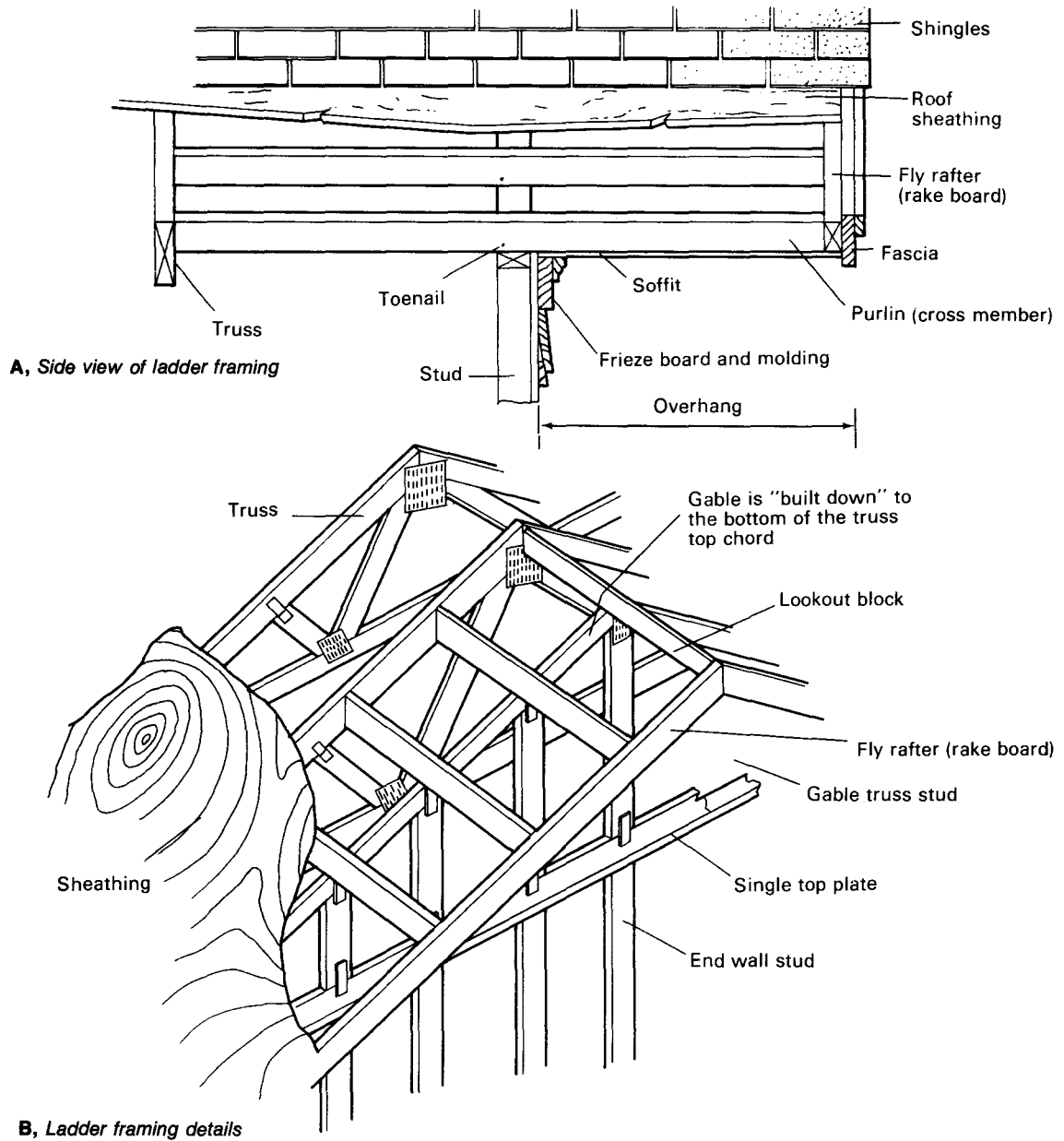
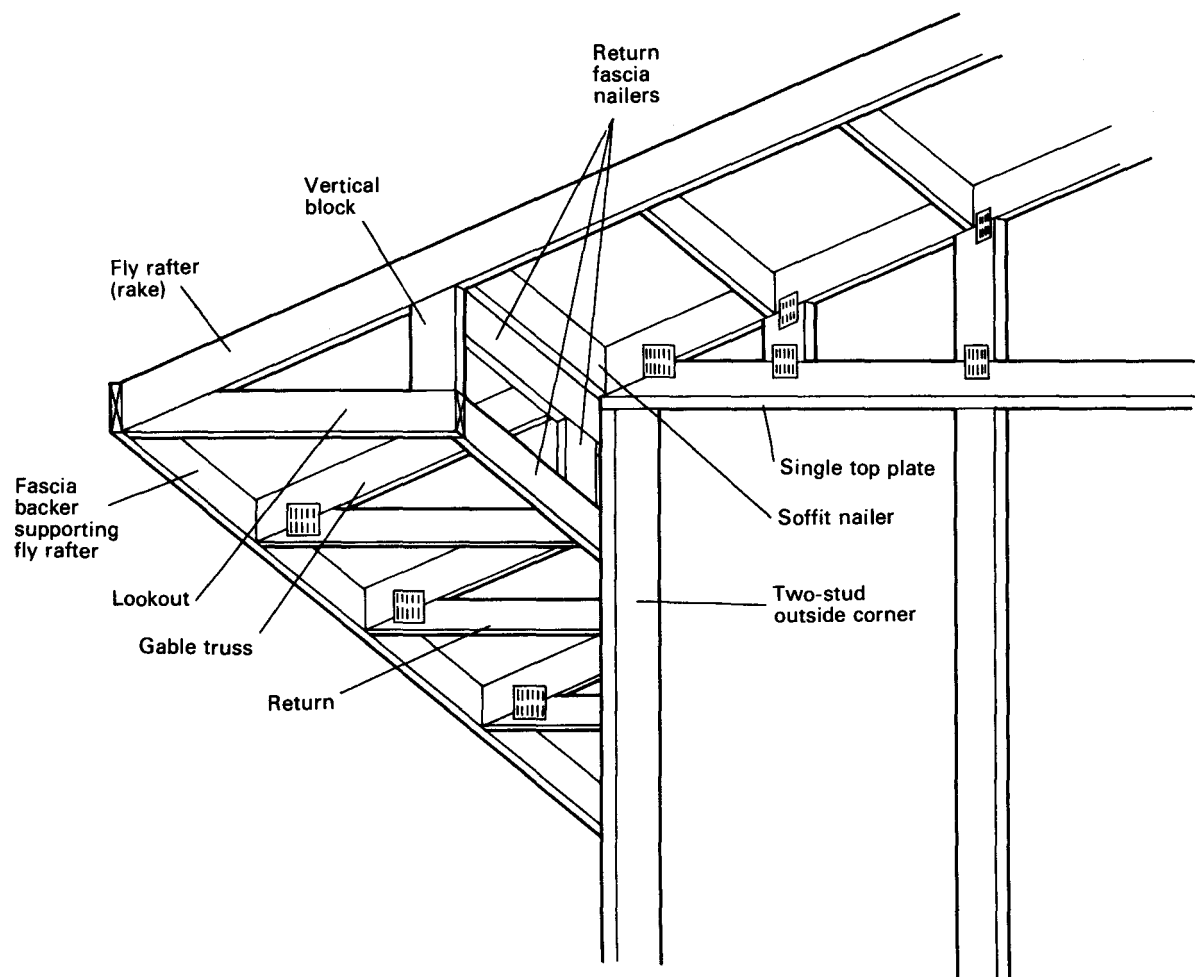
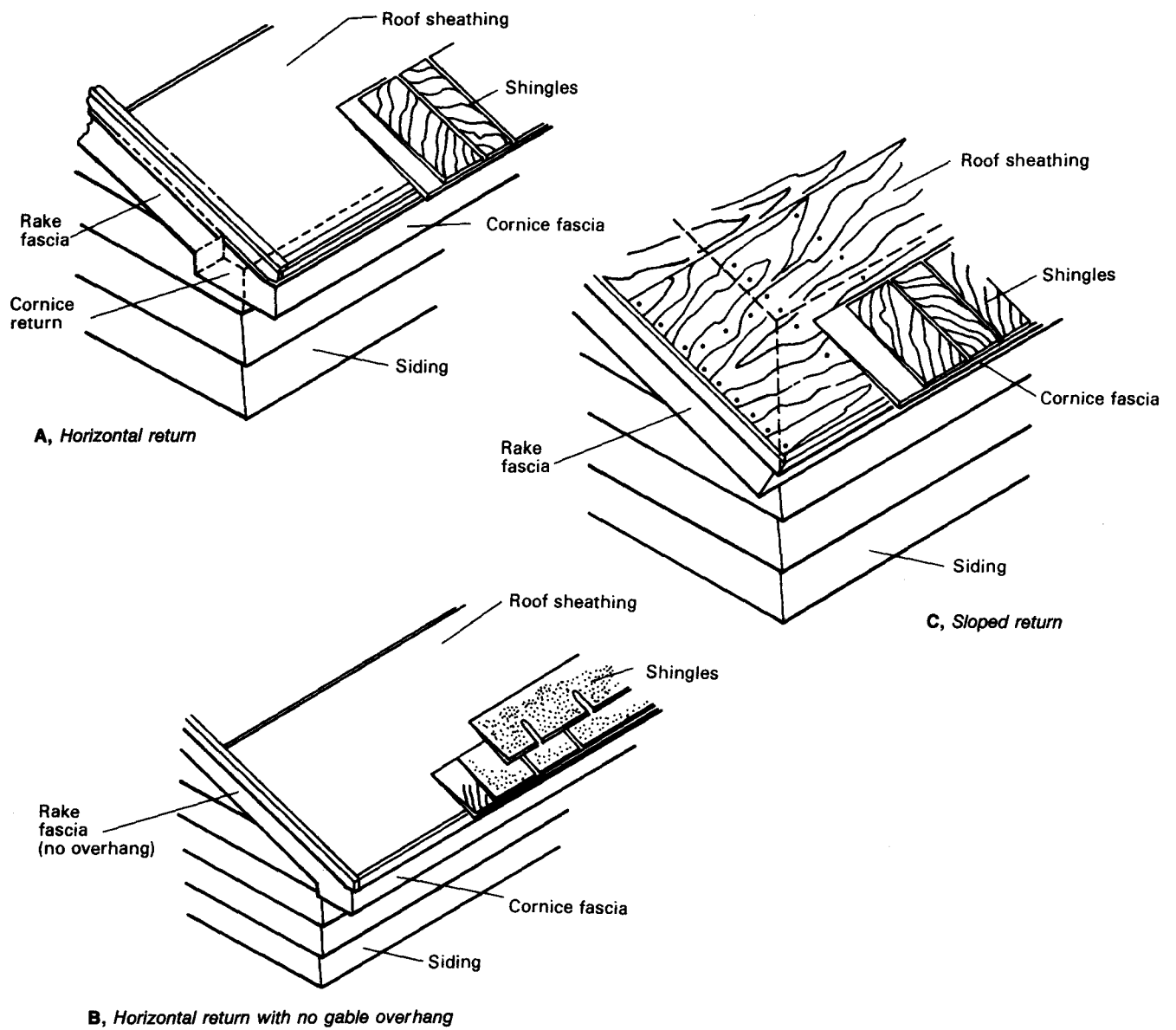


Figure 127 – Cornice return framing detail.



**Figure 128**—Cornice return types:







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## Specialty Features

The topics discussed in this chapter include a variety of specialty features that are included in some but not all home construction plans.

### Fireplaces, Wood Stoves, and Chimneys

The installation of fireplaces, wood stoves, and the chimneys that they require for operation involves significant structural considerations relating to safety and efficiency. Basic information is provided below.

#### *Fireplaces*

From the standpoint of heating, fireplaces could be considered a luxury, their heat production efficiency being estimated to be only 10 percent. However, they are often desired as a decorative feature. As indicated in the next two sections, improved efficiency can usually be obtained by the installation of a factory-made circulating fireplace. This metal unit, enclosed by masonry, allows heated air to be circulated throughout the room in a system separate from the direct heat of the fire.

Satisfactory fireplace performance can be achieved by following several rules relating the fireplace opening size to flue area, depth of the opening, and certain other measurements.

It is generally recommended that the depth of the fireplace should be about two-thirds the height of the opening. Thus, a 30-inch-high fireplace would be 20 inches deep from the face to the rear of the opening.

The flue area (inside length times inside width) should be at least one-tenth of the area of the fireplace opening (width times height) when the chimney is 15 feet or more in height. When less than 15 feet, the flue area should be one-eighth of the area of the opening of the fireplace. This height is measured from the throat (fig. 129) to the top of the chimney. Thus, a fireplace with a 30-inch width and 24-inch height (720 in<sup>2</sup>) would require an 8- by 12-inch flue, which has an inside area of about 80 in<sup>2</sup>, when the chimney height is 15 feet or over. A 12- by 12-inch flue liner has an area of about 125 in<sup>2</sup>, and would be large enough for a 36- by 30-inch opening when the chimney height is 15 feet or over.

Steel angle iron should be used to support the brick or masonry over the fireplace opening. The bottom of the inner hearth, the sides, and the back should be built of a heat-resistant material such as firebrick. The outer hearth

should extend at least 16 inches out from the face of the fireplace and be supported by a reinforced concrete slab. This outer hearth provides protection against flying sparks and should be made of noncombustible materials such as glazed tile. Other details relating to clearance, framing of the wall, cleanout opening, and ash dump are also shown in figure 129. Hangers and brackets for fireplace screens are often built into the face of the fireplace.

The back width of the fireplace is usually 6 to 8 inches narrower than the front. This helps to guide the smoke and fumes toward the rear. A vertical back wall about 14 inches high tapers toward the upper section or throat of the fireplace (fig. 129). The area of the throat should be about 1 ¼ to 1 ⅓ times the area of the flue to promote better draft. An adjustable damper is used at this area for easy control of the opening.

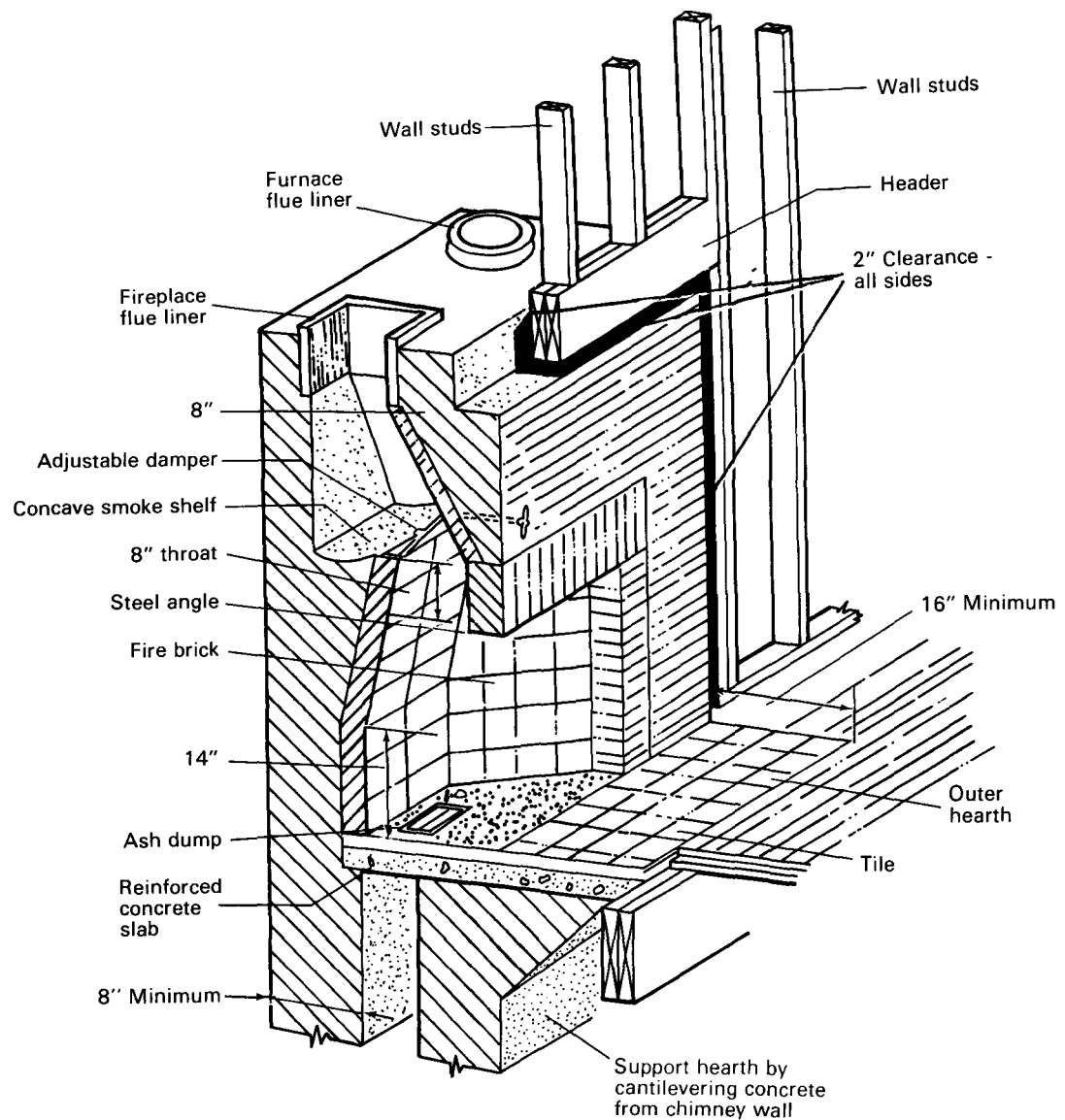
The smoke shelf (top of the throat) is necessary to prevent back drafts. The height of the smoke shelf should be 8 inches above the top of the fireplace opening (fig. 129). The smoke shelf is concave to retain any slight amount of rain that may enter.

Fireplaces with two or more openings (fig. 130) require much larger flues than conventional fireplaces. For example, a fireplace with two open adjacent faces (fig. 130A) would require a 12- by 16-inch flue for a 34- by 20- by 30-inch (width, depth, and height, respectively) opening. Local building regulations usually specify sizes for these types of fireplaces.

**Air-circulating firebox forms.** The heating capacity of a fireplace can be increased by using steel air-circulating firebox forms. These usually form the firebox sides and rear, plus the throat, damper, smoke shelf, and smoke chamber. The sides and back of the circulator are double, enclosing a space within which air is heated. Cool air is introduced into this space near the floor level and, when heated by the hot steel, rises and returns to the room through registers located at a higher level.

Air-circulating firebox forms can also prevent smoke from entering the room. The volume of air drawn up the chimney is substantial and is normally replaced by cold air infiltrating through cracks in the house. In modern tight house construction, however, the caulking and weatherstripping that reduce air infiltration also hamper the chimney draft, with the common result that smoke is drawn into the room. This problem is solved by installation of an air-circulating firebox, along with glass doors

Figure 129 – Masonry fireplace components.



across the fireplace front that prevent room air from entering the firebox.

The firebox form is set on a firebrick floor laid on reinforced concrete. The chimney flue is begun at the top of the form, and, facing the room, decorative masonry is laid around the unit opening. Small fans are often installed to increase the heating efficiency of the unit, and the inlets and outlets are covered with decorative grates.

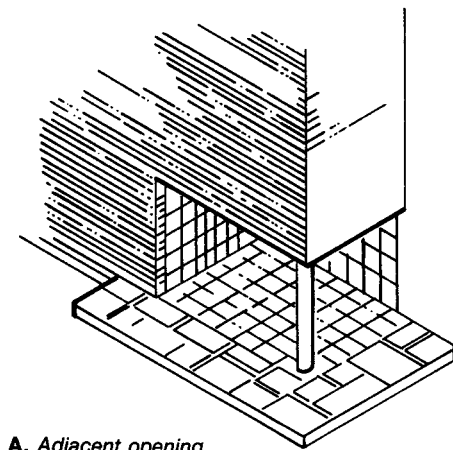
**Zero-clearance prefabricated fireboxes.** Factory-built fireplace units can be ordered that include all fireplace and chimney components from the hearth to the chimney cap. These are called “zero-clearance units” because they can be installed on wood floors and against wood framing (fig. 131). Such units must have an inspection label on them from a third-party testing agency (such as from UL,

Warnock-Hersey, or PFS Corporation) to qualify for use. The units have steel walls and include insulation that protects wood structures from excessive heat. They frequently include dampers, screens, glass doors, circulating fans, and external air supply ducts. Some are of freestanding contemporary type. Others can be placed on raised hearths and faced with stone or brick to provide a traditional appearance, or they can be covered with sheetrock and trimmed in wood. Their insulated steel chimney pipe can be housed in a wood stud chimney utilizing the same style of siding as the house.

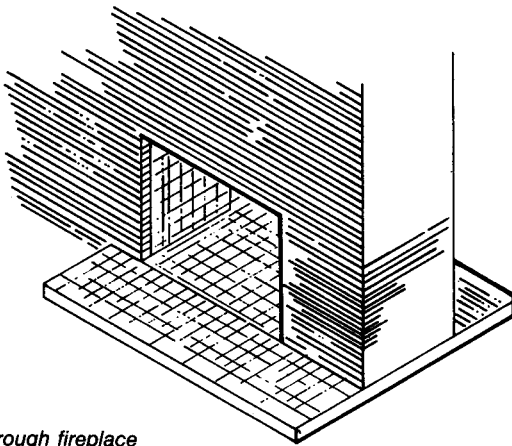
#### Wood stoves

Some types of wood stoves are freestanding; others are designed for insertion into fireplace openings. Their air intake is controlled to produce efficient, slow, and more

Figure 130—Dual opening fireplace:



A, Adjacent opening



B, Through fireplace

complete combustion than is possible with fireplaces, with little loss of room air up the chimney. Airtight wood stoves can provide a combustion efficiency of 30 to 40 percent (a gas furnace is typically 80 percent efficient). Some models are made of steel or cast iron, which radiates heat. Others are enclosed in thin steel jackets, allowing air to circulate between the stove and the jacket. The cooler outer jacket provides a desirable safety feature. Air enters and leaves the space between stove and jacket through vents and heats the room through convection (see the technical note on heat flow and insulation). Fans are sometimes employed to improve circulation. In some systems the heated air is collected in a plenum and distributed to other rooms through ducts. To assure safe operation when properly installed, such units should have a label indicating they comply with safety standards as tested by a third-party testing agency.

Some models contain coils through which water circulates; the heated water can be employed for domestic uses

or for space heating. Water can be pumped to various locations or circulated through convection.

Some wood stoves have glass doors, which make them appear more like a fireplace. They can be set on brick, tile, or stone hearths and surrounded with walls of the same materials.

Wood stoves can be connected either to insulated steel or to masonry flues (fig. 132).

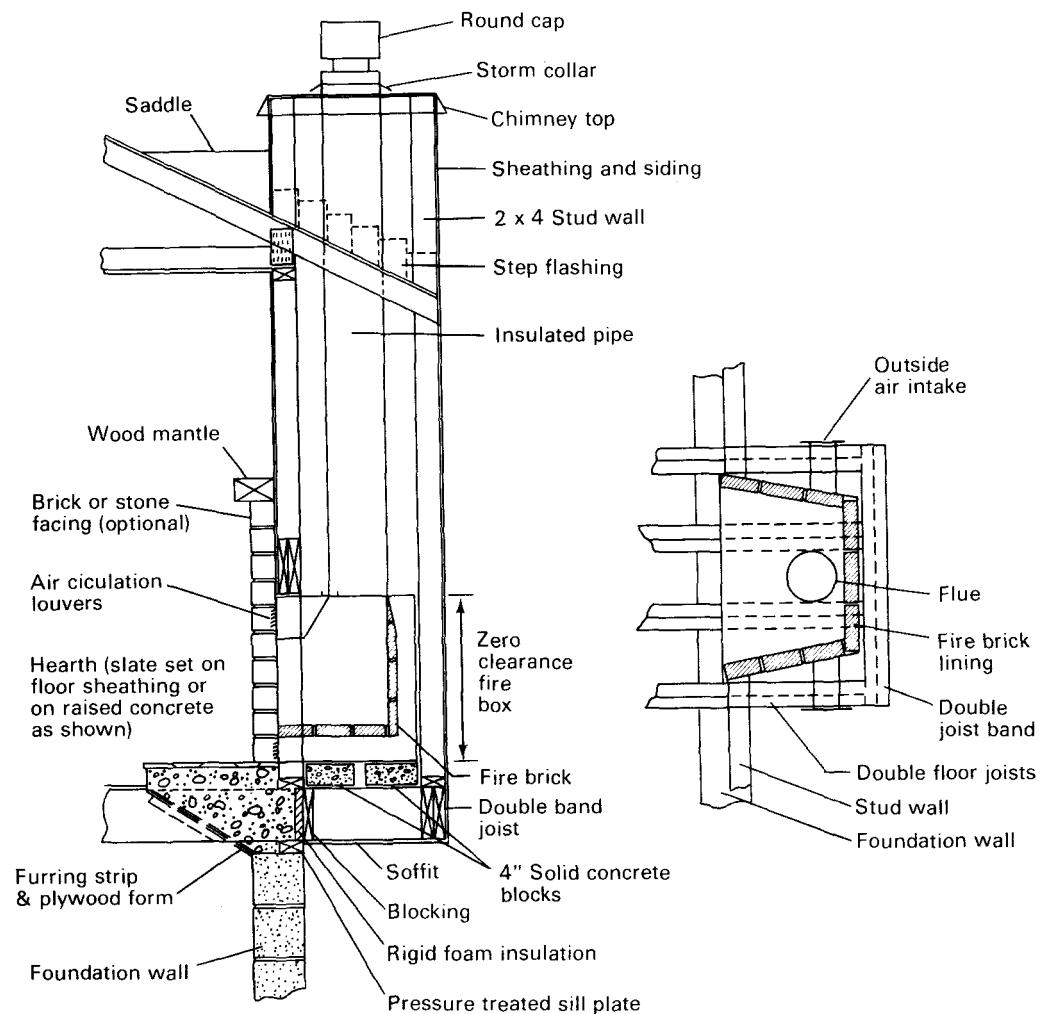
As the use of wood stoves has increased in popularity, failure to observe proper fire safety precautions in construction and installation has resulted in fires and accidents. *In particular, it must be recalled that wood and other combustibles can be heated to the flash point without direct contact between the hot stove and such combustible material.* Sufficient heat to ignite combustibles can be passed from the stove across air spaces through convection and radiation, or through intervening noncombustible materials such as masonry that are in contact with combustible material. The following paragraphs describe precautions that should be taken against fire.

**Pipe insulation.** When an uninsulated metal pipe or thimble passes through or comes in contact with walls, ceiling, or framing, at least 6 inches of fiberglass insulation should be packed between the pipe and such materials at all points of passage or contact. The fiberglass insulation should not have paper facings. Cement, stone, brick, or asbestos cannot serve as substitutes for such insulation, because all these materials can conduct sufficient heat to bring adjacent combustibles to the flash point.

**Clay thimbles.** Clay thimbles should not be run directly through concrete block or other nonflammable masonry. The thimble, masonry, or both, may crack, allowing heat to rise within the masonry cavities and ignite the wood sill. For passage through nonflammable block or masonry, an insulated steel pipe should be used. Alternatively, a steel pipe can be passed through the thimble, using any of a variety of techniques to maintain an air space between the two pipes. This air space should be open to the basement room.

**Safe distance from walls.** Manufacturers of various types of stoves specify the minimum distances from walls and other combustible materials judged safe for their stoves. These specifications should be carefully followed. In general, freestanding wood stoves should be kept at least 3 feet from combustibles, including wood studs covered with gypsum board and half-bricks. If a stove is placed closer to a wall or other combustible material than the minimum distance specified by the manufacturer, a steel heat shield should be placed between the stove and such materials, with air space on both sides of the shield.

Figure 131—Zero-clearance fireplace in external wood chimney.



**Safe distance from ceiling.** Uninsulated steel flue pipes should not be closer than 3 feet from ceilings.

**Hearths.** Freestanding wood stoves should be set on brick or concrete hearths. Bricks of standard  $2\frac{3}{4}$ -inch thickness or 3 inches of concrete should be used. Other hearths may be used only if specified in the stove manufacturer's installation instructions.

### Chimneys

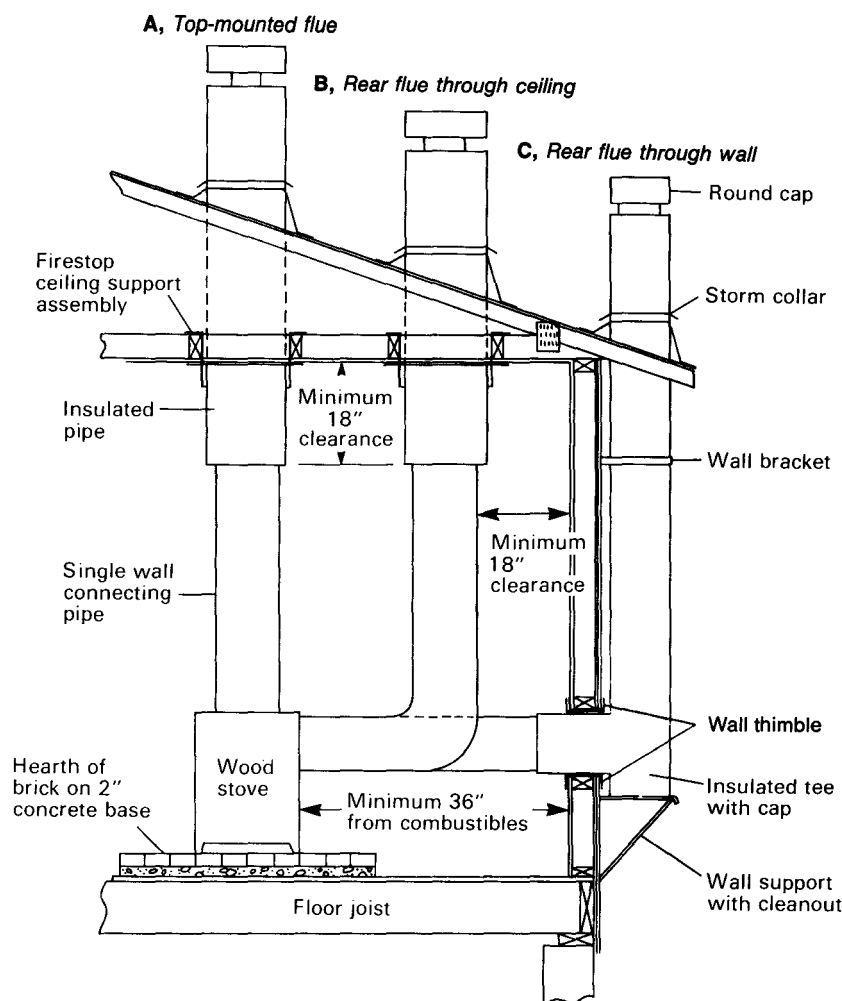
Chimneys can be constructed of masonry units supported on a suitable foundation or of lightweight insulated stainless steel pipe. They must be structurally safe and capable of producing sufficient draft for fireplaces, stoves, and/or other fuel-burning equipment. Steel flue pipe should bear a label signifying approval by Underwriters Laboratories, Inc., or other third-party testing agencies.

The chimney should be built on a concrete footing of sufficient area, depth, and strength for the imposed load. It is usually freestanding, and is constructed in such a way that it neither supports nor is supported by the structural framework of the house. The chimney footing should be below the frost line. For houses with a basement, the footings for the walls and fireplace are usually poured together and at the same elevation.

The size of the chimney depends on the number of flues, the presence or absence of fireplaces, and the design of the house. Each fireplace should have a separate flue. For best performance, flues should be separated by a 4-inch-wide brick spacer (withe) placed between them (fig. 133A).

Certain house designs include a room-wide brick or stone fireplace wall that extends through the roof. Although only two or three flues may be required for

Figure 132 – Wood stove:



heating units and fireplaces, several false flues may be added at the top for appearance.

Flue sizes conform to the width and length of a brick so that full-length bricks can be used to enclose the flue lining. Thus, an 8- by 8-inch flue lining (about 8½ in by 8½ in, outside dimensions) with the minimum 4-inch thickness of surrounding masonry will use six standard bricks for each course (fig. 134A). An 8- by 12-inch flue lining (8½ in by 13 in, outside dimensions) will be enclosed by seven bricks at each course (fig. 134B), and a 12- by 12-inch flue (13 in by 13 in, outside dimensions) by eight bricks (fig. 134C).

The height of the chimney and the size of the flue are important factors in providing sufficient draft. In addition, the greater the difference in temperature between chimney gases and outside atmosphere, the better the draft. A chimney constructed within the house framework has better draft than a chimney constructed in an exterior wall because the masonry retains heat longer.

The height of a chimney above the roofline usually depends on its location in relation to the roof ridge. If the chimney is within 10 feet of the roof ridge, the top of the flue liner must extend a minimum of 24 inches above the ridge and must be a minimum of 36 inches above the highest part of the roof next to the chimney. When the chimney is more than 10 feet from the roof ridge, the top of the chimney must extend a minimum of 24 inches above the highest point on the roof within 10 feet of the chimney and at least 36 inches above the highest point on the roof next to the chimney (fig. 133B). For flat or low-pitched roofs, the chimney should extend at least 3 feet above the highest point of the roof.

To prevent moisture from entering between the brick and flue lining, a concrete cap is usually poured over the top course of brick (fig. 133C). Precast or stone caps with a cement wash are also used.

Flashing for chimneys is illustrated in figures 93 and 135. Masonry chimneys should be separated from wood

framing, subfloor, and other combustible materials. Framing members should have at least a 2-inch clearance and should be firestopped at each floor with a noncombustible material (fig. 136). Subfloor, roof sheathing, and wall sheathing should have a  $\frac{3}{4}$ -inch clearance.

A cleanout door is included in the bottom of chimneys for fireplaces and other solid fuel burning equipment. The cleanout door for the furnace flue is usually located just below the smokepipe thimble, with enough room for a soot pocket.

**Flue linings.** Rectangular fire-clay linings or round vitrified (glazed) tile are normally used for chimney flues. Local codes usually require vitrified tile or a stainless-steel lining for gas-burning equipment.

Rectangular flue lining is made in 2-foot lengths and in various sizes from 8 by 8 inches to 24 by 24 inches. Wall thicknesses vary with the size of the flue. Linings of a smaller size have a wall  $\frac{5}{8}$  inch thick; larger sizes vary from  $\frac{3}{4}$  inch to  $1\frac{3}{8}$  inches in thickness. Most commonly, vitrified tiles 8 inches in diameter are used for the flues

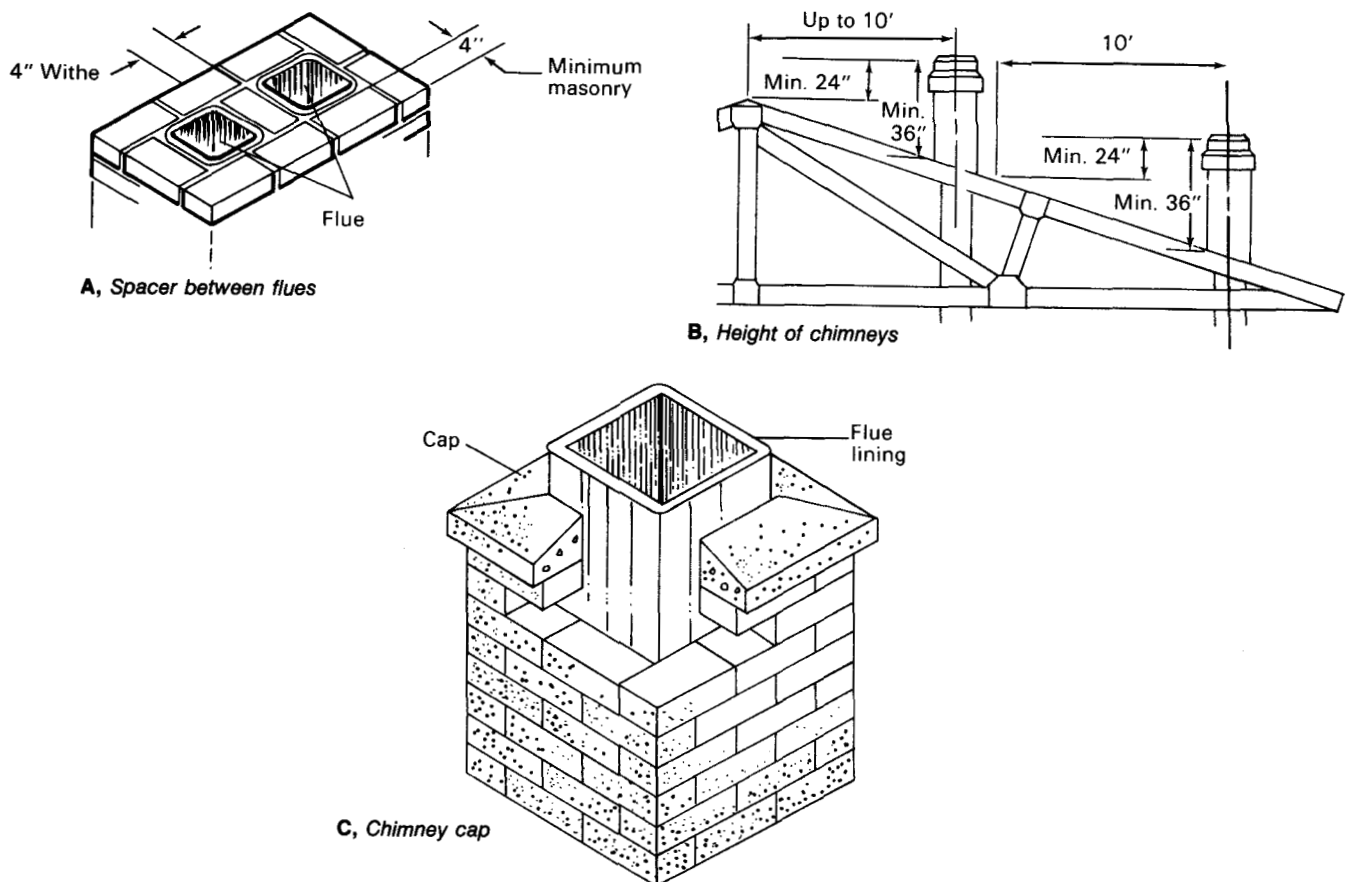
of the heating unit, although larger sizes are also available. This type of tile has a bell joint.

Flue lining should begin at least 8 inches below the thimble for a connecting smoke or vent pipe from the furnace. For fireplaces, the flue liner should start at the top of the throat and extend to the top of the chimney.

Flue liners should be installed so far ahead of the brick or masonry work, as it is carried up, that careful bedding of the mortar results in a tight and smooth joint. When diagonal offsets are necessary, the flue liners should be beveled at the directional change in order to have a tight joint. It is also good practice to stagger the joints in adjacent tile.

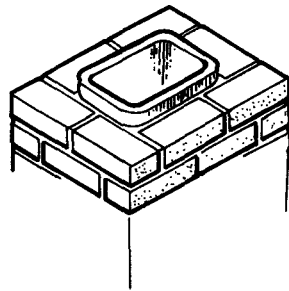
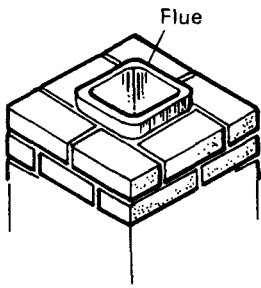
Standard flue blocks are available for building less expensive chimneys. These blocks are 8 inches high by 16 inches square or larger, with holes in the center sized to fit standard flue liners. Other blocks have half-circular holes on one side; two of these form a circular hole through which a thimble can be placed.

**Figure 133** – Chimney details:

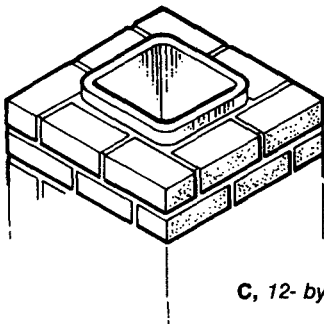


**Figure 134 – Chimney brick and flue combinations:**

**A, 8- by 8-inch flue lining**



**B, 8- by 12-inch flue lining**



**C, 12- by 12-inch flue lining**

**Insulated steel chimneys.** Insulated steel chimneys are made in tubular sections from 12 to 36 inches long. Sections are fastened together to form a long pipe. Triple-wall pipe consists of three pipes with spaces between them through which air circulates to remove heat. The inner pipe is made of stainless steel; the outer pipes are galvanized. Another type consists of double-wall stainless steel pipe with asbestos insulation between the walls.

Both types come with a full line of accessories including tees, wall supports and brackets, roof supports and flashing, storm collars, caps to keep rain from going down the flue, and spark arrestors. Both types can be fully exposed to weather or enclosed in wood chimneys. Wood chimneys normally consist of conventional stud walls covered with sheathing and siding. The entire top, 2 feet square or larger, is covered with galvanized flashing through which the last section of insulated steel pipe extends.

Unlike clay flues, which could crack in flue fires, steel chimneys do not crack when subjected to the heat of such fires. If creosote buildup is ignited in a steel flue, the fire can burn until the creosote burns off, and if the manufacturer's installation recommendations have been followed, the flue should not be damaged.

**Figure 135 – Chimney flashing.**

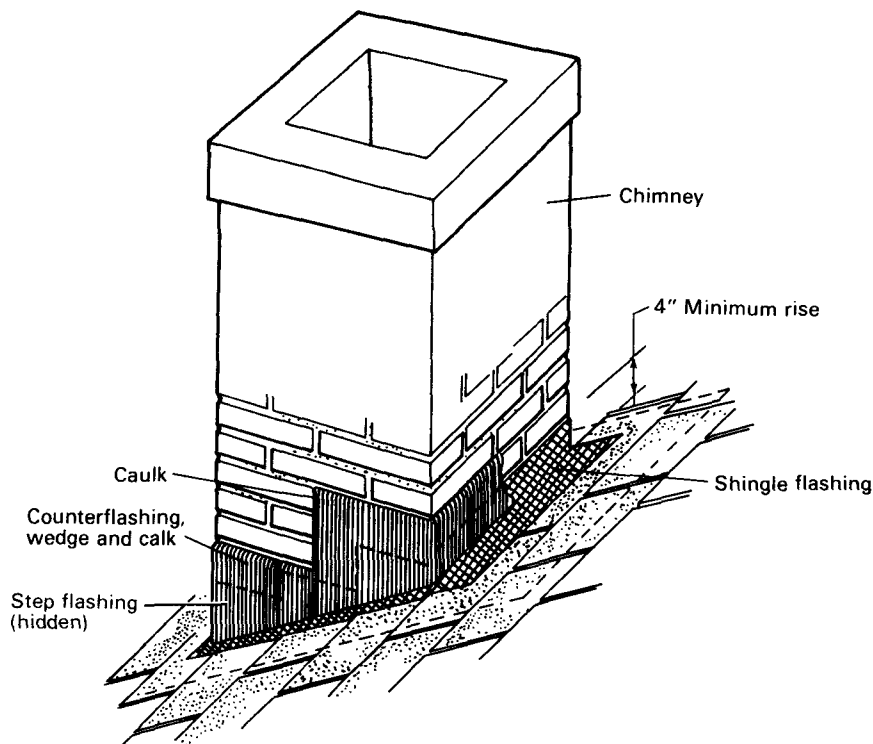
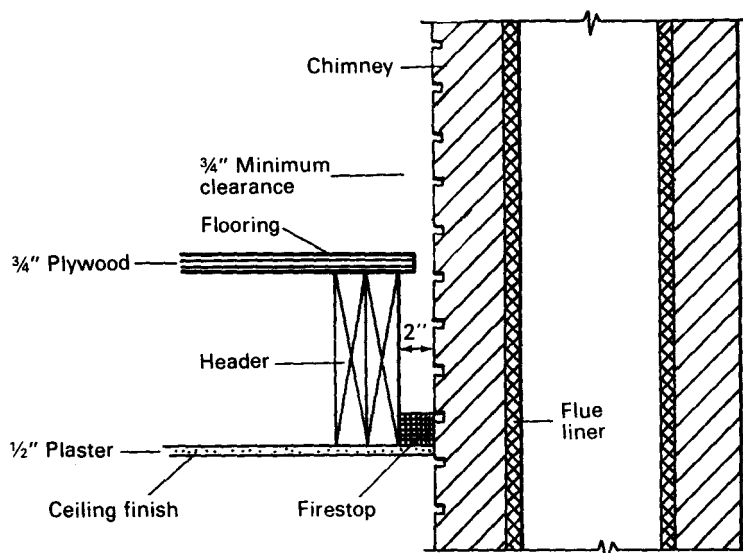


Figure 136 – Chimney clearances for wood frame construction.



## Garages and Carports

Garages can be classified as attached, detached, or basement. A carport is a roofed, open structure for sheltering vehicles.

### Garages

An attached garage has a number of advantages. It can give better architectural lines to the house, it is warmer during cold weather, and it provides convenient space for storage. It also provides covered protection for entering or leaving vehicles and a short, direct entrance to the house. An attached garage is also less expensive to build than a detached garage because it shares one wall with the house.

Where there is considerable slope to a lot, basement garages may be desirable. Such garages generally cost less than those above grade.

Detached garages are independent structures built on a slab foundation. The specifications for the slab foundation are generally the same as those for an attached garage.

**Size.** Many car models are 215 inches long, and larger, more expensive models are usually over 230 inches—almost 20 feet—in length. While the garage need not necessarily be designed to take all sizes with adequate room around the car, it is good practice to provide a minimum distance of 21 to 22 feet between the inside faces of the front and rear walls. If additional storage or work space at the back is desired, greater depth is required.

The inside width of a single garage should never be less than 11 feet; 13 feet is more satisfactory. The recom-

mended minimum outside size for a single garage, therefore, would be 14 by 22 feet. A double garage should be not less than 22 by 22 feet in outside dimensions to provide reasonable clearance. The addition of a shop or storage area would increase these dimensions.

For an attached garage, the foundation wall should extend below the frost line and about 8 inches above the exterior final grade level. It should be not less than 6 inches thick. The sill plate should be anchored to the foundation wall with anchor bolts spaced about 8 feet apart, with at least two bolts in each sill piece. Extra anchors may be required at the sides of the main door.

If fill is required below the floor, it should be sand or gravel. If some other type of soil fill is used, it should be well compacted. If these precautions are not taken, the concrete floor may settle and crack.

The concrete floor should be not less than 4 inches thick. It should be laid with a pitch of about 2 inches from the back to the front of the garage. Welded wire mesh is often used to help control surface cracks. However, unless it is placed in the top third of the concrete, it has little value.

The garage floor should be set about 1 inch above the drive or apron level. It is desirable to have an expansion joint between the garage floor and the driveway or apron.

The framing of the side walls and roof and the application of the exterior covering material should be similar to that of the house. Interior studs can be left exposed or covered with some type of sheet material. Building codes require that the wall between the house and the attached

garage be covered with fire-resistant material. Local building regulations and fire codes should be consulted before construction is begun.

**Doors.** The overhead sectional type of garage doors are used most commonly (fig. 137). They are made in four or five horizontal hinged sections and have a track extending along the sides under the ceiling framing with a roller for each side of each section. They are opened by lifting and are adaptable to automatic electric opening with remote control devices.

The standard size for a single door is 9 feet wide by 6½ feet or 7 feet high. Doors for two-car garages are usually 16 feet wide.

In design, the door most often used is the panel type with solid stiles, rails, and panel fillers. A glazed panel section is often included; translucent fiberglass and embossed steel or aluminum are also available. Clearance from the top of the door to the ceiling must usually be about 12 inches, although low-headroom brackets are available that can reduce required clearance to 6 inches.

The header beam over garage doors should be designed for the total dead load and live load that may be imposed by the roof above. If floor loads are also carried by this header, the floor live loads must also be considered. Three 2- by 12-inch boards, 18 feet long, are often required for 16-foot doors. If a load-bearing truss is used in the gable-end wall over a garage door, no header is needed.

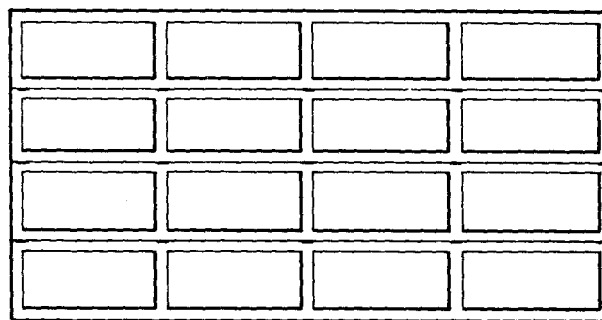
To keep the garage warmer in cold climates, overhead door units can be ordered with insulation kits and weatherstripping for the perimeter of the door. Weatherstripping is typically made of vinyl for head and side jambs and rubber or vinyl for contact with the floor.

### ***Carports***

Carports are often built with 4- by 4-inch solid wood posts (6- by 6-in posts in areas with heavy snow load) at all corners and at other intermediate points determined by the size of the load-bearing headers. Typically, there are four posts (with three spaces) in the long direction. The headers that span between the posts are normally 2 by 8 inches, or 2 by 12 inches on two-car ports in heavy snow areas.

Metal post bases are often used to fasten posts to the concrete slab. The load-bearing header is either bolted or nailed to the posts. Connectors must be able to resist strong wind uplift forces. Clearances should be the same as for garages, to allow for the possibility that the carport will be closed in at a later date.

**Figure 137** – *Sectional overhead garage door.*



Carports are usually attached to the house. To improve their appearance and utility, storage cabinets are often built on the open side or at the end.

### ***Porches and Decks***

Porches or decks should be joined to the main house by means of the framing members and roof sheathing. Rafters, ceiling joists, and studs should be securely attached by nailing, bolting, or lag-screwing to the house framing.

When additions are made to an existing house, it may be desirable to remove siding or other exterior finish so that the framing members of the addition can be easily fastened to the house. In many instances, siding can be cut to the outline of the addition and removed only where necessary. With wood or plywood siding, metal joist hangers are sometimes applied directly to the siding, but only at points where the attachment is to be made to framing members behind the siding at the point of application. Footings should be of sufficient size, with bottoms located below the frost line, and the foundation walls should be anchored to the house foundation when possible.

All lumber used outside, especially joists, flooring, posts, and lattices, should be either pressure-treated or of a species with natural resistance to decay, such as redwood, cypress, and cedar.

### ***Porches***

Some porches have roof slopes continuous with the roof of the house. Other porch roofs may have just enough pitch to provide drainage and may require continuously sealed roofing or hot-tar built-up roofing rather than shingles. Basic construction principles for porches are similar, however, and a general description can cover various types.

Figure 138 shows the construction details for the juncture of a concrete slab floor and the house foundation wall. An attached porch can be open or fully enclosed. It can be

constructed with a concrete slab floor, insulated or uninsulated, or with wood floor framing over a crawl space (fig. 139). Construction details should comply with those previously outlined for various parts of the house itself.

**Framing and floors.** Porch floors, whether wood or concrete, should have sufficient slope away from the house to provide good drainage. Weep holes or drains should be provided in any solid or fully sheathed perimeter wall. Open wood balusters with top and bottom railings should be constructed so that the bottom rail is free of the floor surface.

Wood floor framing should be at least 18 inches above the soil. It is good practice to use a soil cover of polyethylene or similar material under a partially open or a closed porch.

Lattice or grillwork around an open crawl space should be made with a removable section for entry in areas

where termites may be present (see the section on protection against decay and termites in chapter 8). A fully enclosed crawl space foundation should be vented or have an opening to the basement.

Wood for porch flooring should have good decay and wear resistance, be nonsplintering, and be resistant to warping. Species commonly used are cypress, Douglas-fir, western larch, southern pine, and redwood.

**Columns.** Roof support for enclosed porches usually consists of fully framed stud walls. Because finished coverings are used on both interior and exterior, the walls are constructed much like the walls of the house. In open or partially open porches, however, solid or built-up posts or columns are used. Solid posts, normally 4 by 4 or 6 by 6 inches, are used mainly for open porches. A more finished column can be made up of doubled 2- by 4-inch

**Figure 138** – Porch concrete slab floor.

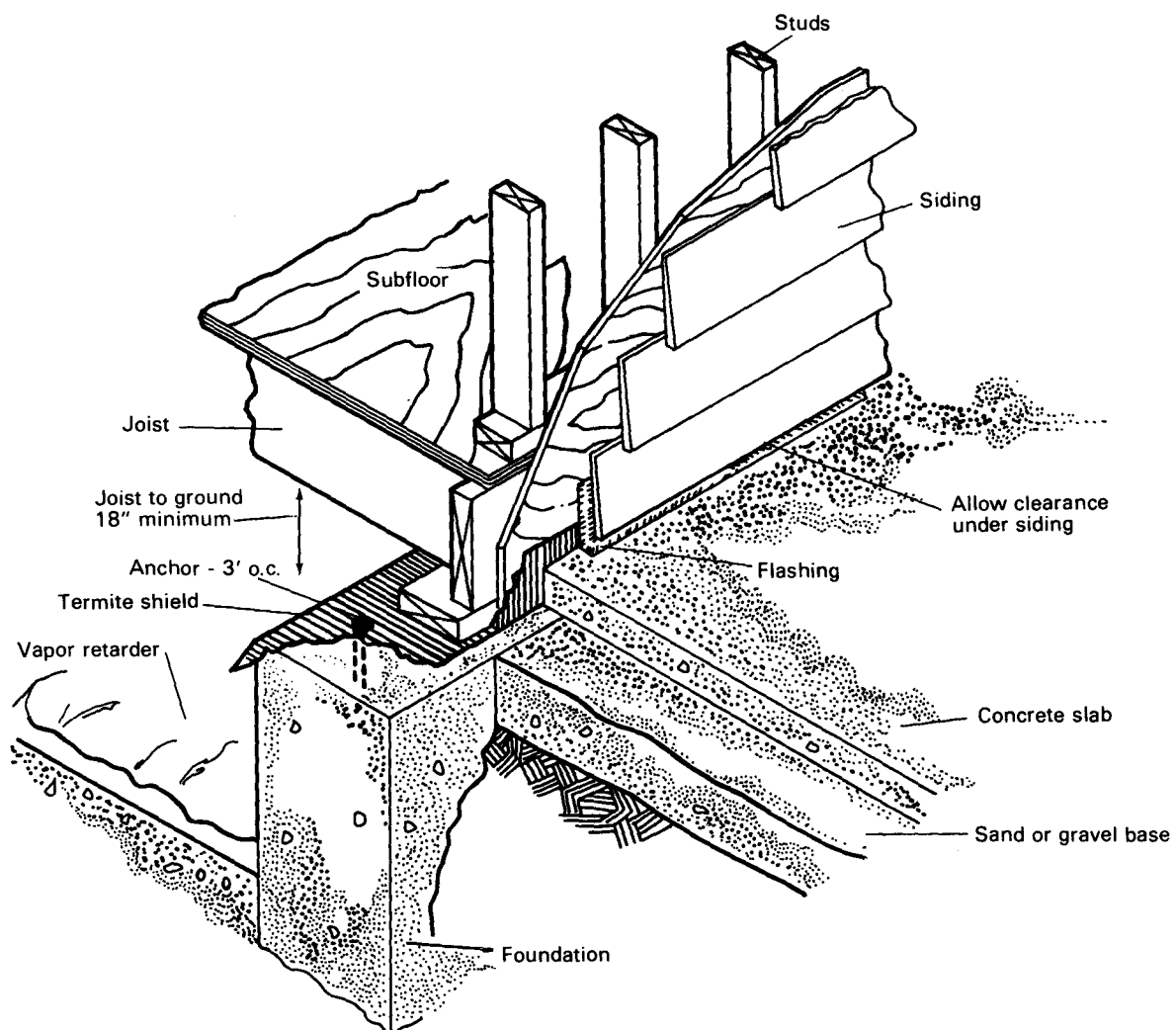
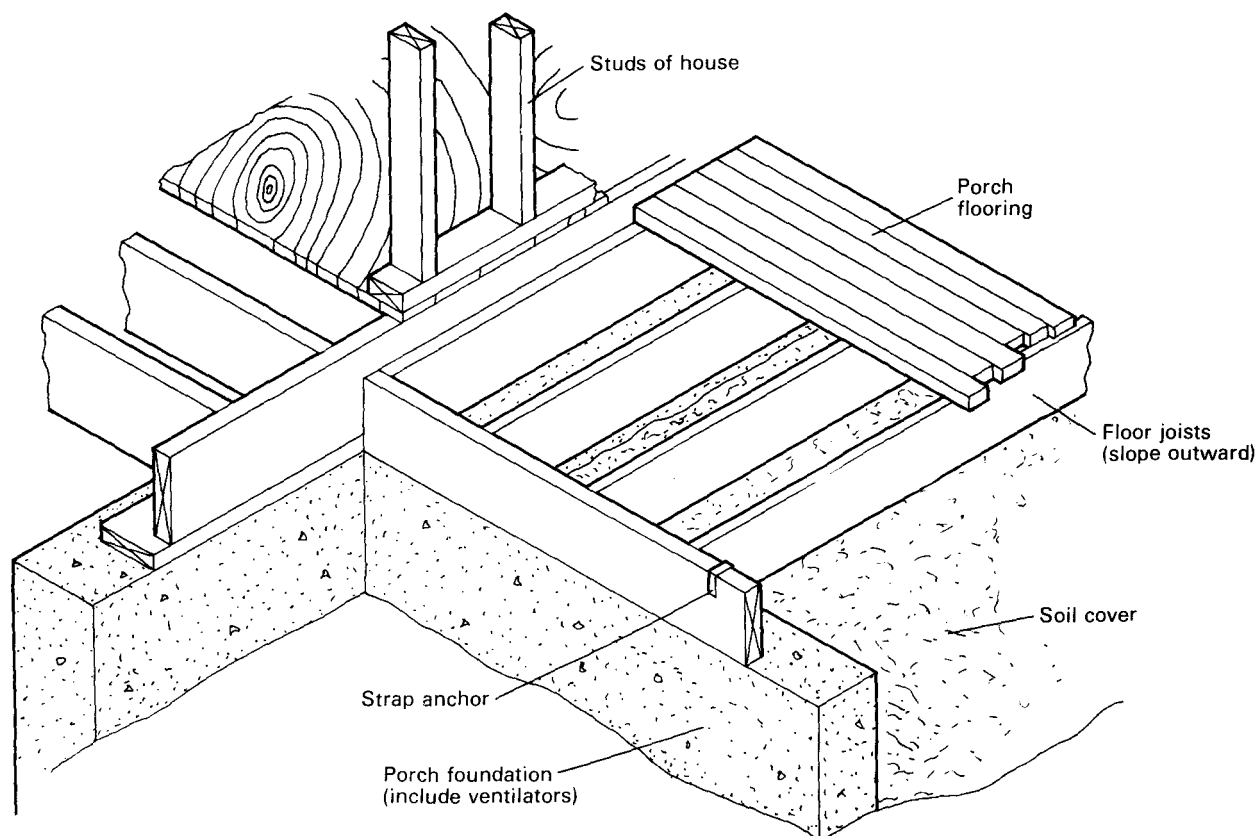


Figure 139 – Porch crawl space floor.



lumber covered with 1-by 4-inch boards on two opposite sides and 1-by 6-inch boards on the other sides (fig. 140A). An open railing may be used between posts.

A large house entrance often includes columns topped by capitals. These factory-made columns are ready for installation when they reach the building site.

The bases of posts or columns in open porches should be designed so that no pockets are formed that can retain moisture. In single posts, a steel pin can be used to locate the post, and a large galvanized washer or similar spacer can be used to keep the bottom of the post above the concrete or wood floor (fig. 140B). Alternatively, a variety of metal post bases are available at lumberyards. One should be selected that provides space for drainage under the end of the post (fig. 140C). The bottom of the post should be treated with water-repellent preservative (WRP) to minimize moisture penetration. Single posts of this type are often made from a decay-resistant wood species or pressure-treated wood.

**Balustrades.** Porch balustrades usually consist of one or two railings with balusters between them. A closed balustrade can be used in combination with screens or combination windows (fig. 141A). A balustrade with

decorative railings can be used for an open porch (fig. 141B). This type can also be used with full-height removable screens.

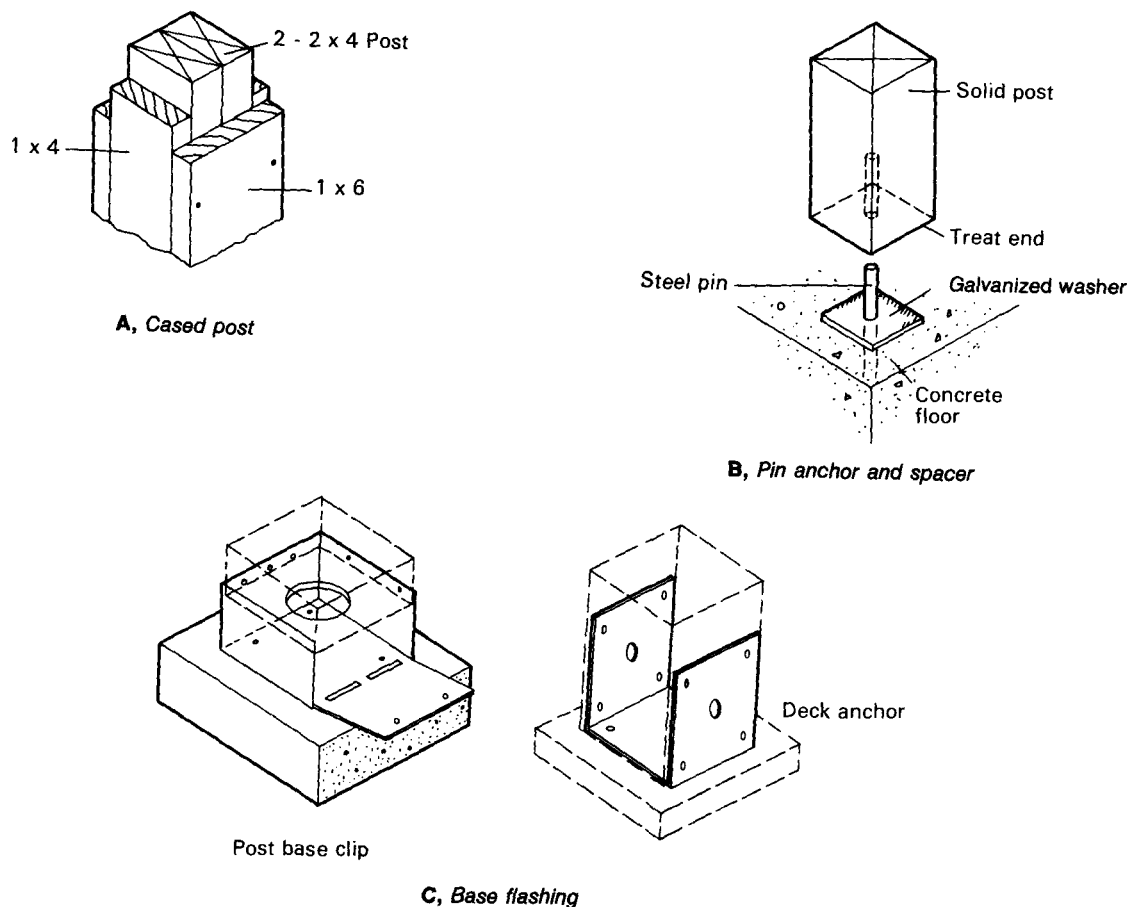
All balustrade members that are exposed to water and snow should be designed to shed water. The top of the railing should be tapered, and connections with balusters should be protected as much as possible (fig. 142A). Railings should not contact a concrete floor, but should be blocked to provide a small space beneath. When wood such as the blocks must be in contact with the concrete, it should be pressure-treated to resist decay.

Connection of the railing to a post should be made in a way that prevents moisture from being trapped. One method provides a small space between the post and the end of the railing (fig. 142B). When the railing is painted or treated with water-repellent preservative, this type of connection should provide good protection. Exposed members, such as posts, balusters, and railings, should be all heartwood stock of decay-resistant or pressure-treated wood.

### Decks

A variety of wood species can be used for building decks. For long life and reduced maintenance, either

Figure 140—Post details:



pressure-treated wood or wood with natural resistance to decay, such as redwood, cedar, or cypress, should be used. Some woods that are easy to work, such as hemlock, most pines, spruce, and Douglas-fir, have either low resistance or only moderate resistance to decay and insect attack. Such species can be used for deck construction if they are pressure-treated.

Decks should be designed to withstand heavy loads because they tend to be places where many people congregate. Local building codes should be checked in case they specify minimum load-bearing requirements for live load (people, snow, furniture, equipment, etc.) and dead load (the deck itself). If there are no code requirements, assume a live load of 40 pounds per square foot (lb/ft<sup>2</sup>) and a dead load of 10 lb/ft<sup>2</sup>. Spacing of posts, beams, and joists should be based on these requirements. Span tables for floor joists such as are shown in the section on floor framing should be consulted.

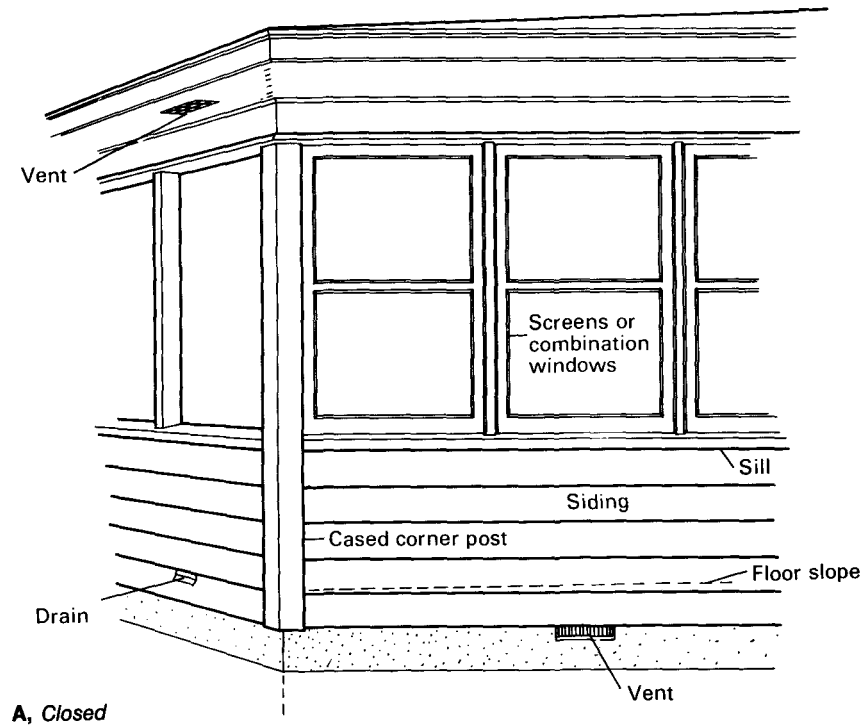
**Layout.** Most decks are attached to the house, although some are freestanding. For those that are attached to the house, the top of decking should be located 1 inch below the inside floor level. If no doorway

is in place and measurements cannot easily be made, some other point of reference should be used that can be transferred to the outside. For example, the measurement from the top of the inside floor to the bottom of a window sash can be transferred to the outside from the bottom of the same window sash. One inch should be added to this measurement to locate the top of the decking.

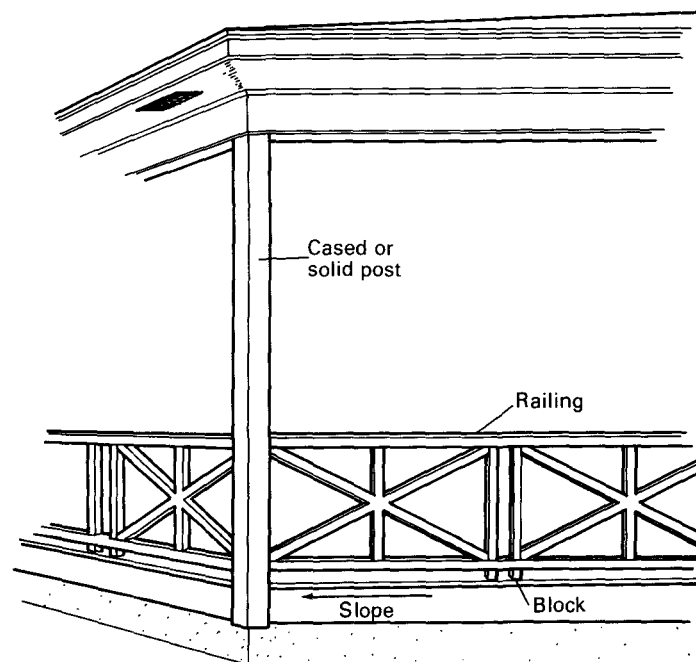
Next, a measurement should be made down from the top of the deck to a distance equal to the thickness of the deck flooring plus the height of the deck joists. This point represents the bottom of the deck joists. The bottom of the deck joists can be located in this manner at both ends of the proposed deck, and a chalk-line string snapped through the points.

Joist spacing should be marked along the length of the chalk line. The outside face of the first floor joist will be in line with the end of the deck. Beginning with the outside face of the first-floor joist, a distance of 15¼ inches should be measured to mark the beginning face of the second joist. Thereafter, the beginning faces of the floor joists should be marked at 16-inch intervals. The final mark at the end of the deck marks the outside face of the final floor joist.

Figure 141—Types of balustrades:



A, Closed



B, Open

Several methods can be used to attach the deck floor joists to the house along the chalk line. The simplest method is to attach joist hangers directly to the siding with lag screws (fig. 143). The lag screws must penetrate either the floor framing members or the wall studs of the house. The bottoms of the joist hangers are aligned with

the chalk line, and the sides of the hangers are aligned with the marks indicating deck floor joist spacing.

Another method is to attach a header joist to the side of the house with lag screws that are long enough to penetrate the floor framing or wall studs of the house

(fig. 144). The bottom of the header joist should be aligned with the chalk line; its height is the same as the deck floor joists. Metal joist hangers should be nailed to the header joist with their bottoms aligned with the bottom edge of the joist. The sides of the joist hangers should be aligned with the marks indicating deck floor joist spacing.

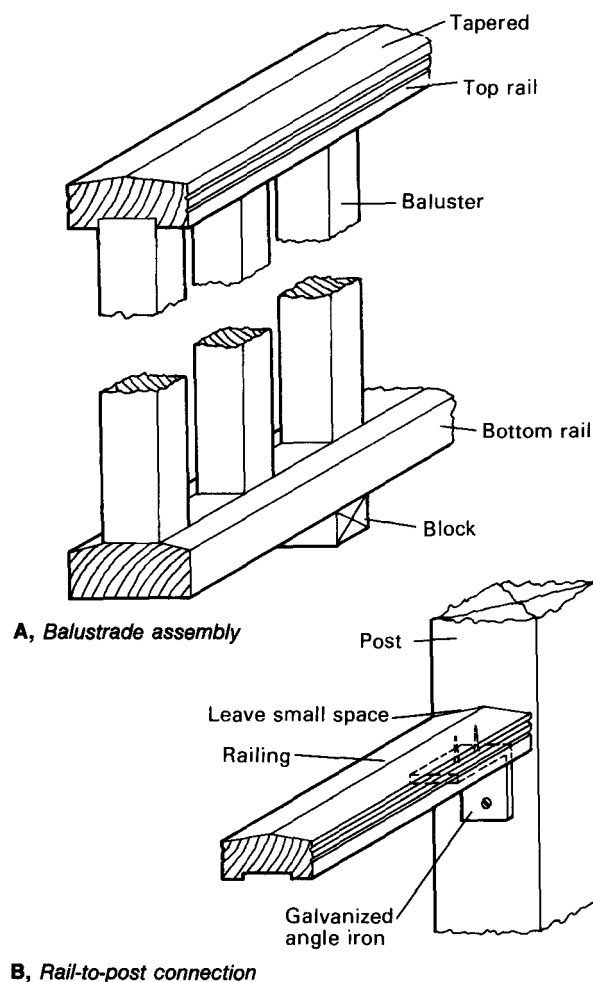
A third method is to attach a 2- by 4-inch or 2- by 6-inch wood ledger to the side of the house with lag screws (fig. 145). The top of the ledger should be aligned with the chalk line. No joist hangers are required since the deck floor joists rest on top of the ledger.

If either the header joist method or the ledger method is chosen for use against wood siding, flashing must be installed. A circular saw should be used to cut through the siding at the top and along the entire length of the header or ledger. The siding should be pried out with a flat bar, and Z-flashing installed to prevent water accumulation between the wood siding and the header or ledger (figs. 144 and 145).

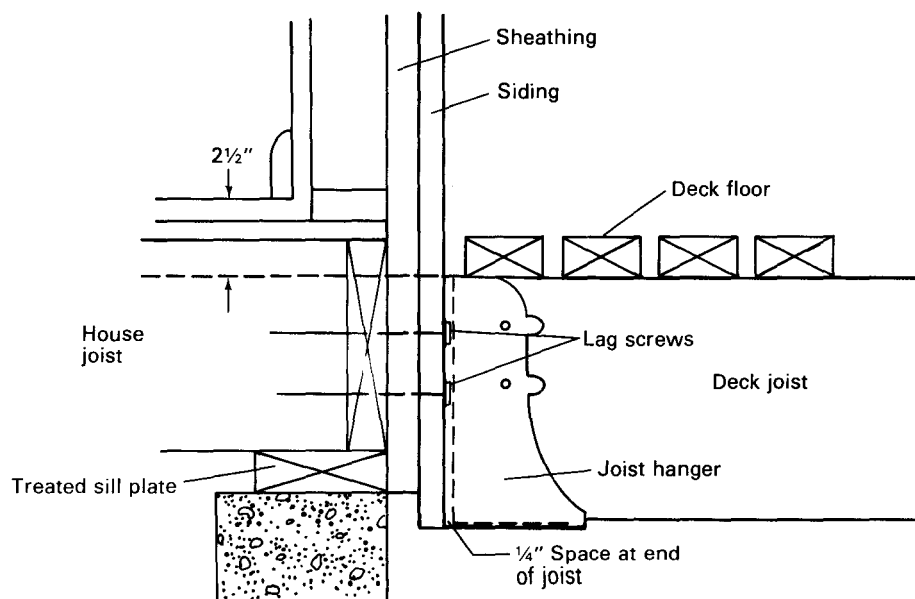
If the deck floor framing is attached to a brick or block wall, lead anchors and expansion bolts should be used in place of lag screws.

The deck floor framing should be assembled on the ground by nailing a header joist to the ends of the floor joists on the side of the deck away from the house, using 16d hot-dipped galvanized nails, three per joist. A second header joist should then be nailed to the first. The floor joists should be lifted and the ends placed into the joist hangers or onto the ledger. The header joist should be

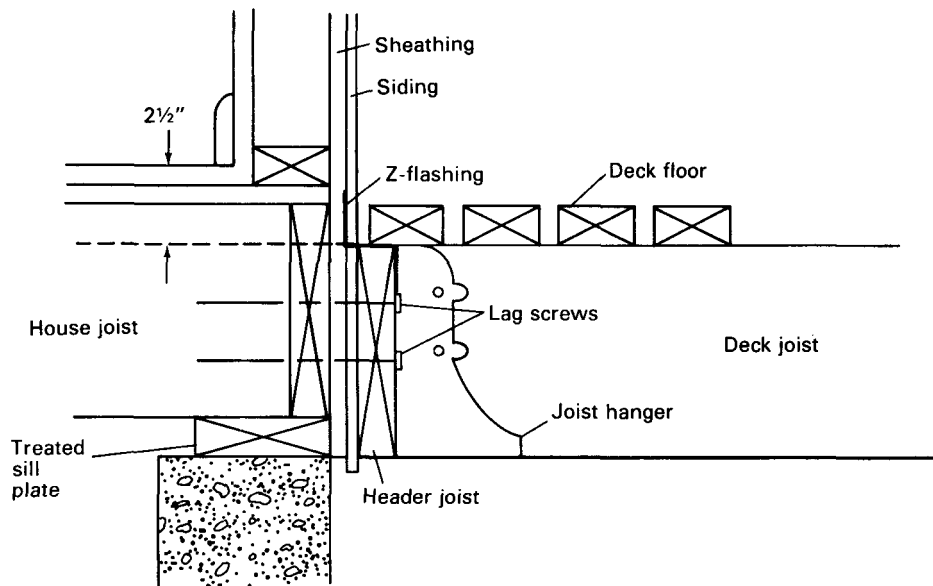
**Figure 142 – Railings:**



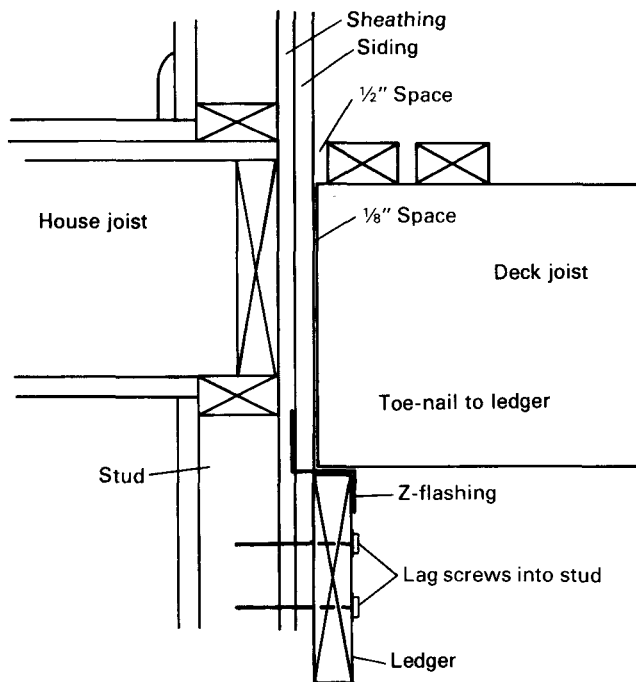
**Figure 143 – Deck attachment to house with joist hangers.**



**Figure 144 —Deck attachment to house with header joist.**



**Figure 145 —Deck attachment to house using ledger.**



raised until the deck floor framing is level, and temporarily braced with 2 by 4 posts.

The deck should be squared with diagonal measurements and a temporary brace placed across the framing to maintain squareness. From a ladder, a plumb line should be dropped to locate footings and posts, and stakes should be driven at these points. The deck should be set on the ground while post holes are being dug.

Footings for the deck support posts should be deep enough to extend to undisturbed soil below frost line (fig. 146). One method of digging footing holes is to use a post-hole digger. A 6-foot steel bar may be useful for loosening the soil. An 8-inch-diameter hole is sufficient for 4- by 4-inch posts.

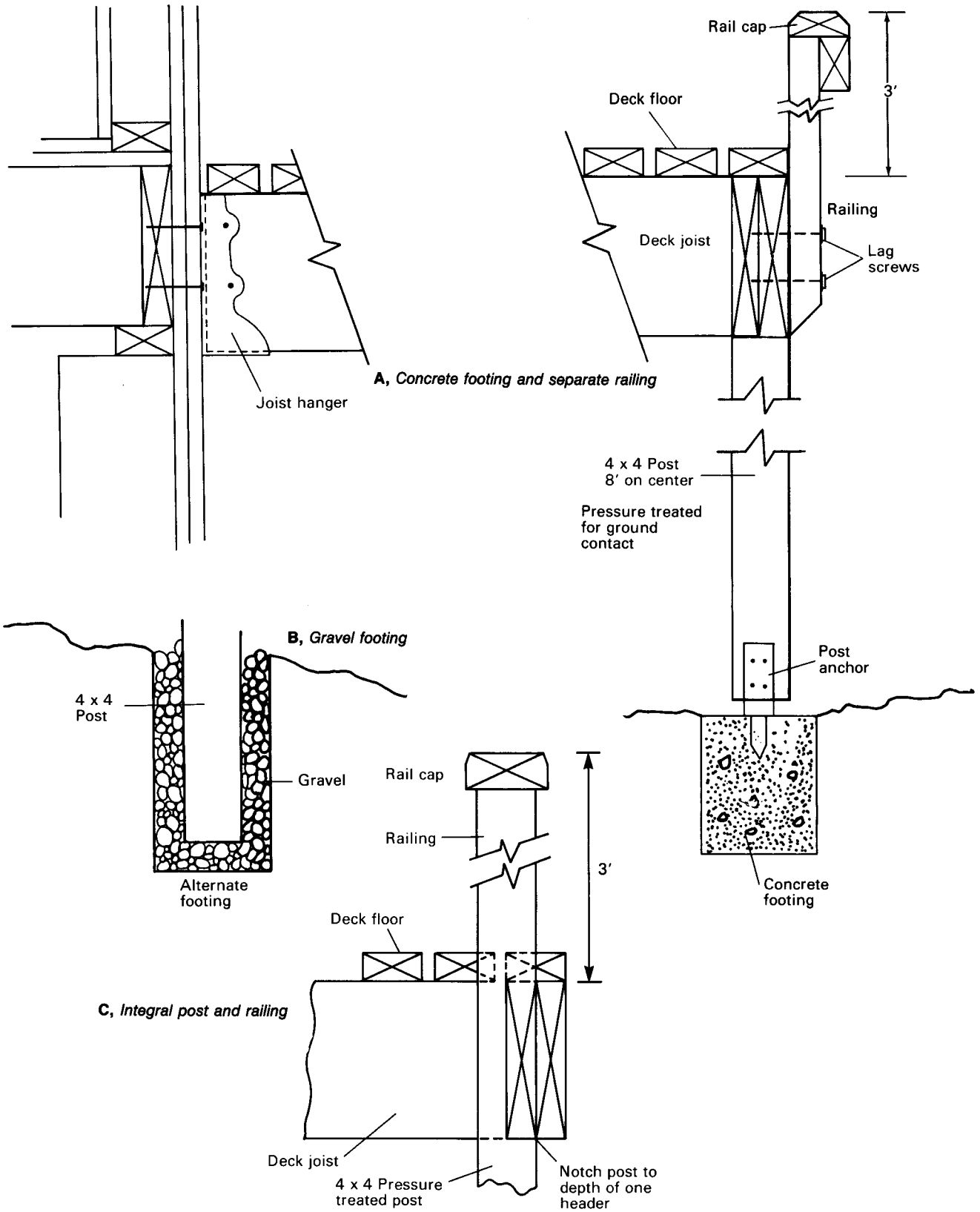
When the post footing holes have been dug, the deck should again be raised, leveled, and temporarily braced. The joist ends at the house should then be permanently nailed to the hangers or ledger.

If concrete footings are used, the holes should be filled with concrete and post anchors fastened in the concrete. It may be worthwhile to check the location of the anchor with the plumb line. It should be remembered that the plumb line will probably be at the outside corner of the post, and the anchor should be positioned accordingly. Four- by four-inch pressure-treated posts should be cut to fit between the anchor and the deck joists, and nailed to the joists (fig. 146A).

Curing of the footings requires about 7 days. When they have been cured, the temporary deck bracing can be removed and the support posts set on and nailed to the anchors.

As an alternative to the use of a concrete footing, about 4 inches of gravel can be placed in the bottom of the hole, its depth measured, and the post cut, set in the hole on top of the gravel, and nailed to the deck floor framing. The hole should then be backfilled with gravel, and the gravel tamped (fig. 146B).

Figure 146 – Deck posts and footing:



**Flooring.** Starting from the house, chalk-line string should be snapped for placement of deck flooring. If 2- by 4-inch lumber is used, marks should be made every 4 inches; if 2- by 6-inch lumber is used, marks should be made every 6 inches. For a 12-foot-deep deck, 36 2 by 4's or 24 2 by 6's are needed. The marking provides a ½-inch space between boards. The first ½-inch space should be adjacent to the house. This allows rainwater to drain past the decking.

Corrosion-resistant nails should be used. Two 16d nails should be driven at each deck-joint intersection. If nails are driven at about a 30° angle, they are less likely to loosen. Three 16d nails should be used at butt joints.

Decking boards should be inspected visually for straightness as they are being placed. Any boards having a slight edgewise crook can be straightened somewhat by nailing one end and bending the board into place as it is nailed. Occasionally, a pry bar may be needed to straighten difficult boards. Boards that are slightly bowed should be laid with the crown up to prevent the accumulation of water. It may sometimes be necessary to discard boards that are badly deformed.

**Railings.** Railings must be sturdy enough to withstand the weight of people leaning against them. They should also be designed to prevent children from falling through. Local codes may specify minimal height and maximal space between rails.

In an extended post deck, the posts extend 36 inches up through the deck flooring and serve as the major rail posts.

Many builders use 2- by 2-inch rail posts, spaced 6 inches on center and lag-screwed to the deck header or to an edge joist. A vertical 2- by 4-inch board at the top of the 2 by 2's and a horizontal cap board complete the top of the railings. Edges of the cap board can be routed to give the board a more finished look and to minimize splinters (fig 146).

### Driveways and Walkways

Driveways and walks should be installed prior to such landscaping as final grading, planting of shrubs and trees, and seeding or sodding of lawn areas.

Concrete and bituminous pavement are most commonly used in the construction of walks and drives, especially in areas where snow removal is important. In some areas of the country, a gravel driveway and a flagstone or precast concrete walk may be satisfactory, thereby reducing cost.

#### Driveways

The grade, width, and radius of curve in a driveway are important in establishing a safe entry to the garage.

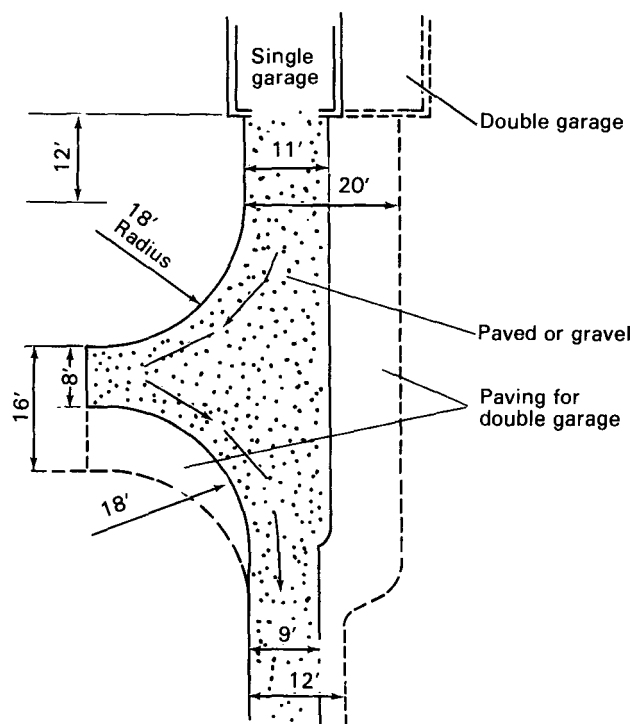
When attached garages are located near the street on relatively level property, driveway width is the basic consideration. Driveways that are long and require an area for turnaround require careful planning and design. Figure 147 shows a driveway and turnaround that allow the driver to back out of a single or double garage into the turnaround, and proceed to the street or highway in a forward direction. This is much safer than having to back onto the street or roadway, particularly in areas of heavy traffic. As shown in figure 147, a double garage should be serviced by a wider entry and turnaround.

Driveways that must be steep should have a near-level area 12 to 16 feet long in front of the garage for safety. Driveways that have a grade more than 7 percent (7-ft rise in 100 ft of length) should have some type of pavement to prevent erosion.

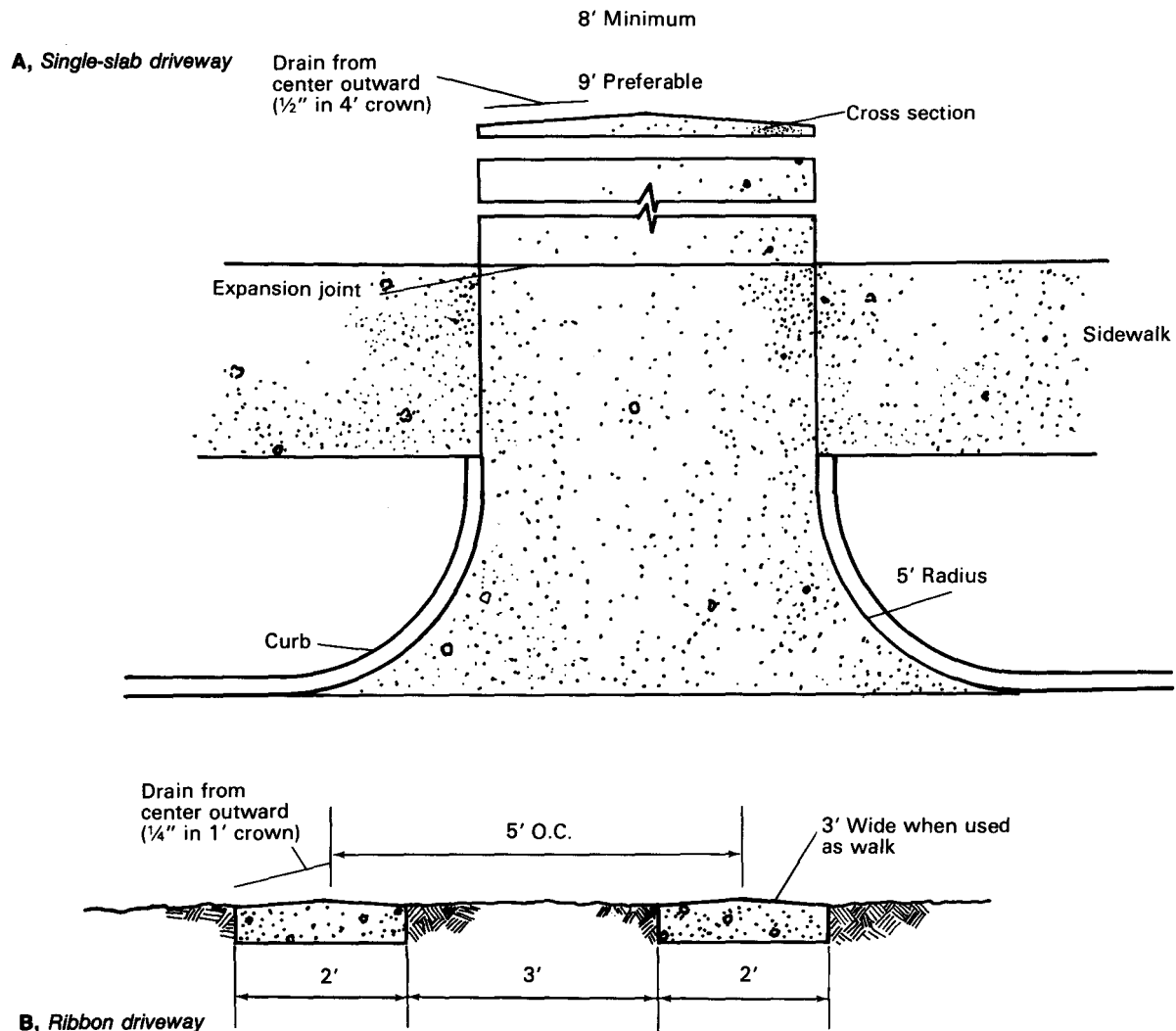
Two types of paved driveways are the slab or full-width type, which is more common, and the ribbon type (fig. 148). When driveways are fairly long or steep, the full-width type is the most practical. The ribbon driveway is cheaper and perhaps less conspicuous because of the grass center strip between the two concrete runners. However, it is not practical if there is a curve or turn involved or if the driveway is long.

The width of the slab driveway should be 9 feet, although 8 feet is often considered acceptable (fig. 148A). When the driveway is also used as a walk, it should be at least

Figure 147 – Driveway with turnaround.



**Figure 148 – Driveway details:**



10 feet wide to allow for a parked car as well as a walkway. The width should be increased by at least 1 foot at curves. The radius of the drive at the curb should be at least 5 feet (fig. 148A). Relatively short double driveways should be at least 18 feet wide, and 2 feet wider when they are also to be used as a walk from the street.

The concrete strips in a ribbon driveway should be at least 2 feet in width and located so that they are 5 feet on center (fig. 148B). When the ribbon is also used as a walk, the width of strips should be increased to at least 3 feet.

A 5-bag or 5½-bag commercial concrete mix is ordinarily used for driveways. However, a 5½-bag to 6-bag mix containing an air-entraining mixture should be used in areas having severe winter climates. Pouring a concrete driveway over an area that has been recently filled is poor practice unless the fill, preferably gravel, has settled and is well tamped. A gravel base is not

ordinarily required on sandy undisturbed soil but should be used in all other conditions. Concrete should be about 4 inches thick. Lengths of 2 by 4 are often used for side forms to produce a 3½-inch-thick slab. The side forms establish the elevation and alignment of the driveway and are used for finishing the top surface of the concrete.

Under most conditions, the use of steel reinforcing is good practice. Steel mesh, 6 by 6 inches in size and installed in the upper one-third of the poured concrete, normally prevents or minimizes cracking.

Isolation joints, sometimes called expansion joints, should be used (a) at the junction of the driveway with the public walk or curb, (b) at the junction with the garage slab, and (c) about every 40 feet on long driveways. The purpose of the isolation joint is to separate two adjacent concrete sections that may move relative to each other. The isolation joint should be filled with a material

such as asphalt-impregnated fiber sheathing. The joint filler material should be set  $\frac{1}{2}$  inch below the concrete surface to allow placing of a sealant at the top to make the joint watertight.

Control joints should be provided at 10- to 12-foot intervals. These crosswise grooves, cut into the partially set concrete, predispose the concrete to crack in a controlled fashion along these lines during the cold weather rather than to form irregular cracks in other areas. In order to be effective, the control-joint depth should be approximately one-quarter of the concrete thickness.

Blacktop driveways, normally constructed by paving contractors, should also have a well-tamped gravel or crushed rock base. The top should be slightly crowned for drainage.

### Walkways

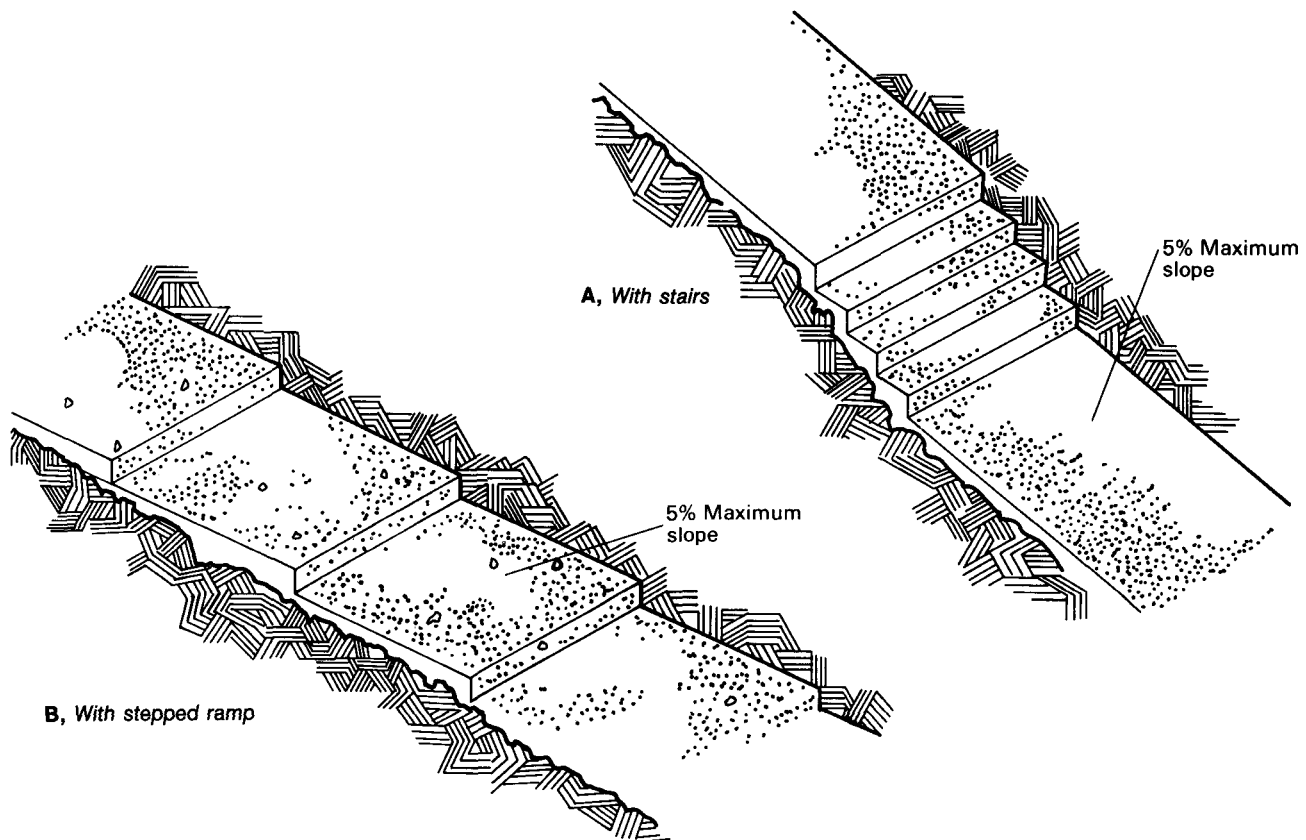
Main walkways generally extend from the front entry to the street or front sidewalk, or to a driveway leading to the street. A 5-percent grade is considered maximum for sidewalks; any greater slope usually requires steps. Walks should be at least 3 feet wide.

Concrete walkways should be constructed in the same general manner as concrete driveways. They should not be poured over filled areas unless such areas have settled and are very well tamped. This is especially true of the areas near the house after basement excavation backfill has been completed.

The thickness of the concrete over normal undisturbed soil should be about 4 inches. A 2 by 4 is commonly used as a side form. As described for concrete driveways, control joints should be used and spaced on 4-foot centers. Isolation joints should be used to separate the walkways from steps, driveway, and the public sidewalk.

When slopes to the house are greater than a 5-percent grade, stairs or steps should be used. This may be accomplished with a flight of stairs at a terrace, a continuing sidewalk (fig. 149A), or a ramp sidewalk (fig. 149B). Such stairs should have 11-inch treads and 7-inch risers when the total stair size is 30 inches or less. When the rise is more than 30 inches, the tread should be 12 inches and the riser 6 inches.

Figure 149 – Sidewalks on slopes:



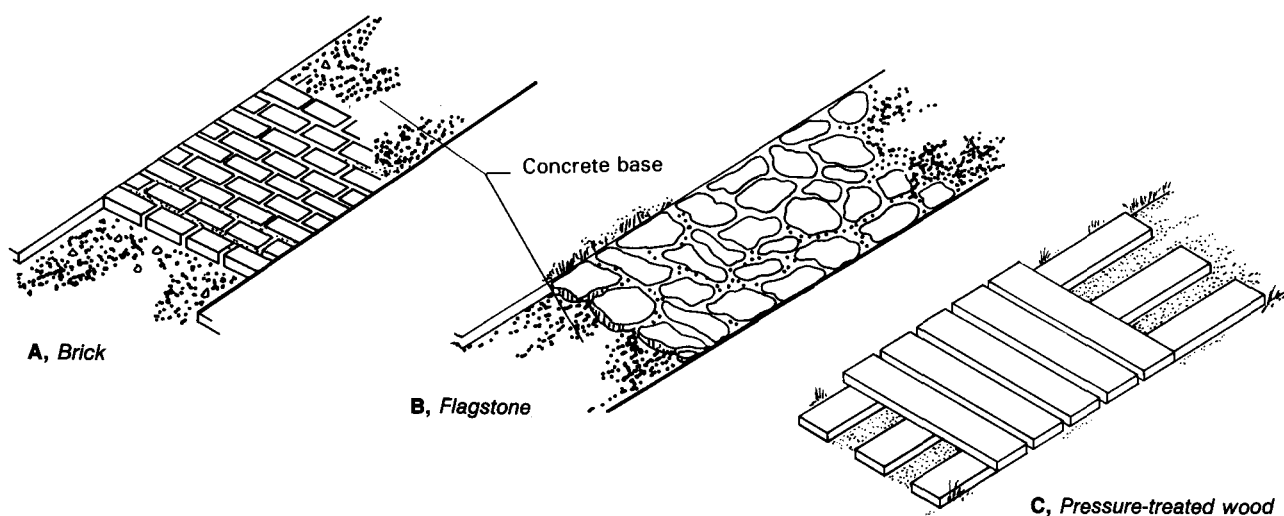
For a moderately uniform slope, a stepped ramp may be satisfactory (fig. 149B). Generally, the rise should be about 6 inches to 6½ inches and the length between risers sufficient for two or three normal paces.

Walks can also be made of brick, flagstone, or other types of stone. Brick and stone are often placed directly over a well-tamped sand base. However, this system is not completely satisfactory where freezing of the soil is possible. For a more durable walk in cold climates, the brick or stone topping should be embedded in a freshly laid reinforced concrete base (fig. 150).

As with all concrete sidewalks and curbed or uncurbed driveways, a slight crown should be included in the walk for drainage. Joints between brick or stone may be filled with a cement mortar mix or with sand.

Walkways made of pressure-treated wood can be used in conjunction with decks. Two 2- by 4-inch boards can be fastened to the ground, 24 inches on center, with steel rebar stakes, to which 2 by 6 decking is attached. Such a walkway can lead to the wood steps of the deck.

**Figure 150** – *Offer sidewalks:*







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## Working Inside

Sections in this chapter discuss the work to be done inside the house after the shell is complete.

### Interior Wall Framing

Some interior partitions, called load-bearing partitions, support the joists of the roof or second floor. The others are called non-load-bearing partitions.

Interior load-bearing partitions are framed in the same manner and with the same types of studs, plates, and headers as exterior load-bearing walls.

Wood stud framing is commonly used for non-load-bearing partitions because of its cost-effectiveness, simplicity, and efficiency. It requires no special fastening and can be finished with a variety of easily available materials.

Most building codes accept 2- by 3-inch studs spaced 24 inches on center with single top and bottom plates for non-load-bearing partitions. Alternatives include 2- by 3-inch studs spaced 16 inches on center, or 2- by 4-inch studs spaced either 16 inches or 24 inches on center. These methods require more material.

It is not necessary to coordinate the placement of non-load-bearing partitions with either ceiling or floor framing members. Partitions may be located either parallel or perpendicular to such members. When located perpendicularly the partitions may be anchored by nailing through the top and bottom plates directly into the ceiling and floor framing as shown in figure 151A.

Partitions running parallel to ceiling or floor framing can be located between the framing members. In such instances top anchoring can be accomplished by installing precut 2- by 3-inch or 2- by 4-inch blocks between the overhead joists or trusses (fig. 151B). These blocks should be spaced no more than 24 inches apart to provide adequate backup for ceiling finish. Nails should be driven through the block into the top plate of the partition.

Non-load-bearing partitions running parallel to and between floor framing members are adequately supported by  $\frac{5}{8}$ -inch or  $\frac{3}{4}$ -inch plywood subflooring. They may be anchored by nailing directly through the bottom plate into the plywood flooring.

Interior partitions can be attached directly to studs in intersecting walls at the point where the walls meet. If the juncture occurs between the studs of the intersecting wall,

a 2- by 3-inch or 2- by 4-inch block should be installed at midheight between the studs (fig. 152). The end stud of the interior partition can be anchored to this block by nailing directly through the stud into the block.

When two interior partitions meet to form a corner, they can be joined and anchored by nailing the end studs of the partitions together (fig. 152).

Studs and plates used in framing partitions form the backup structure to which interior wall finish is attached. Additional backup is required at corners and intersections.

Supplementary backup for standard gypsum wallboard or drywall (fig. 153) can consist of cleats of  $\frac{3}{8}$ -inch plywood, or metal backup clips spaced up to 24 inches apart. Strips of 1- by 3-inch or 1- by 4-inch lumber 36 to 48 inches long can also be used. The gypsum wallboard is not fastened to these clips or wood backers. The drywall sheet supported by the backers should be installed first so that the adjacent sheet wedges it into place. This technique provides the nonrigid drywall joint recommended to minimize cracking.

Similar methods are used to provide backup for ceiling gypsum wallboard at the top of partitions. Such backup should not be necessary for partitions running parallel to overhead members if blocking has been installed 24 inches on center.

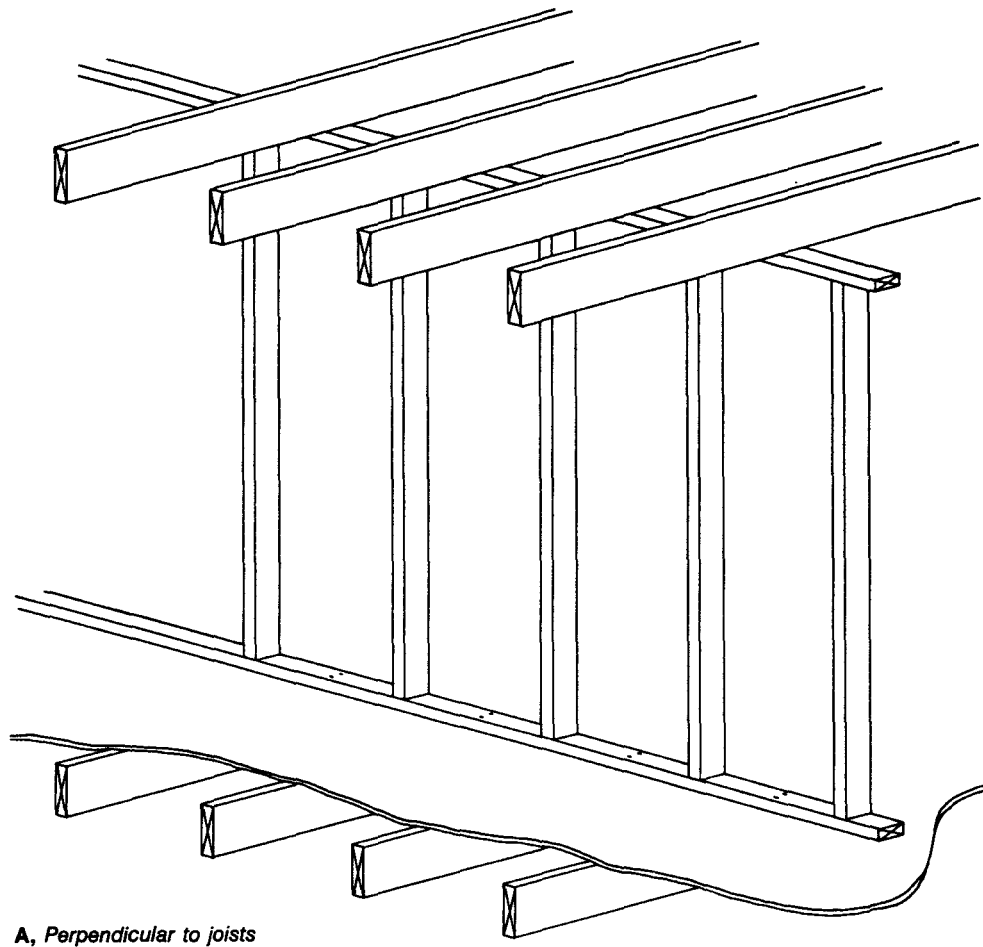
Backup for other types of interior finish such as wood paneling or plaster-base lath may require other methods or materials. Instructions provided by the manufacturer of the interior finish material should be followed.

Installation of drain, waste, or vent plumbing within interior partitions can require special framing. Figure 154A shows an interior partition that has a 2- by 6-inch or 2- by 8-inch top and bottom plate to accommodate large-diameter pipes. The arrangement of the 2- by 4-inch studs is designed to accommodate the plumbing laterals. It is also possible to use 2- by 4-inch framing materials with pipe diameters up to 3 inches. However, it is necessary to reinforce the top plates penetrated by these pipes by applying a double scab (fig. 154B). The scabs should be well nailed on each side of the pipe and should extend over two studs. Small angle irons can also be used.

### Plumbing, Heating, and Electrical Installation

Installation of utilities must take place while the wall cavities are open and accessible. This is commonly called

**Figure 151** – *Partition anchoring:*



“roughing in” the plumbing lines, heating ducts, and electrical wiring that will eventually be concealed in the walls. Because of this concealment, inspection by a code authority is usually required for the roughed-in utilities while wall cavities are still visible. Wiring for other services is not mandatory, but is much easier to accomplish while the walls are open. These items include thermostat, telephone, doorbell, intercom, and cable TV. To be most effective all of this requires advance planning of room usage and furniture placement. At least one telephone jack in each room may be advisable. Where cable TV is available, TV jacks should be placed in several locations.

### **Insulation and Vapor Retarders**

After utilities are roughed in, insulation should be installed. The most widely used home insulation is made of mineral fibers and is called rock wool or fiberglass. It is composed of very fine inorganic fibers made from rock, slag, or glass, with other materials added to enhance service properties. Available forms include flexible batts and blankets (with and without facings), semi-

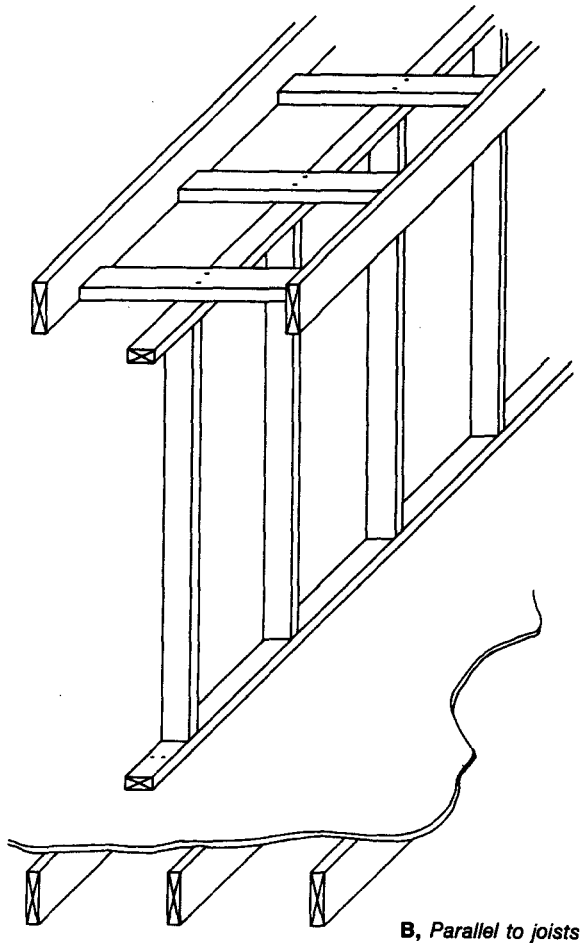
rigid and rigid boards (with and without facings), and a loose form for blowing or pouring.

Batt and blanket insulation usually has a kraft paper vapor-retarder facing, with stapling flanges. Sometimes an enclosure or breather paper that is not a vapor retarder is used on the back side. Batts and blankets are also available with aluminum foil facings, including stapling flanges, and in an unfaced form held in place by pressure.

Mineral wool board insulation can be used on the inside face of crawl space walls. Mineral wool blankets and boards are also available for use as duct insulation. (Building blankets should not be used for this purpose.) Preformed mineral wool pipe insulation is also available through industrial insulation contractors for both hot and cold water piping.

Among other types of insulation used in residential construction, foamed plastic insulation boards or sheets are sometimes used as exterior wall sheathing, foundation

**Figure 151** – *Partition anchoring (continued):*



insulation, and quite commonly as perimeter edge insulation for slab-on-grade construction. Cellulose fiber insulation is used primarily in ceilings and in walls of existing homes. It should be pneumatically installed, preferably by an insulation contractor. Multiple-layer aluminum foil insulation is sometimes used between furring strips on masonry wall construction. It is fragile and must be installed with great care if it is to be effective. Whatever the insulating material, once it is installed, it becomes a permanent part of the house.

Combustible vapor-retarder facings on insulation should not be left exposed but should be covered with finish materials. Breather paper is combustible and, when exposed in accessible space, should be either covered or stripped off after the batts are in place.

Effective locations for installing insulation are the following:

1. **EXTERIOR WALLS.** Sections sometimes overlooked are the wall between living space and an unheated garage or storage room, dormer walls, and the portion of the wall above the ceiling of an adjacent section of a split-level house. Insulation should be stuffed into the narrow spaces around window and door openings between jambs and framing.
2. **CEILINGS BENEATH COLD SPACES AND DORMER CEILING.** The attic access panel can be insulated by stapling the edges of a piece of blanket insulation to its top. The use of adhesive-backed foam tape on the bottom side around the edge of the attic access panel is a convenient method of weatherstripping this opening.

**Figure 152** – *Anchoring partition intersections*

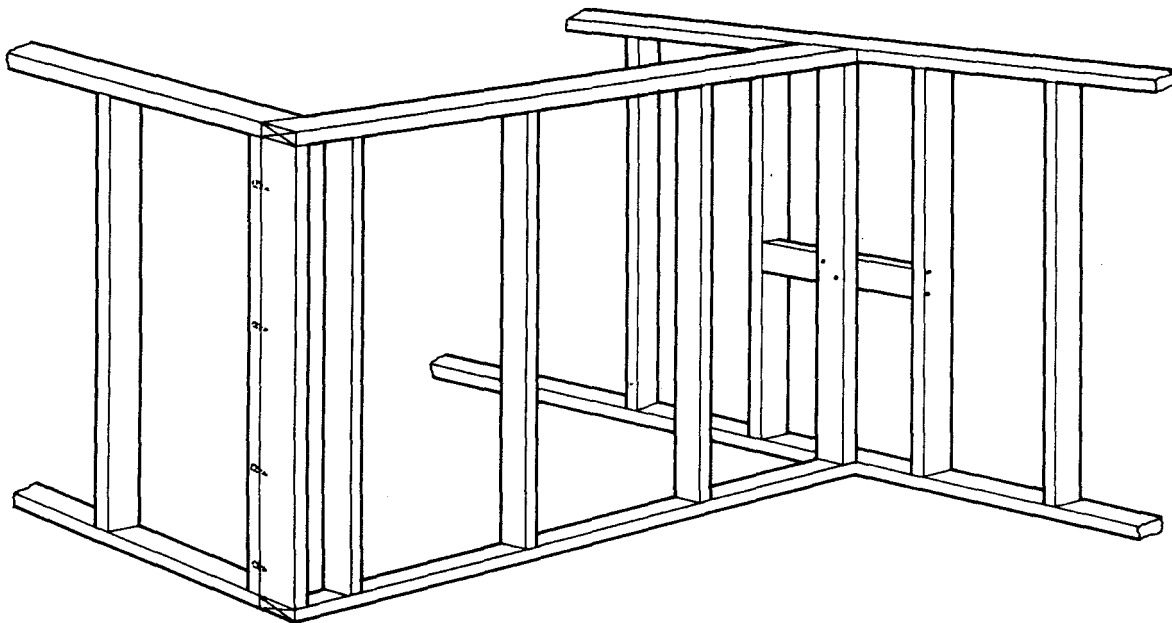
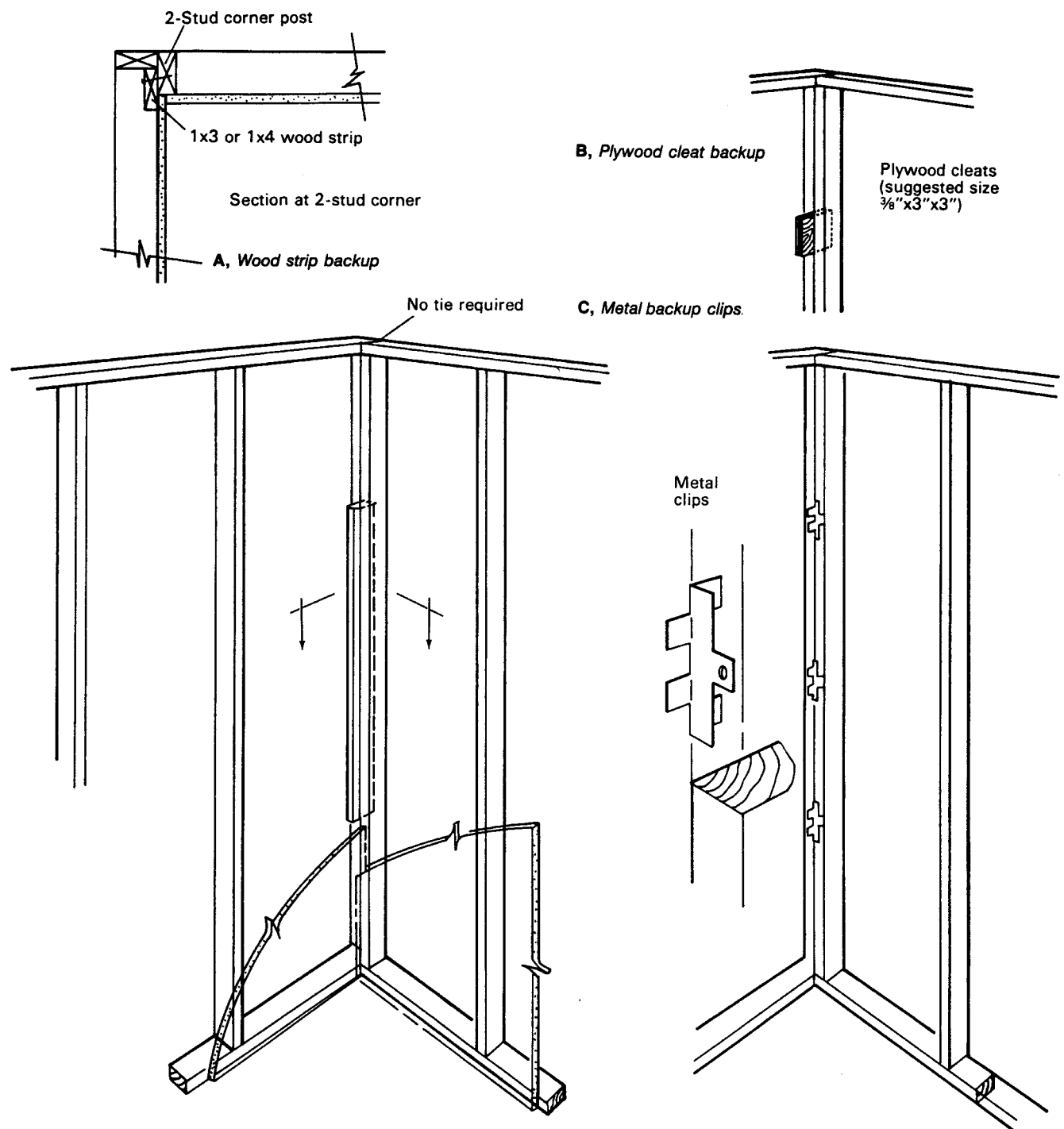
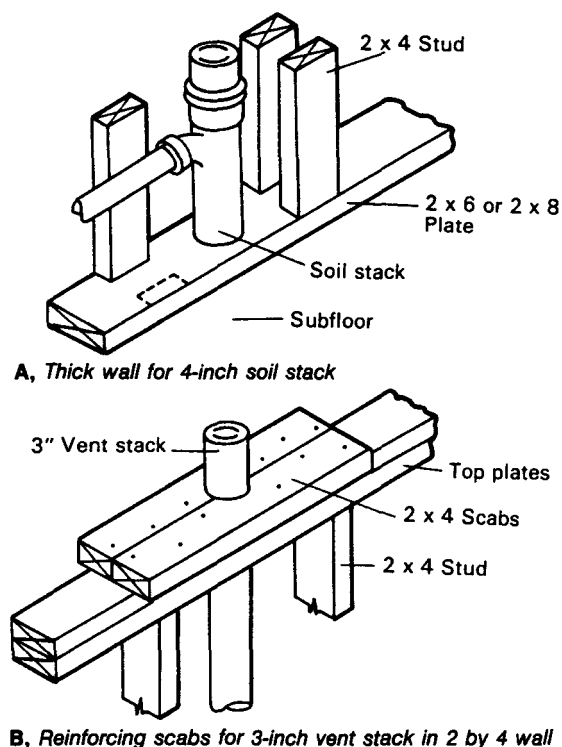


Figure 153 – Backup for wall finish



3. KNEE WALLS WHEN ATTIC SPACE IS FINISHED AS LIVING SPACE.
4. BETWEEN COLLAR BEAMS AND RAFTERS ABOVE ATTIC SPACE THAT IS FINISHED AS LIVING SPACE, leaving open space above for ventilation.
5. AROUND THE PERIMETER OF A SLAB-ON-GRADE WHEN REQUIRED.
6. FLOORS ABOVE VENTED CRAWL SPACES. When a crawl space is used as a plenum, insulation should be applied to crawl space walls instead of to the floor above.

**Figure 154 – Plumbing inside of partitions:**



- Insulate all large and small spaces of the building walls, floors, and ceilings.
- Place insulation on the cold side (in winter) of pipes and ducts or partially tear or slit the back of the insulation batt so the pipe or wire can be surrounded with insulation without compressing the batt.
- Install insulation so the vapor-retarder side faces the interior of the home.
- Apply batt or blanket flanges snugly against the framing members.
- Butt ends of batts or blankets tightly to each other and to framing as appropriate.
- Repair major rips or tears in the vapor retarder.

**Ceilings.** There are three methods of installing blanket insulation in ceilings: (1) Stapling from below. (2) Installing unfaced blankets (no vapor retarder) fitted by pressure. (3) Laying the insulation in from above after the ceiling finish material is in place.

Staple flanges to the ceiling joists when installing ceiling insulation from below. Extend the insulation entirely across the top wall plate, keeping the blanket as close to the plate as possible. If necessary, stuff the gap between the blanket and plate with loose insulation. Where eave vents exist, the insulation should not block the movement of air from the eaves into the attic.

Wedge unfaced blankets between ceiling joists, fitting them by pressure. Allow insulation to overlap the top plate of the exterior wall, but not enough to block eave ventilation. The insulation should touch the top of the plate of the exterior wall, but not enough to block eave ventilation. The insulation should touch the top of the plate to avoid heat loss and wind penetration beneath the insulation.

Fit separate batt sections snugly together at the intersection of rafters and collar beams, insulating the collar beams first. If there is no continuous space for ventilation between the back of the rafter batts and the roof sheathing, apply a separate polyethylene vapor retarder, stapling it to the faces of the rafters and the beams.

Ceiling batts should be butted together snugly, with adjoining vapor retarders in the same plane. Poor fit substantially reduces the effectiveness of the vapor retarder. At ceiling joist plates over interior bearing partitions, fit separate sections of batts at framing offsets. Do not run a batt or a blanket continuously through the offset area; this practice results in poor vapor-retarder coverage and excessive heat loss and gain. Vapor retarders of all three batt sections should be in the same plane.

When insulating a sloped or cathedral ceiling, the insulation should extend over the wall plate with the vapor

7. FLOORS OF HABITABLE ROOMS OVER AN UNHEATED OR AN OPEN SPACE (e.g., over a garage or a porch; under the cantilevered portion of a floor).
8. BASEMENT WALLS, especially when below-grade space is finished for living purposes. Sill sealer (insulation) between the sill and foundation provides an effective wind infiltration barrier.
9. ON THE INSIDE OF BAND OR HEADER JOISTS.
10. IN AN ANNULAR SPACE AROUND PIPES AND WIRES PENETRATING TOP PLATE FRAMING to prevent cold attic air from streaming down into interior and exterior wall cavities. If the spaces are small, it is easier to caulk them than to stuff them with insulation.

### *Installing insulation*

Proper installation of insulation is essential for good performance. Quality control of the installation is necessary to ensure that the expected performance is delivered. Insulation installation techniques vary somewhat with different constructions, but the fundamentals of proper application are the same. While these are not complicated, certain details are important.

Some general guidelines and installation tips for proper insulation installation are:

retarder stapled to the plate. When the back of the insulation touches the roof sheathing, a continuous polyethylene sheet should be stapled to the faces of the rafters.

Specific guidelines for installing blanket ceiling insulation are:

- Make sure that the vapor retarder faces the side heated in winter.
- Cover as much of the top wall plate with insulation as possible, leaving at least 1 inch clear between the top of the insulation and the underside of roof sheathing when eave vents are installed.
- With no soffit vents, make sure that gable ventilation is adequate.
- With two-layer insulation, run the second layer perpendicular to the framing whenever possible, to cover thermal “short circuits” caused by framing members.
- Leave the top layer of two layers of blankets unfaced or have the vapor-retarder facing removed.
- Butt the ends of insulation pieces snugly together where they meet.
- Stuff insulation between the vapor-retarder face and the top wall plate, as necessary.
- Use enough staples to eliminate gaps between stapling flanges and the sides of ceiling framing.
- Use two separate pieces of blanket or cut the blanket or roll at the framing offsets. Do not run the insulation continuously at the offset or gaps and buckling will result at the joint.
- Where collar beams meet rafters and rafters meet knee walls, butt separate insulation pieces snugly together. If rafter insulation requires that the full rafter depth be filled, ventilation above the collar beams is a must.
- Stuff pieces of mineral wool insulation in ceiling voids such as those around vent pipes and chimneys. (Check the local code for chimney framing clearance requirement.)
- Do not cover recessed lighting fixtures with insulation. The heat generated by their operation must be dissipated to the attic.
- Take special care to ensure that dropped soffit areas above built-in cabinets are insulated. If blankets cannot be installed between the ceiling framing and separately down the exterior wall behind the soffit, they should be installed at the inside face and across the bottom face of the soffit construction, making sure that there are no gaps at the intersection of the exterior side wall insulation.
- Insulate and weatherstrip the attic access panel.

The many variable factors pertaining to blown attic insulation can cause differences in installed heat resistance (R-value). For a given manufacturer’s insulation, the installed resistance depends upon thickness and weight of insulating material applied per square foot. For this reason, the current Federal specification for mineral fiber

insulation requires that each bag of insulation be labeled to show the minimum thickness, the maximum net coverage, and the minimum weight required per square foot to produce specified resistance values. Most manufacturers also provide instructions on each bag for determining the number of bags required for a given attic area necessary to achieve a specific resistance value. These procedures must be followed. Do not purchase or specify the amount of blown attic insulation to be installed solely on the basis of the number of inches of thickness.

Specific guidelines for installing loose-fill attic insulation are:

- Proper coverage per bag, weight per square foot, and no less than the thickness indicated on the bag are a must if full R-value is to be achieved. Most bag labels show the minimum number of bags per 1,000 ft<sup>2</sup> for several different R-values.
- With gable roof construction, baffles or pieces of blanket insulation should be installed adjacent to the top exterior wall plates at the eaves.
- When eave ventilation is installed with low-slope hip roof constructions, blanket insulation should be installed around the entire periphery of the ceiling area, because corners of hips and ceiling periphery areas of such roofs are difficult to insulate properly by blowing.
- A separate polyethylene ceiling vapor retarder may be needed.
- Careful application is important to ensure adequate coverage at the far side of chimneys and vent pipes.
- Small spaces between framing members around chimneys or at obstructions should be hand-packed with mineral wool before the ceiling is blown.
- Do not cover recessed lighting fixtures with insulation.
- Dropped soffits and other lowered ceiling areas should be covered with plywood or similar material before blowing, or should be blown full.
- Insulate and weatherstrip the attic access panel.

**Walls.** Push blankets into stud spaces so they touch the sheathing or siding. Working from the top down, space staples about 8 inches apart, pulling flanges to fit snugly against the studs. Cut blanket ends to fit tightly against the top and bottom wall plates. As an alternative, cut the blankets slightly overlength and staple through the vapor retarder to the plates by compressing the insulation.

When pressure-fitted blankets are used without a vapor retarder, wedge them into place. Cover the inside face of wall studs with a 4-mil-thick polyethylene vapor retarder stapled to the top and bottom plates. Unroll the sheet across the entire wall area including window and door openings. Cut out openings later. Foil-backed gypsum board may be used as a vapor retarder instead of a polyethylene sheet.

Push insulation behind pipes, ducts, and electrical boxes. As an alternative, the space may be packed with loose insulation, or a piece of insulation of the proper size can be cut to fit.

Stuff small spaces between rough framing and door and window heads, jambs, and sills with pieces of insulation. Staple insulation vapor retarder paper or polyethylene to cover the spaces.

Insulate nonstandard-width stud or joist spaces by cutting the insulation and vapor retarder an inch or so wider than the space to be filled. Staple the uncut flange as usual. Pull the vapor retarder on the cut side to the other stud, compressing the insulation behind it, and staple through the vapor retarder to the stud. Unfaced blankets are cut slightly oversize and wedged into place.

Specific guidelines for installing blanket wall insulation are:

- Vapor retarders should face the side heated in winter.
- Blankets should be snugly butted to each other and at horizontal framing members. If the insulation is too short, another small piece should be cut to fill the gap. If the insulation is too long, it should not be doubled over or compressed at the framing member; rather it should be cut to fit properly.
- For non-standard-width spaces, insulation should be cut about 1 inch wider than the space. The vapor retarder on the cut side should be pulled to the side or face of the stud and stapled.
- Enough staples should be used to avoid gaps when stapling to the sides of the studs.
- Insulation should be wedged behind electric boxes and wiring. If excessive compression will result, the blanket may be cut or split so that the full installed thickness will be achieved. If the vapor retarder is cut, tape over the cut.
- Water piping must be protected in locales where freezing temperatures may occur. The blanket insulation should be wedged behind the piping.
- Insulate behind all exterior wall ductwork.
- Narrow areas between framing members around window and door areas should be stuffed with insulation. Cover these areas with vapor-retarder material.
- At exterior corners and intersections of exterior and interior walls, insulation should be placed in openings between studs. This must be done before exterior sheathing is applied.
- When stapling insulation flanges to the sides of studs (inset stapling), do not compress the insulation at the stapling flange more than is absolutely necessary. The greater the compression, the more the reduction in R-value. Do not staple flanges to the face of studs.
- Wedge insulation or caulk around any penetrations through the top and bottom wall plates.

- A separate small piece of insulation behind electrical boxes will minimize heat loss in these areas. The insulation blanket and vapor retarder should then be carefully cut to fit snugly at the top, bottom, and sides of the box.
- Be sure to insulate portions of walls separating air-conditioned or heated spaces from unconditioned spaces in multilevel homes.
- Overhanging cantilevered soffit areas should be carefully insulated. A single blanket length may be extended horizontally and turned up at the exterior band joist, or two separate pieces may be used. The vapor retarder should face the inside at the band joist and to the top side for the horizontal portion.
- Sill sealer between the bottom wall plate and the sub-floor is desirable to cut air infiltration.
- Areas behind bath or shower units installed at exterior walls must be insulated before the units are installed.

Floors, basements, and crawl spaces. Floors over crawl spaces may be insulated either by insulating the foundation walls if the crawl space is unvented, or if the crawl space is vented by placing insulation between the joists.

Place the vapor retarder (polyethylene film) covering the crawl space ground against the wall, using tape to hold it against the wall until the insulation has been put into place. Place one edge of the insulation on top of the foundation wall, taping it temporarily in place as needed. The remainder of the insulation should be draped over and against the inside of the wall. Insulation is held permanently in place by the sill plate or header joist if no sill plate is used. At the bottom where the insulation stands away from the wall, use stones, bricks, or blocks spaced as needed to hold the insulation against the wall. The vapor retarder on the insulation should face inward (the warm side in winter). In this method of installation, the insulation also serves as a sill sealer.

Walls of unvented crawl spaces may also be insulated by fastening rigid insulation board to the inside face of the wall, extending from the ground to the top of the wall. Follow the manufacturer's instructions for the method and type of adhesive or fasteners to attach the insulation to the wall.

Floors over vented crawl spaces can be insulated by installing insulation between the joists and holding it in place by:

1. Using heavy-gauge wires pointed at both ends (they are made especially for this purpose); bow the wires and wedge them under the insulation and between the joists.
2. Lacing wire back and forth between nails placed in the bottom of joists.
3. Nailing chicken wire to bottoms of joists.

In all cases, the vapor-retarder side of the insulation should face the floor above.

Polyethylene may be used as a vapor retarder to cover the ground. If it is desired to protect the insulation from the weather, as may be the case in open crawl spaces, nail interior-grade softwood plywood, nail-base insulation board, or similar covering to the bottom of the floor joists. Be sure the water pipes are on the interior (warm-in-winter) side of the insulation envelope in all cases.

In basement and unvented crawl space constructions, sill sealer insulation may be used if necessary to prevent air infiltration between sill and foundation or between the header joist and foundation. The sill sealer is merely unrolled on top of the foundation wall and temporarily taped in place as necessary.

Wedge or staple short pieces of blanket insulation behind the band or header joists. As an alternative, when using insulation at the bottom of joists, the header joist may be insulated by folding the end of the blanket up and pushing it against the header.

Headers in cantilevered floor construction can be insulated as mentioned above. Insulate soffits below cantilevered floors by cutting blankets to fit and wedging them in place, vapor retarder up. As an alternative, these headers and soffits can be insulated by folding the end of the blanket against the header.

Specific guidelines for installing insulation under floors, in basements, and in crawl spaces are:

- Insulation installed in floors over unheated basements and vented and unvented crawl spaces should be applied with the vapor-retarder side facing up. When floor insulation is applied over a partially heated basement, the vapor retarder may face down.
- Commercially available wire fasteners with pointed ends or galvanized lacing wire may be used to support insulation blankets between the joist with vapor retarder facing up.
- If the bottom surface of the blanket is at the bottom of the floor joists, separate blanket pieces should be installed at the band joist area with the vapor retarder facing in.
- Sill sealer should be applied over the top of the foundation wall before the sill plate, if any, is placed to minimize infiltration at the joint.
- Openings around ductwork, pipes, and wiring between heated and nonheated spaces should be stuffed with insulation.
- Exposed vapor-retarder facings in floors above partially heated basements or on basement walls should be covered, as they are to some degree combustible. Gyp

sum board, paneling and ceiling tiles, or panels with acceptable flame-spread ratings may be used.

- To ensure full R-value when insulating basement walls with R-11 blankets, 2- by 3-inch studs may be installed 1 inch from the surface of the wall, thus achieving a full 3½-inch cavity.
- When needed, rigid perimeter insulation should be installed at the edges of slab-on-grade floors. The insulation should extend either down the foundation wall or down the wall and horizontally under the slab for total distance of at least 24 inches. The ground-cover vapor-retarder membrane should be below any horizontal perimeter insulation.

### *Vapor retarders*

Vapor retarders are used in walls, ceilings, and sometimes in floors for the purpose of limiting migration of water vapor to a cold surface where it may condense or freeze. The term “vapor barrier” is common construction language. However, construction vapor barriers such as polyethylene and facings on insulation batts and blankets do not completely bar moisture vapor transmission. As a result, the term “vapor retarder” is used in this handbook.

In a typical house for a family of four, about 2 to 3 gallons of water are produced per day. About half of this is moisture exhaled from the body in the normal breathing process. The other half is a result of showering, bathing, cooking, washing dishes, washing clothes, and similar water-consuming tasks. Water vapor from these activities increases indoor relative humidity.

The ability of air to retain water in the vapor state decreases as the air temperature drops. When the water vapor content (humidity) in the air becomes high enough or the temperature becomes low enough, the water vapor saturation point of the air is reached. (The relative humidity is 100 percent.) The dewpoint has then been reached, and water vapor in the air condenses to the liquid state. Condensation can also occur at relative humidities well below 100 percent when moisture-laden air comes in contact with a cold surface. This is why condensation sometimes occurs in winter on inside colder surfaces such as window glass, the inside surface of metal grilles of exhaust fans, and even the inside surfaces of exterior walls. A little such condensation is only a nuisance, but a lot of it can cause deterioration of some building materials.

In older houses, problems with condensation of moisture in winter were relatively rare because enough dry winter air leaked into and out of the house to remove the moisture that was produced.

Since energy-conserving houses are being built to reduce air infiltration, it is necessary to pay careful attention to vapor retarders and ventilation to avoid winter moisture problems.

There are good reasons to minimize the migration of warm, moisture-laden air through building sections such as exterior wall or ceilings. The temperature progressively decreases in winter from the warmer inside to the colder outside of the building section. It may become low enough to cause the water vapor to condense and accumulate in the framing and building materials. This can ultimately cause deterioration if such moisture condensation is frequent or continuous. Sometimes the water vapor freezes as it comes in contact with a colder surface, such as the inside of the roof sheathing in the attic. If so, on a warm day the ice melts, causing perhaps substantial water problems.

There are three ways to minimize potential problems with water vapor in wall, floors, and attics: (1) vapor retarders can be used to limit water vapor transmission; (2) sufficient ventilation can be provided to reduce excessive water vapor in the habitable space; or (3) the building section can be ventilated so that excessive water vapor is dissipated by outdoor air. Providing sufficient ventilation of the habitable space to do away with the need for vapor retarders would be wasteful of energy.

Ventilation of floor and wall sections is generally not necessary and causes some additional heat loss. So, the use of vapor retarders is advisable on the warm-in-winter side of insulated floor sections over crawl spaces and on exterior walls.

In attic spaces that can be adequately ventilated, a vapor retarder in the ceiling may not be necessary, or even in some cases desirable. Where the roof pitch is low, or in flat or cathedral roof constructions where adequate ventilation is difficult to achieve, vapor retarders in the ceiling are generally advisable.

It is desirable to use a vapor retarder in the ceiling and adequate attic ventilation when design temperatures are  $-20^{\circ}\text{F}$  or lower in winter. If there is adequate attic ventilation, it is believed that vapor retarders are not usually necessary in climates with design temperatures higher than  $-20^{\circ}\text{F}$  in winter. Experience indicates that water vapor condensation problems in the attics and ceilings are a very rare occurrence and that in almost every case when they occur, the cause is inadequate attic ventilation or excessive moisture production in the house. Usually such high moisture production is related to the excessive use of humidifiers, water seepage into basements, lack of vapor retarder over damp ground in crawl spaces, water seepage into heating ducts located under a slab, unvented gas space heaters, or similar items.

When it is possible to provide adequate attic ventilation, it may be undesirable to install a ceiling vapor retarder in houses where no air is required for combustion. Air from combustion and air escaping through gas or oil furnace and hot water heater flue (resulting in infiltration of an equal amount of makeup air) help to remove substantial amounts of indoor water vapor. Electrically heated houses (where no combustion air is needed) with low air infiltration rates, normal rates of household vapor production, and a vapor retarder in the ceiling may have sufficient moisture buildup to require periodic operation of a dehumidifier.

A precise formula for when and where to use and not to use vapor retarders in ceilings cannot be simply stated. There are too many variables that affect their use, and only a limited amount of information is available from applied research. Local experience is the best guide.

As an alternative to using a vapor retarder on a batt or blanket, 4-mil polyethylene film can be stapled to the inside faces of wall plates and studs or to the bottom of ceiling joists or trusses. As installed, this may be considered a more effective vapor retarder than batts or blankets with vapor retarder facings. Other vapor retarders include:

1. Foil-backed gypsum board on the inside surface of exterior walls or ceilings.
2. Two coats of a paint resistant to vapor penetration on the inside surface of exterior walls or ceilings. One major manufacturer of household paints has determined that two coats of its alkyd semi-gloss interior paint, having a dry film thickness 2.4 mils, has a vapor permeance of 0.9 perms. Typical latex paints have a relatively high vapor permeance.

A vapor retarder, such as 4- or 6-mil polyethylene film, is usually desirable over the ground in a crawl space. Four mils is adequate, but 6-mil film is more puncture-resistant. Stretch the film over the ground and turn up the edges a few inches at the walls. At intervals tape the film to the wall: Rocks, bricks, blocks, or similar (nonwood) weights can also be used to hold the film in place. If a lap is necessary, about 1 foot is adequate. Place a few weights on the lapped films.

Two factors related to condensation in a thermally well-protected house tend to offset each other. Because such houses have significantly lower amounts of air infiltration, the effect of dry (winter) air diluting the water vapor is reduced, relative humidity is increased, and condensation is more likely to occur. However, because such houses have warmer inside surface temperature, there is less tendency for condensation to occur.

In houses that have low amounts of air infiltration, condensation may occur on double glass or metal sash in cold

climates. Thermal breaks in the metal sash and/or triple glazing usually solve the problem, unless there is some excessive moisture source. If so, it must be reduced or eliminated.

### **Interior Wall and Ceiling Finish**

The most widely used wall and ceiling finish is gypsum board. It has the advantages of being economical, non-combustible, and easy to install and repair. Another popular wall covering is paneling, in 4- by 8-foot sheets that may be plywood, hardboard, or particleboard. Often this paneling is applied over a gypsum board base. A more costly and labor-intensive type of paneling is available in the form of tongue-and-groove or shiplap boards.

#### ***Gypsum board***

Several types of gypsum board, such as fire-rated, water-resistant, and sound-deadening board, are available to satisfy specific needs, but regular board is used most commonly. Regular gypsum board is faced with a strong paper that accommodates almost any type of decorative treatment. Edges may be tapered, square, beveled, or tapered with a round edge. The tapered edges are designed to be finished with joint compound and tape. Square edges are used where another finish surface such as wallpaper, paneling, or tile is to be applied. Beveled edges give the effect of paneling. Gypsum board is available in 4-foot widths and in lengths up to 16 feet.

Although all gypsum board is noncombustible and thus provides some fire protection, fire-rated board gives added protection. The core is reinforced so that it remains intact even after the chemically combined water has been released from the gypsum. This type of board is primarily used where a rated firewall is required or where major structural members require fire protection. Such protection may be required in multifamily or special types of buildings but is not normally required in single-family dwellings, except that some codes may require fire-rated board on a wall between the garage and the house. Fire-rated board may provide a finished surface or be used as a backer board for some other type of finish.

Water-resistant board is most often used as a backer for tile, but could be used with other finishes in high-moisture areas such as bathrooms or kitchens. It is particularly important that it be used around bathtubs and showers where leaks could develop and cause deterioration of regular gypsum board. The water resistance is provided by an asphalt-wax emulsion combined with the gypsum.

Sound-deadening board is normally used between living units in multifamily dwellings, but can also improve privacy for single-family houses. This board is also

primarily a backer with regular gypsum board applied over it.

The regular and fire-rated boards are also available with a variety of finishes laminated to the face. The most widely used finish is vinyl with colors, textures, or patterns imprinted. The patterns may be wood grain applied with a photographic process that gives the appearance of wood paneling. These usually have a finished beveled edge, so that no further finish is required.

Table 14 lists maximum member spacing for the various thicknesses of gypsum board.

When the single-layer system is used, the 4-foot-wide gypsum sheets are applied vertically or horizontally on the walls after the ceiling has been covered. Vertical application covers three stud spaces when studs are spaced 16 inches on center, and two when spacing is 24 inches. Edges should be centered on studs, and only moderate contact should be made between edges of adjacent sheets.

Fivepenny cooler-type nails ( $1\frac{5}{8}$  in long) should be used with  $\frac{1}{2}$ -inch gypsum, and fourpenny ( $1\frac{3}{8}$  in long) with material  $\frac{3}{8}$  inch thick. Ring-shank nails, about  $\frac{1}{8}$  inch shorter, can also be used. Many builders prefer to use screws rather than nails in order to avoid nail pops (nails working their way out of framing) as a result of changes in moisture content of the framing. Screws should be 1 $\frac{1}{2}$  inches long. Nail pops are relatively few if the moisture content of framing members is less than 15 percent when gypsum board is applied. It is good practice, when framing members have a high moisture content, to allow them to approach moisture equilibrium before the gypsum board is applied. Nails should be spaced 6 to 8 inches for side walls and 5 to 7 inches for ceiling application (fig. 155). Minimum edge distance is  $\frac{3}{8}$  inch.

The horizontal method of application is best adapted to rooms in which full-length sheets can be used, because then it minimizes the number of vertical joints. Where joints are necessary, they should be made at windows or doors. Nail spacing is the same as that used in vertical application. Normally, horizontal nailing blocks between studs are not required, if stud spacing is not greater than 16 inches on center and gypsum board is  $\frac{3}{8}$  inch or thicker. However, nailing blocks may be used when spacing is greater, or when an impact-resistant joint is required (fig. 155).

Another method of gypsum-board application (laminated two-ply) includes an undercourse of  $\frac{3}{8}$ -inch material applied vertically and nailed in place. The finish  $\frac{3}{8}$ -inch sheet is applied horizontally, usually in room-size lengths, with an adhesive. This adhesive is either applied in ribbons, or is spread with a notched trowel. The manufacturer's recommendations should be followed in all respects.

**Table 14—Gypsum board thickness (single layer)**

Orientation of length of sheet to framing members	Minimum thickness (in)	Maximum spacing of supports (on center) (in)	
		Walls	Ceilings
Parallel	3/8	16	—
	1/2	24	16
	5/8	24	16
Perpendicular	3/8	16	16
	1/2	24	24
	5/8	24	24

Gypsum board with laminated finish may also be applied on walls with an adhesive so the surface is left undisturbed. An alternative is to use nails with heads that are coated to match the finish. In either case the boards are 4 by 8 feet and applied vertically, like paneling. Edges are finished, so no additional finishing is required.

Nails and screws in the regular gypsum wallboard should be driven with the heads slightly below the surface. The crowned head of the hammer forms a small dimple in the wallboard (fig. 156A). A nail set should not be used, and care should be taken to avoid breaking the paper face.

Joint cement, or spackle, is used to apply the tape over the tapered edge joints and to smooth and level the surface. It comes in powder form and after mixing with water is a soft putty consistency easily spread with a trowel or putty knife. It can also be obtained in premixed form. The general procedure for taping (fig. 156B) is as follows:

1. Use a wide spackling knife (5 in) and spread the cement in the tapered edges, starting at the top of the wall.
2. Press the tape into the recess with the putty knife until the joint cement is forced through the perforations.
3. Cover the tape with additional cement, feathering the outer edges.
4. Allow the cement to dry, sand the joint lightly, and then apply the second coat, feathering the edges. A steel trowel is sometimes used in applying the second coat. For best results, a third coat may be applied, feathering beyond the second coat.
5. After the joint cement is dry, sand smooth (an electric vibrating hand-sander works well).
6. For hiding hammer indentations, fill with joint cement and sand smooth when dry. Repeat with a second coat if necessary.

Interior comers may be treated with tape. Fold the tape down the center to a right angle (fig. 156C) and (a) apply cement at the comer, (b) press the tape in place, and

(c) finish the comer with joint cement. Sand smooth when dry and apply a second coat.

The interior comers between walls and ceiling may also be concealed with some type of molding (fig. 156D). When moldings are used, the joint need not be taped.

Wallboard comer beads (metal) at exterior comers prevent damage to the gypsum board (fig. 156E). They are fastened in place and covered with joint cement.

### *Paneling*

Plywood, hardboard, and particleboard are usually in 4-by 8-foot sheets for vertical application. However, 7-foot-long panels can sometimes be purchased for use in basements or other low-ceiling areas. Plywood can be purchased in a number of species and finishes with wide variation in costs. Hardboard and particleboard imprinted with a wood grain pattern are generally less expensive than plywood. A photograph of wood is used to imprint a facing material, which produces a very realistic pattern. Both smooth and textured facings are also available in solid colors as well as designs. Facing materials are usually easy to clean.

Paneling material should be delivered to the site and placed in the heated space at least 24 hours before installation to allow it to adapt to the moisture and temperature of the room. Stack the panels, separated by full-length strips, to allow air to get to all panel faces and backs (fig. 157). Conditioning can also be accomplished by standing panels around the room.

Installation of the first panel is critical for establishing vertical edges and locating edges over a stud. Place the first panel butted against a comer of the room. Make sure the outer edge is vertical by holding a plumb bob at the top comer; then if the outer edge is over a stud, the panel can be secured. If there is no stud at that point, measure the width that must be cut off for the edge to coincide with a stud. Then, mark or scribe the amount to be cut off, measuring from the comer. The use of an art compass to scribe the panel (fig. 158) assures the right cut even if the comer is uneven or not vertical. After the cut is made, fit the panel snugly into the comer and secure it. Successive panels are placed with moderate contact against the preceding one, and 16-inch or 24-inch stud spacing should assure that all edges are over a stud.

Cutouts for doors and windows or heat registers require careful measurement. Take dimensions from the edge of the last applied panel for width, and from the ceiling or floor for height. Then transfer these to the panel and proceed with cutting. For electrical boxes, paint or run chalk around the box edges. Next carefully position the panel

Figure 155 – Installing gypsum board on walls:

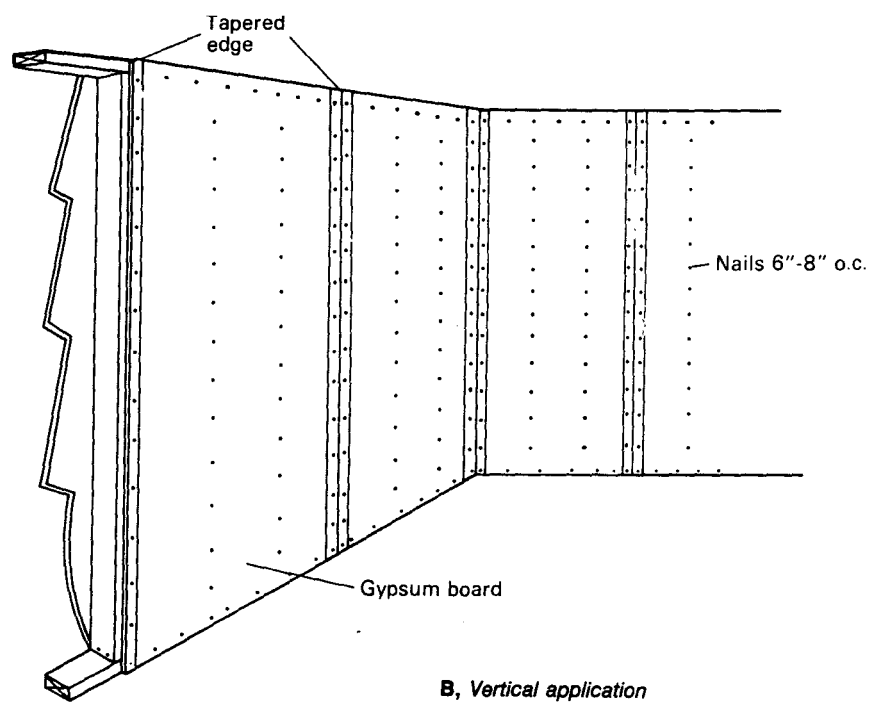
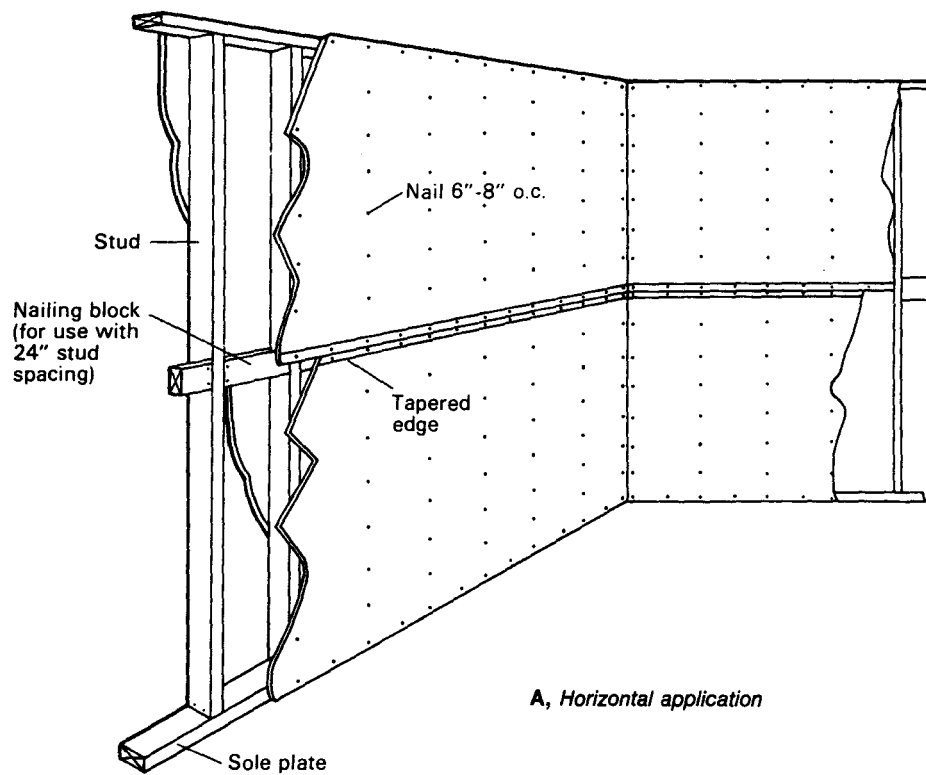
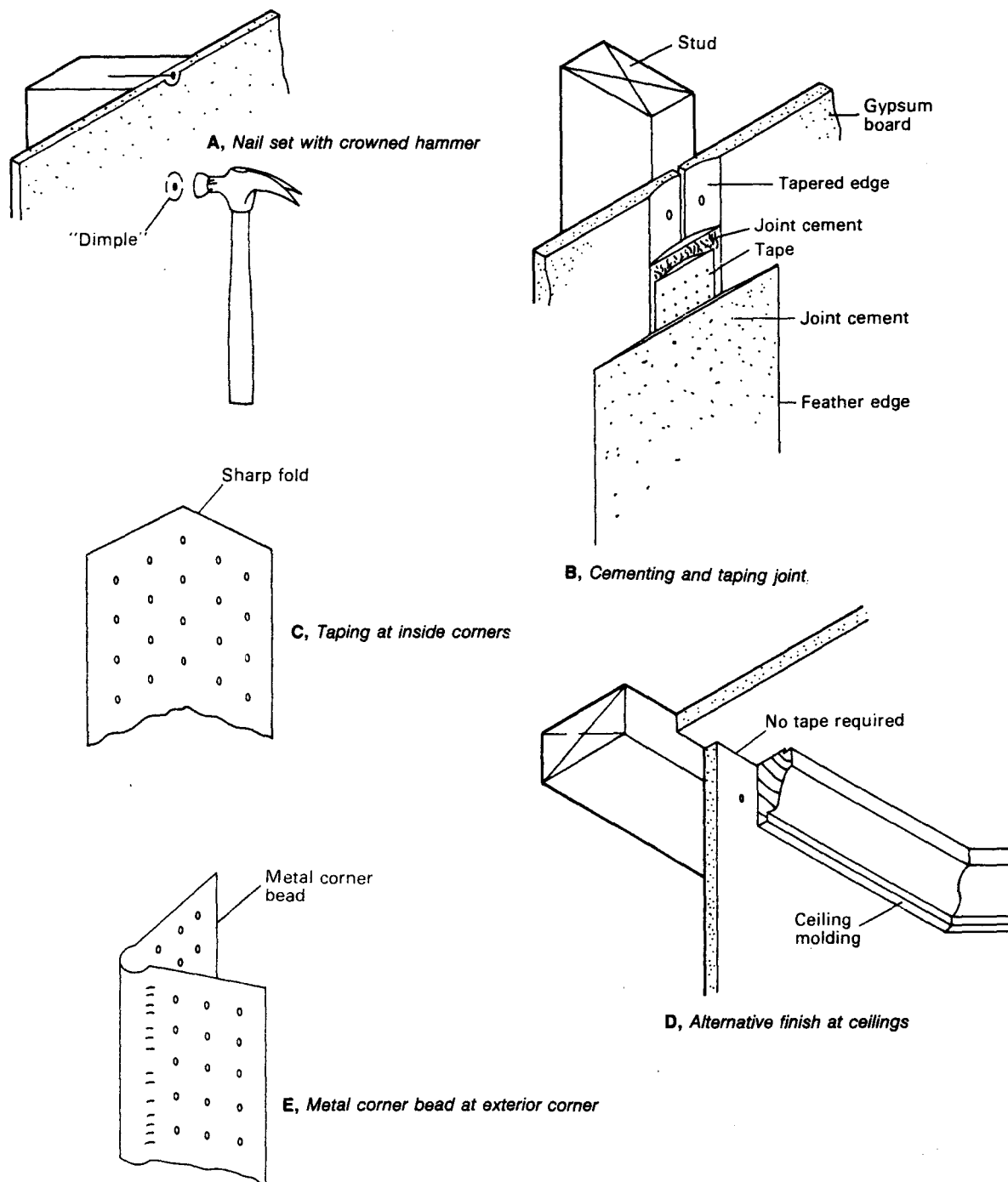


Figure 156 – Finishing gypsum board:

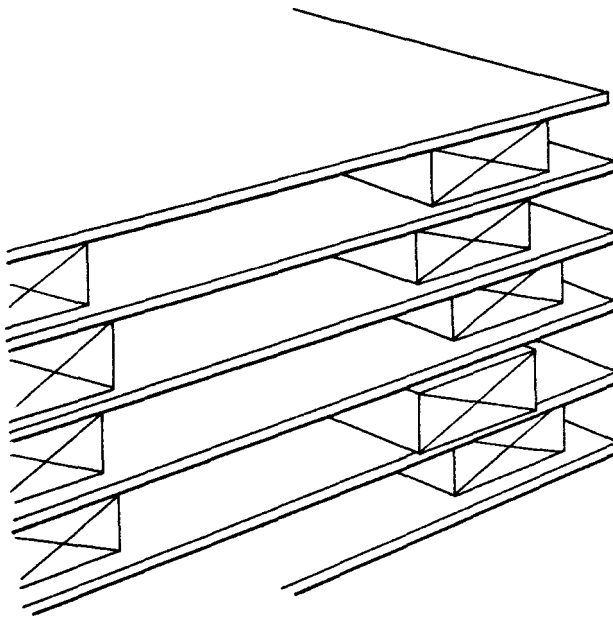


and press it firmly over the box, transferring the outline to the back of the panel (fig. 159), and cut out the section.

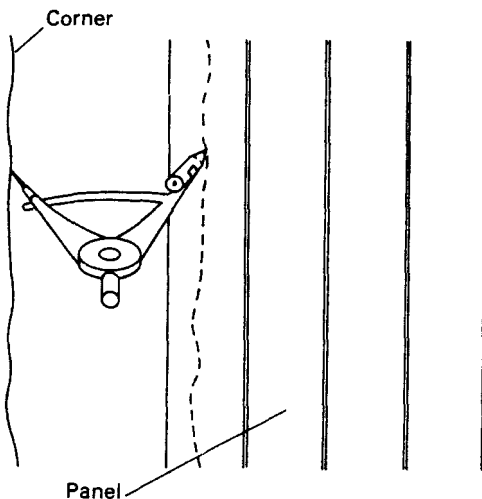
Panels can be fastened with nails or adhesive. Adhesive is sometimes preferable because no nailheads can mar the finish. Most adhesives include instructions for application, and these instructions should be followed carefully. Use an adhesive that allows enough open assembly time to adjust the panel for a good fit. Where panels are nailed,

use small finishing nails (brads). Use 1 $\frac{1}{2}$ -inch-long nails for materials  $\frac{1}{4}$  or  $\frac{3}{8}$  inch thick, and 8 to 10 inches apart on edges and at intermediate supports. Many panels are grooved and nails can be driven in these grooves. Set nails slightly with a nail set. Many prefinished materials are furnished with small nails having heads that match the color of the finish; thus no setting is required.

**Figure 157**—Sacking panels for conditioning to room environment prior to use.



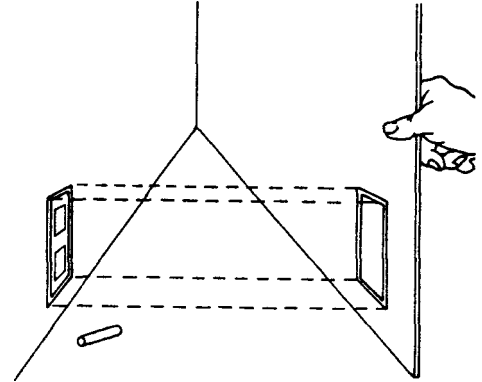
**Figure 158**—Scribing of cut at panel for conditioning to room environment prior to use.



The right moldings add the final decorative accent for fine paneling. And, very practically, they also cover seams and joints at ceiling and floor, and protect corners. Moldings also provide a variety of midwall transitions from one sheet of paneling to the next.

Measure each piece of molding separately for the area it is to occupy. For example, don't assume that lengths at the floor and ceiling are identical. When you measure, remember to allow for mitering—molding will be longer than its corresponding wall section if either end is an outside corner, and shorter if two inside corners frame it.

**Figure 159**—Chalk outlet box for marking cutout.



Molding should be cut with a fine-tooth saw and miter box for accuracy. To splice molding sections along a wall, 45° cuts are made in the same direction on both pieces. Where moldings meet at right angles, trim both pieces at opposite 45° angles so that they will join to form a tight right angle. Finish moldings with stain or paint after cutting and before installing in place. Use 3d nails, finished or colored, countersink, and cover with matching putty stick.

Tongue-and-groove or shiplap wood paneling is available in various widths. Wood is usually limited to no more than 8 inches nominal width. This paneling should be stacked in the room to be paneled, as recommended for 4- by 8-foot panels, to stabilize at the temperature and moisture of the room. Paneling is usually applied vertically, but may be applied horizontally for special effects.

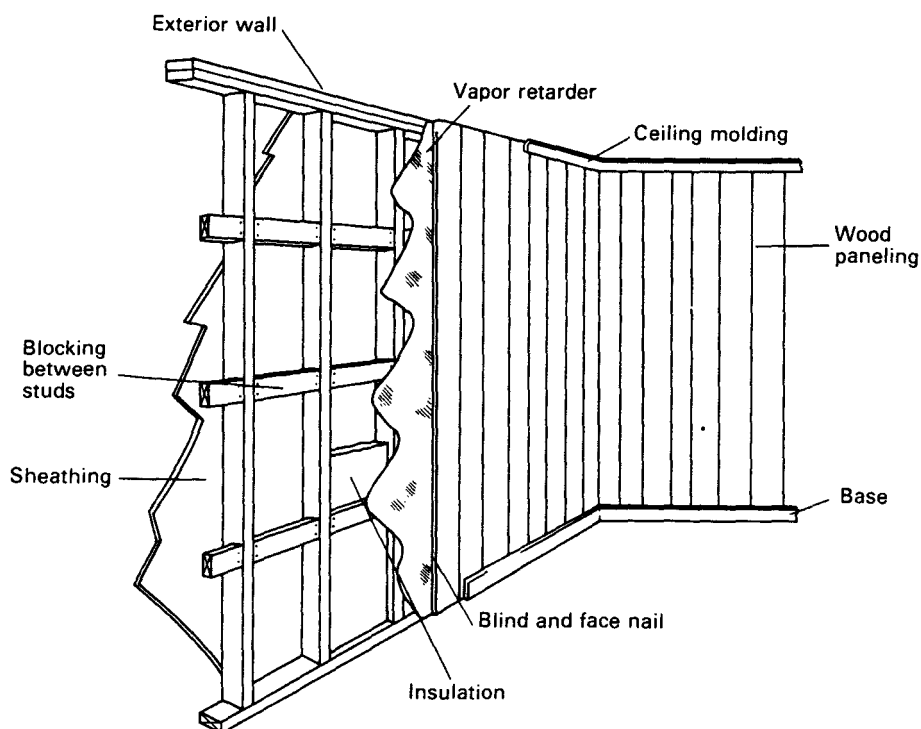
Vertically applied paneling is nailed to horizontal furring strips or to nailing blocks between studs (fig. 160). Nail with 1½- to 2-inch finishing or casing nails. Blind nail through the tongue and, for 8-inch boards, face nail near the opposite edge. Where adhesive is used, only blind nail through the tongue. Moldings can also be used with wood paneling.

### Wainscot

Wainscoting is a lining applied to the lower 3 to 4 feet of a wall. It is used in specific types of rooms to protect that portion of the wall but may be decorative as well as functional.

In dining rooms, studies, or offices, the wainscot is about the height of a chair back to protect the wall when chairs are pushed against it. The traditional height is 36 inches; however, 32 inches is often used in order to make optimal use of 4- by 8-foot panels. A molding or cap is applied at the top of the wainscot and is sometimes

**Figure 160**—Blocking between studs for vertical wood paneling.



referred to as a chair rail. Application of this type of wainscot and of paneling is similar except that longer nails may be required to go through the wall covering under the wainscot and penetrate the studs adequately.

Wainscoting is also used in wet areas such as bathrooms or rooms with swimming pools or hot tubs. Ceramic tile is the usual material for this application. Tile should be installed around bathtubs, behind sinks or laundry tubs, and in any other area where water may be splashed. In these areas, application should always be made over water-resistant gypsum board.

Commonly, tile is applied to a gypsum board base with an adhesive. The gypsum board should be prepared as for painting, having all joints taped and nailheads covered with two coats of joint compound. In wet areas, water-resistant gypsum board must be used, and installed on framing not to exceed 16 inches on center. A 1/4-inch gap should be left between the paper edge of the gypsum board and a bathtub or shower receptor. This gap must be filled with a nonhardening caulk.

Where tile is applied to a plywood base, use underlayment grade plywood with exterior glue or exterior grade C-C plugged or better. Use 3/8-inch or thicker plywood with face grain perpendicular to studs or 1/2 inch or thicker with face grain parallel to studs. Allow 1/8-inch expansion joints between sheets. Provide 2- by 4-inch solid blocking between framing members at horizontal

edges. Prior to installation, seal all plywood edges with a quality exterior primer or aluminum paint.

### Wood Flooring

Flooring is available in a variety of species and types of wood. Although some softwood flooring is used, most strip flooring in new construction is hardwood. Species graded for flooring use include oak, beech, birch, hard maple, and pecan. In addition, some foreign species are used for parquet flooring.

Appearance alone determines the grades of hardwood flooring because all grades are equally strong and serviceable in any application. Oak, the most popular of the hardwoods, has four basic grades (table 15). Flooring that is practically free of defects and made mostly of heartwood is known as Clear, though it still may contain minor imperfections. The grade Select is almost clear, but contains more knots and color variations. The No. 1 and No. 2 Common grades have more markings than either of the other two grades and are often specified because of these natural features and the character they bring to the installation. Top grades are sometimes combined (as Select & Better) and special combinations are made for "shorts," the short pieces produced in manufacturing. The grades for other species also are shown in table 15. Usual strip flooring is 1 1/2, 2, or 2 1/4 inches wide, and thickness may vary from 1/2 to 3/4 inch. Planks are available up to 8 inches wide,

**Table 15 – Hardwood flooring grades**

Unfinished oak	Unfinished beech, birch, and hard maple	Unfinished pecan	Prefinished oak
Clear	First grade white hard maple	First grade red	Prime
Select & Better	First grade red beech and birch	First grade white	Standard & Better
Select	First grade	First grade	Standard
No. 1 Common	Second & Better	Second grade red	Tavern & Better
No. 2 Common	Second grade Third & Better Third grade	Second grade Third grade	Tavern

#### *Preparation of wood joists to receive flooring*

In joist construction with no basement, outside cross ventilation through vents or other openings in the foundation walls must be provided, with no dead air areas. A ground cover of 6-mil polyethylene film is essential as a moisture barrier.

Use exterior plywood, common pine, or other softwood suitable for subfloors. The plywood must be at least ½ inch thick. Lay panels with grain of faces at right angles to joists. Use appropriate nail sizes, nail spacing, and leave expansion space between plywood panels as recommended by the American Plywood Association. Mark location of joists on the plywood so that flooring can be nailed into them.

#### *Preparation of a concrete slab to receive flooring*

Hardwood flooring can be installed successfully over a slab that is on grade or above grade. *Installations on slabs that are below grade are not recommended.* The slab must be constructed properly and the instructions below must be followed precisely.

Watch out for water. New concrete is heavy with moisture, an inherent enemy of wood. Proper on-grade slab construction requires a vapor retarder between the gravel fill and the slab. While this retards moisture entry through the slab, it also retards curing of the slab. So test for dryness, even if the slab has been in place over 2 years.

1. **THE RUBBER MAT TEST.** Lay a flat, noncorrugated rubber mat on the slab, place a weight on top to prevent moisture from escaping, and allow the mat to remain overnight. If there is moisture in the concrete, the covered area will show water marks when the mat is removed. Note that this test is worthless if the slab surface is other than light in color originally.

2. **THE POLYETHYLENE FILM TEST.** Tape a 1-foot square of heavy clear polyethylene film to the slab, sealing all edges with plastic packaging tape. If, after 24 hours, no clouding or drops of moisture develop on the underside of the film, the slab can be considered dry enough to install wood floors.
3. **THE CALCIUM CHLORIDE TEST.** Place a quarter teaspoonful of dry (anhydrous) calcium chloride crystals (available at drug stores) inside a 3-inch-diameter putty ring on the slab. Cover with a glass so that the crystals are totally sealed off from the air. If the crystals dissolve within 12 hours, the slab is too wet for a hardwood flooring installation.
4. **THE PHENOLPHTHALEIN TEST.** Put several drops of a 3 percent phenolphthalein solution in grain alcohol at various spots on the slab. (These products are available at drug stores or chemical supply houses.) If a red color develops in a few minutes, there is a moist alkaline substance present, and it would be best not to install hardwood flooring.

**NOTE:** The test used should be made in several areas of each room on both old and new slabs. The remedy for a moist slab is to wait until it dries naturally, or accelerate drying with heat and ventilation.

If the slab is sufficiently dry, start by installation of a good vapor retarder. To give added assurance that moisture does not reach the finished floor, a vapor retarder must be used on top of each slab. Where this is placed will depend on the type of nailing surface and/or the type of wood flooring used.

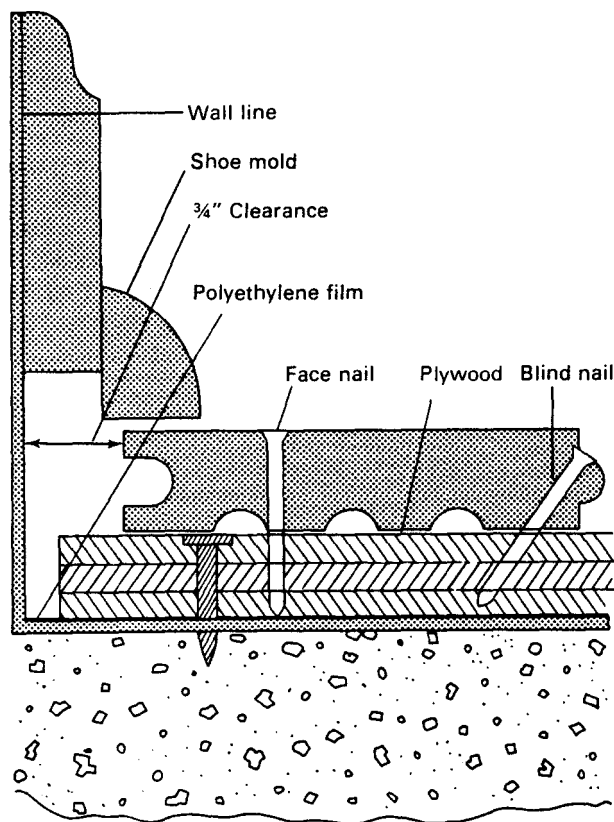
In all cases, prepare the slab by sweeping it clean. The slab must be sound, level, and free of grease, oil stains, and dust.

**Plywood subflooring.** This system uses ¾-inch or thicker exterior plywood as the subfloor nailing base (fig. 161), installed according to the following instructions.

Roll out 4-mil or heavier polyethylene film over the entire slab, overlapping edges 4 to 6 inches and allowing enough to extend under the baseboard on all sides. It does not require imbedding in mastic.

Lay plywood panels out loose over the entire floor. Cut the first sheet of every run so that end joints in adjacent runs will be staggered 4 feet. Leave a ¾-inch space at all wall lines and ¼ to ½ inch between panels. At doors and other vertical obstructions where molding will not be used to cover the void, cut the plywood to fit, leaving about ⅛ inch of space.

**Figure 161**—Plywood on slab method of installing strip oak flooring.



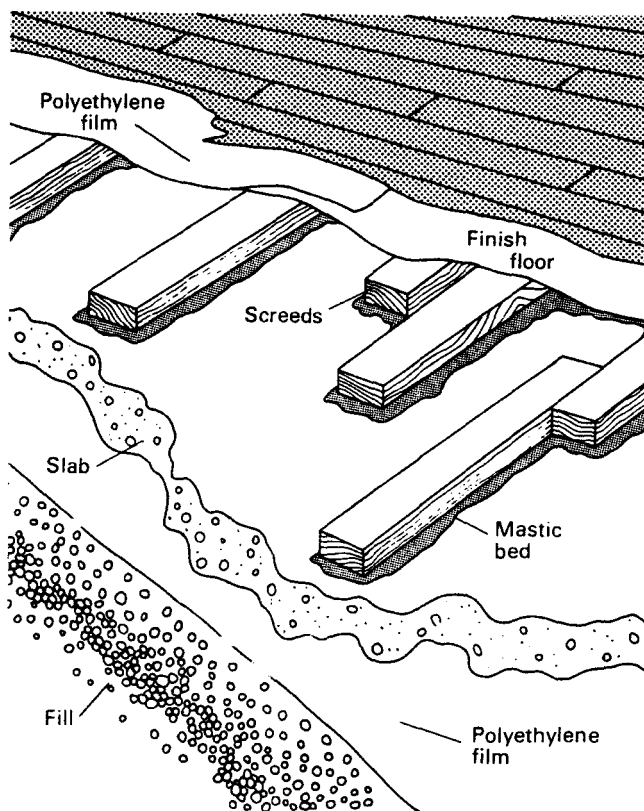
Fasten the plywood to the concrete with a power-actuated concrete nailer or hammer-driven concrete nails. Use a minimum of nine nails per panel, starting at the center of the panel and working toward the edges to be sure of flattening out the plywood and holding it securely.

An alternative method is to cut the plywood into 4- by 4-foot squares, score the back, and lay in mastic. However this requires the use of moisture retarders laid in mastic.

**Subflooring on screed.** This method uses flat, dry, 2- by 4-inch screeds (sometimes called sleepers) of random lengths from 18 to 48 inches. They must be preservative-treated with a product other than creosote, which might bleed through and stain the floor finish, and they must be dried after each treatment if the treatment process involves saturation with water (e.g., treatment with waterborne preservatives).

Sweep the slab clean, prime with an asphalt primer, and allow to dry. Apply hot (poured) asphalt mastic and imbed the screeds, 12 inches on center, at right angles to the direction of the finished floor. Stagger joints and lap ends at least 4 inches. Leave a 1/8-inch space between ends of screeds and walls (fig. 162).

**Figure 162**—Screed method of installing strip oak flooring over a concrete slab.



Over the screeds spread a vapor retarder of 4- or 6-mil polyethylene film with edges lapped 6 inches or more. It is not necessary to seal the edges or to affix the film with mastic but avoid bunching or puncturing it, especially between screeds. The flooring finish is nailed through the film to the screeds.

Some installers prefer to use the two-membrane asphalt felt or building paper with cut-back or cold stick adhesive as a vapor retarder. The screeds are laid in rivers of mastic on the asphalt felt or building paper. In this system the polyethylene film over the screeds is recommended for the extra moisture protection provided at nominal cost.

The screeds method alone—~~that is~~, without a subfloor and spaced 12 inches on center—is satisfactory for all strip flooring and plank flooring to 4-inch width. Plank flooring wider than 4 inches requires either the plywood-on-slab subfloor or screeds plus a wood subfloor to provide an adequate nailing surface. The subfloor may be 5/8-inch or thicker plywood or 3/4-inch boards.

**Special considerations for parquet, herringbone, and similar flooring over slab.** These floors are normally laid in asphalt mastic and thus do not require a nailing surface on top of the slab. However, the need for a good

moisture retarder is most important, and it can be achieved by either of the following two methods.

**Polyethylene method.** Prime the slab with an asphalt primer and allow to dry. Apply cold, cut-back asphalt mastic with a straight-edge trowel to the entire slab surface. Allow to dry 30 minutes. Unroll 4-mil polyethylene film over the slab, covering the entire area and lapping edges 4 inches. Stepping on every square inch of the floor to insure proper adhesion, “walk in” the film. Small bubbles are of no concern.

**Two-membrane asphalt felt or building paper method.** Prime as above and apply mastic with a notched trowel at the rate of 50 square feet per gallon. Let set 2 hours. Roll out 15-pound asphalt felt or building paper, lapping the edges 4 inches. Butt ends. Apply another coating of mastic with the notched trowel and roll out a second layer of asphalt felt or building paper. Lay both layers in the same direction, but stagger the overlaps to achieve a more even thickness.

This method applies only to tongue-and-groove parquet flooring where tongues and grooves are engaged. Other flooring types require a retarder applied to the slab by the first method.

The floor finish is laid in mastic on the vapor retarder.

### ***Laying and fastening strip flooring***

The following instructions apply to strip flooring laid on plywood-on-slab, on screeds, and on plywood or board subfloors.

Where a plywood or board subfloor is used, start by renailing any loose area and sweeping the subfloor clean. Then cover it with a good grade of 15-pound asphalt felt or building paper, lapped 4 inches at the seams. This helps keep out dust, retards moisture from below, and helps prevent squeaks in dry seasons.

**Direction of floor finish.** For best appearance, lay the flooring in the direction of the longest dimension of the room or building (across or at right angles to the joists). If a hallway parallels the long dimension of the room, begin the flooring by snapping a chalk line through the center of the hall and work from there into the room. At the center of the hall, use a slip-tongue or spline in the two adjacent grooves to reverse direction to complete the hall.

**Starting to lay the floor.** Location and straight alignment of the first course is important. When starting within a room, place a strip of flooring  $\frac{3}{4}$  inch (fig. 163) from the starter wall (or leave as much space as will be covered by base and shoe mold). groove side toward

wall, and mark a point on the subfloor at the edge of the flooring tongue. Do this near both corners of the room, and then snap a chalk line between the two points. Nail the first strip with its tongue on this line. The gap between that strip and the wall is needed for expansion space and will be hidden by the shoe mold.

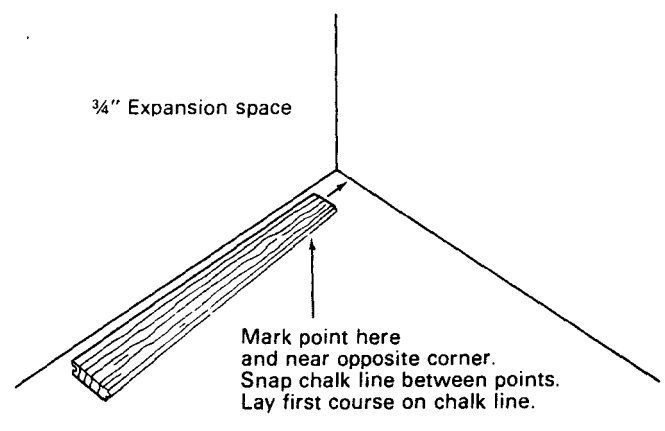
If you're working with screeds on slab, you won't be able to snap a satisfactory chalk line on the loose polyethylene film laid over the screeds, of course. Make the same measurements and stretch a line between nails at the wall edges. Remove line after you get the starter board in place.

Lay the first strip along the starting chalk line, tongue out, and drive an 8d finishing nail at one end of the board, near the grooved edge. Drive additional nails at each joist or screed and at midpoints between joists, keeping the starter strip aligned with the chalk line. (Predrilling nail holes will prevent splits.) The nailheads will be covered by the shoe molding. Nail additional boards in the same way to complete the first course.

**Racking the floor.** Lay out seven or eight loose rows of flooring end to end in a staggered pattern with end joints at least 6 inches apart. Find or cut pieces to fit within  $\frac{1}{2}$  inch of the wall at the end of boards. Watch your pattern for even distribution of long and short pieces and to avoid clusters of short boards.

Fit each board snug, groove-to-tongue, and blind-nail through the tongue (fig. 164) according to the schedule shown in table 16. Countersink all nails. After the second or third course is in place you can change from a hammer to a floor nailing machine, which is easier to use, does a much better job, and automatically sets the nail. Various nailing machines use either a barbed fastener or staples, fed into the machine in clips. Fasteners are driven through the tongue of the flooring at the proper angle.

**Figure 163—Start nailing strip flooring  $\frac{3}{4}$  inch from the wall.**



**Table 16—Nailing schedule for flooring**

Flooring size	Fastener type	Fastener spacing
<b>Tongue-and-groove flooring (blind-nailed)</b>		
¾ x 1½, 2¼ and 3¼ inch	2-inch machine-driven fasteners, 7d or 8d spirally grooved or plain shank nail	10–12 inches apart <sup>a</sup>
¾ x 3- to 8-inch squared plank	2-inch machine driven fasteners, 7d or 8d spirally grooved or plain shank nail.	8 inches apart into and between joists
½ x 1½ and 2 inch	1½-inch machine-driven fastener, 5d screw, cut steel or wire casing nail	10 inches apart
⅜ x 1½ and 2 inch	1¼-inch machine-driven fastener, or 4d bright wire casing nail	8 inches apart
<b>Square-edge flooring (facenailed through top face)</b>		
⅝ x 1½ and 2 inch	1-inch 15-gauge fully barbed flooring brad	2 nails every 7 inches
⅝ x 1⅓ inch	1-inch 15-gauge fully barbed flooring brad	1 nail every 5 inches on alternate sides of strip

<sup>a</sup> If subfloor is ½-inch-thick plywood (actual thickness), fasten into each joist with additional fastening between.

When using the nailing machine to fasten ¾-inch-thick strip or plank flooring to plywood laid on a slab, be sure to use a 1¾-inch cleat, not the usual 2-inch cleat (barbed fastener) which may come out the back of the plywood and prevent nails from countersinking properly. In all other applications the 2-inch cleat is preferred.

Continue across the room, ending up on the far wall with the same ¾-inch space allowed on the beginning wall. It may be necessary to rip a strip to fit.

Avoid nailing into a subfloor joint. If the subfloor is at right angles to the finish floor, don't let ends of the finish floor meet over a subfloor joint.

**Nailing to screeds.** When nailing directly to screeds (no subfloor), nail at all screed intersections and to both screeds where a strip passes over a lapped screed joint. Since flooring ends are tongued and grooved, all end joints do not need to meet over screeds, but end joints of adjacent strips should not break over the same void between screeds.

Some long boards may have horizontal bends or “sweeps” resulting from a change in moisture content. A simple lever device can be made on the job to force such boards into position as well as pull up several courses. An alternative is to hammer against a short strip of flooring fitted against the crooked piece.

**Shoe molding.** Nail this to the baseboard, not the flooring, after the entire floor is in place (fig. 161).

### ***Laying plank flooring***

This flooring is normally made in 3- to 8-inch widths

and may have countersunk holes for securing planks with wood screws. These holes are then filled with wood plugs that are supplied with the flooring (fig. 165).

Plank is installed in the same manner as strip flooring, alternating courses by widths. Start with narrowest boards, then the next width, etc., and repeat the pattern.

Manufacturer's instructions for fastening the flooring vary and should be followed. The general practice is to blind-nail through the tongue as with conventional strip flooring. Then countersink one or more (depending on width of the plank) No. 9 or No. 12 screws at each end of each plank and at intervals along the plank to hold it securely. Cover the screws with wood plugs glued into the holes. Take care not to use too many screws—with the plugs in place, the screws tend to give the flooring a polka-dot appearance.

Be sure the screws are the right length. Use 1 inch if the flooring is laid over ¾-inch plywood on a slab. Use 1 to 1¼ inches in wood joist construction or over screeds.

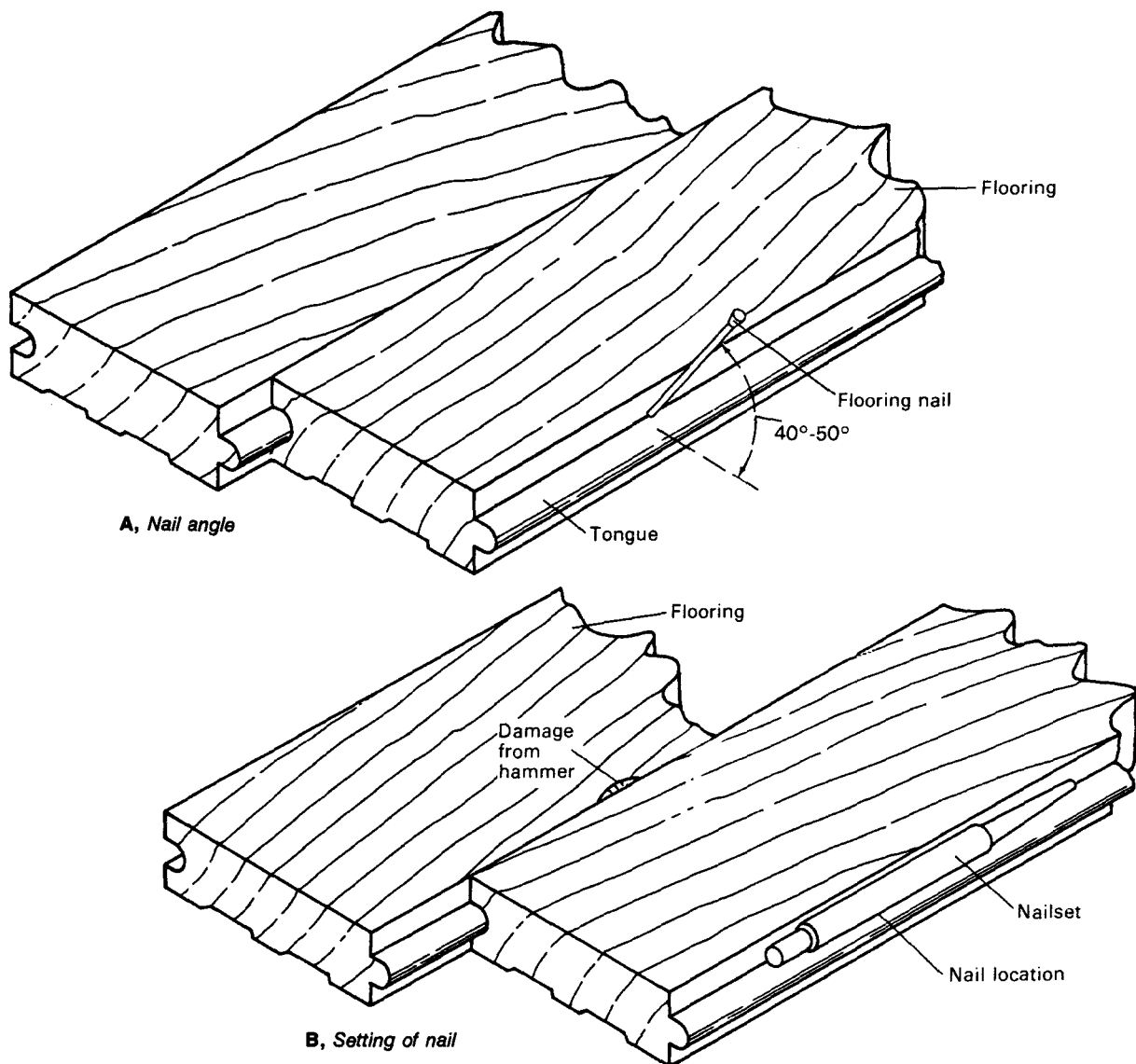
Some manufacturers recommend facenailing in addition to other fastenings. Consult manufacturer's installation instructions for details.

Another practice sometimes recommended is to leave a slight crack, about the thickness of a putty knife, between planks.

### ***Laying parquet flooring***

The styles and types of block and parquet flooring as well as the *recommended procedures for application* vary

Figure 164—Nailing of flooring:



*somewhat among the different manufacturers.* Detailed installation instructions are usually provided with the flooring or are available from the manufacturer or distributor.

**Patterns of parquet flooring.** There are three ways to lay out parquet. The most common is with edges of parquet units (and thus the lines they form) square with the walls of the room. The second way is a diagonal pattern, with lines at a 45° angle to walls. The third is a complex layout with lines running in a herringbone pattern.

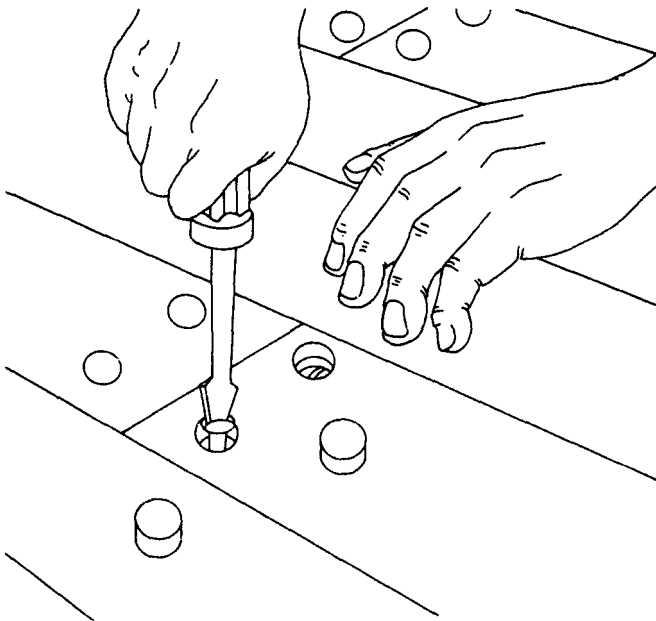
**Square pattern.** Never use a wall as a starting line because walls are almost never truly straight. Instead, use a chalk line to snap a starting line about 3 feet or so from the handiest entry door to the room, roughly parallel to the nearest wall. Place this line exactly equal to four or

five of the parquet units from the center of the entry doorway (fig. 166).

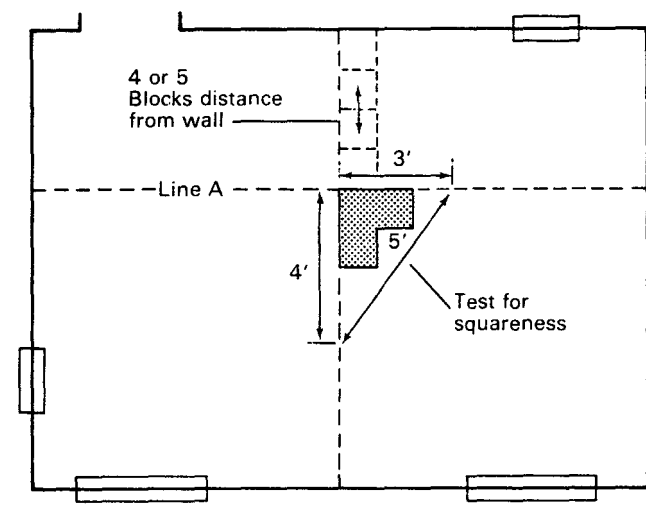
Next, find the center point of this base line (line A, fig. 166) and snap another line at an exact 90° angle to it from wall to wall. This will become your test line to help keep your pattern straight as the installation proceeds. A quick test for squareness is to measure 4 feet along one line from where they intersect, and 3 feet along the other. The distance between these two points will be 5 feet if the lines are truly square (fig. 166).

**Diagonal pattern.** Measure equal distances from one corner of a room, along both walls, and snap a chalk line between these two points to form the base line. (This pattern need not be at a precise 45° angle to walls in order to give satisfactory appearance.) A test line should again

**Figure 165**—Countersink screws in plank flooring and cover with plugs.



**Figure 166**—Working lines for laying block in a square pattern.

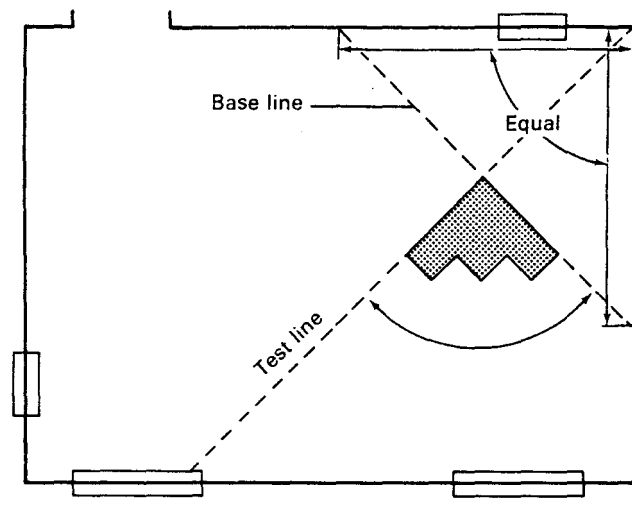


intersect the center of the base line at an exact  $90^\circ$  angle from the corner of the room (fig. 167).

**Herringbone pattern.** Most existing parquet patterns can be laid out with these two working lines. Herringbone, however, requires two test lines: one is at the  $90^\circ$  line already described; the other crosses the intersection of the first two lines, but at a  $45^\circ$  angle to both.

If such elaborate preliminary layout preparation seems a bit overdone, keep in mind that it is wood we are installing. Each piece must be carefully aligned with all of its

**Figure 167**—Working lines for laying block in a diagonal pattern.



neighbors. Small variations in size, natural to wood, must be accommodated during installation to keep the overall pattern squared up. You cannot correct inaccuracies that have grown into a “creeping” pattern; by laying out the floor more carefully you prevent the development of larger problems during installation.

**Building the pattern.** Use a cold, cut-back asphalt mastic spread at the minimum rate of 50 square feet per gallon. Use the notched edge of the trowel. Allow to harden a minimum of 2 hours or up to 48 hours as directed by the manufacturer. The surface will be solid enough after 12 hours to allow you to snap working chalk lines on it. Use blocks of the flooring as stepping stones on the mastic to snap lines and begin the installation.

Wood parquet must always be installed in a pyramid, or stair-step sequence, rather than in rows. This again prevents the small inaccuracies of size in all wood from magnifying, or creeping, to give an appearance of misalignment. Place the first parquet unit carefully at the intersection of the base and test lines. Lay the next units ahead and to the right of the first one along the line. Then continue the stair-step sequence, watching carefully the corner alignment of new units with those already in place. Install in a quadrant of the room, leaving trimming at the walls until later. Then return to the base and test lines and lay another quadrant, repeating the stair-step sequence.

Install the last quadrant from the base line to the door. A reducer strip may be required at the doorway.

Most wood floor mastics, regardless of type or open time (time between applying adhesive and applying wood floor), allow the tiles to slip or skid when sidewise pressure is applied for some time after open time has elapsed.

By working from knee boards or plywood panels laid on top of the installed area of flooring you avoid this side-wise pressure. For the same reason no heavy furniture or activity should be allowed on the finished parquet floor for about 24 hours. Some mastics also require rolling.

Cut blocks or parquetry pieces to fit at walls, allowing  $\frac{3}{4}$ -inch expansion space on all sides. Use cork blocking in 3-inch lengths between flooring edge and wall to permit the flooring to expand and contract by compressing and relaxing the cork.

With blocks, a diagonal pattern is recommended in corridors and in rooms where the length is more than  $1\frac{1}{2}$  times the width. This diagonal placement minimizes expansion under conditions of high humidity.

### **Other Floor Coverings**

Apart from wood, a wide variety of floor coverings are available for application over wood subfloor. Special preparation may be required for installation on a concrete slab, as discussed later. In making a selection of floor covering, the usual considerations are maintenance, durability, comfort, esthetics, and initial cost. The floor coverings commonly used are carpet, sheet vinyl, vinyl tile, and ceramic tile.

Regardless of the type of floor covering, installation should not begin until the work of all other trades has been completed and the area cleared of extraneous materials. If it is necessary to install floor covering before all other work is finished, the installed covering should be immediately covered with heavy paper or other suitable protective covering.

#### ***Carpet***

Carpeting is often desired because of its absorption of sound, resistance to impact, appearance, and ease of maintenance. It can be installed over almost any type of subfloor, or directly to a concrete slab. The thickness of carpet and padding help to even out slight roughness or discontinuities, so little preparation is required. Installation is usually done by a professional with appropriate tools and skills for cutting to a precise size and stretching between tack strips at the room perimeter.

#### ***Sheet vinyl and resilient tile***

A smooth underlayment is required for these resilient floor coverings because they conform to the contour of the surface under them. Plywood subfloor should meet the requirements of U.S. Product Standard PS1 83 published by the American Plywood Association, and be in grades and thicknesses recommended by the floor covering

manufacturer. Hardboard must meet the requirements of ANSI Standard A135.4, Basic Hardboard, Class 4, underlayment grade with a thickness tolerance of  $0.215 \pm 0.005$  inch. This standard is published by the American Hardboard Association. The subfloor and underlayment assembly must be solid, well nailed at the joists, and free from springiness. Install plywood underlayment with cross-joints staggered at least 16 inches. Nail the center of the panel first, working out to the edges. Leave a space between underlayment sheet edges equal to the thickness of a dime (approximately  $\frac{1}{32}$  in). Drive fasteners flush or set not more than  $\frac{1}{16}$  inch below the surface. Fill any low spots, holes, splits, or openings of more than  $\frac{1}{16}$  inch with a hard-set, nonshrinking latex compound. Sand after drying.

The installation of resilient materials is usually done by a contractor specializing in that type of flooring. In any case, it should be installed according to manufacturer's instructions. The flooring and adhesive must be maintained at a minimum temperature of 70 °F for at least 24 hours before, during, and 24 hours after application.

#### ***Ceramic tile***

Where ceramic tile is used over a wood joist floor, maximum joist spacing is 16 inches on center. Plywood  $\frac{5}{8}$  inch thick is required for subfloor. An underlayment of  $\frac{3}{8}$ -inch plywood is secured to the subfloor with an adhesive or by nailing with 6d ring-shank nails at 6-inch spacing along panel edges and 8-inch spacing at interior supports. Plywood can serve as a combination subfloor underlayment if the plywood is  $\frac{5}{8}$ -inch Group 1,  $\frac{3}{4}$ -inch Group 2 or 3, or  $\frac{7}{8}$ -inch Group 4. The face grain of the plywood must be at right angles to the joists, and edges must be either tongue and groove or supported by 2 by 4 blocking. Leave a  $\frac{1}{4}$ -inch-wide space between underlayment sheet edges and all materials they abut, such as other underlayment sheet edges, walls, drains, and posts.

, A variety of mortars and adhesives are available for setting the tile. Follow the manufacturer's instructions for application of these materials. Also follow tile manufacturer's recommendations for type of setting material, and exposure to traffic and environmental conditions.

### **Interior Doors**

Interior doors are usually purchased prehung, hinged to a sidejamb, and with stops and latch hardware in place. The main installation required is nailing to the rough framing. Hollowcore doors are commonly used except where fire resistance or sound transmission are critical, as between the garage and the house. Hollowcore doors consist of thin facings glued to a perimeter frame and to a core material such as expanded paper honeycomb between

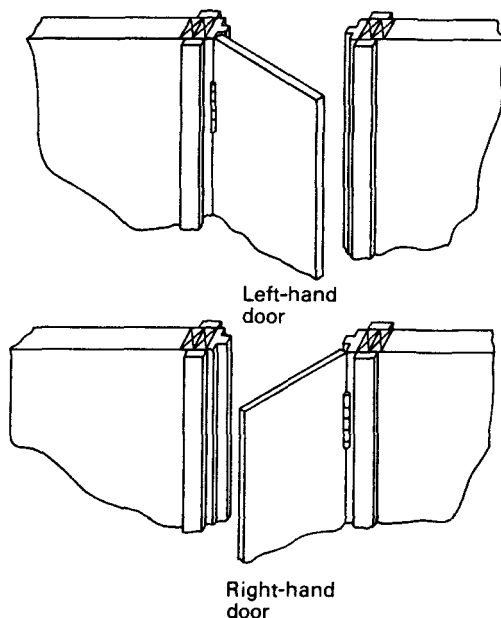
the framing. Where a natural wood finish is desired, plywood with an attractive veneer face is used. Where doors are to be painted, paper-overlaid plywood or hardboard is used. Hardboard may also be overlaid with a simulated wood grain pattern or be molded to give the appearance of a colonial-style panel door. Traditionally constructed panel doors are available at higher cost, and louvered doors can be used where air circulation is desirable.

Rough openings in the stud walls for interior doors are usually framed out to be 2 inches more than the door height and 2 inches more than the door width. The standard door height is 6 feet 8 inches. Common minimum widths for single interior doors are: (a) bedroom and other habitable rooms, 2 feet 6 inches; (b) bathrooms, 2 feet 4 inches; (c) small closet and linen closets, 2 feet. These sizes vary a great deal, and sliding doors, folding door units, and similar types are often used for full-width access to closets.

Folding closet doors can also be purchased in an 8-foot height so that full floor to ceiling access is given, and no header is required. Standard jamb width is  $4\frac{9}{16}$  inches to fit a 2- by 4-inch stud wall with  $\frac{1}{2}$ -inch gypsum board each side. While it may not be necessary to lock many interior doors, privacy locks are often used on bathroom and bedroom doors.

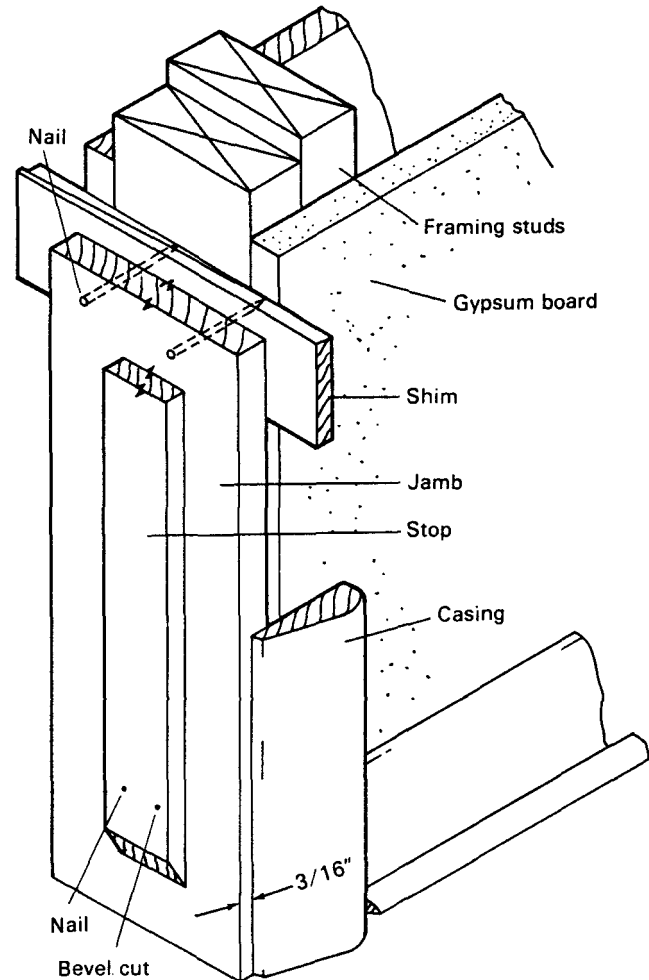
Doors must be purchased as left-hand or right-hand depending on the direction of swing. The right-hand door has hinges on the right as the door swings toward you, whereas the left-hand door has hinges on the left (fig. 168).

**Figure 168**—Direction of swing of right- and left-hand doors.



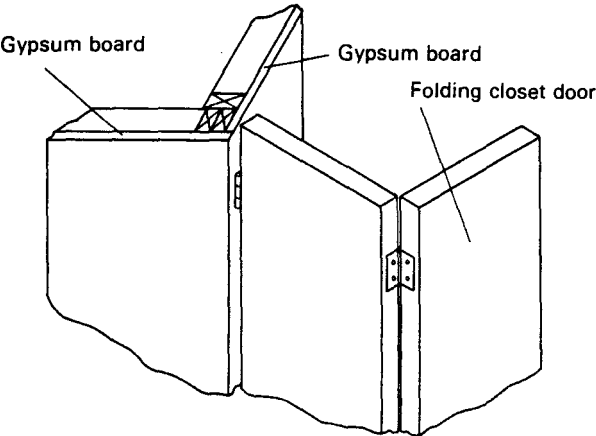
The frame is set in place and jambs are **nailed** to the rough framing. Where there is a gap between jambs and rough framing, place shims **in** the gap before **nailing**. Use two 8d finishing nails about **16** inches apart over the length of the jambs (fig. 169). Folding closet doors can be installed by mounting hinges on the gypsum board at the opening with screws secured into the framing behind the gypsum board (fig. 170).

**Figure 169**—Installation of door frame in rough opening.



**Figure 170**—Folding closet door mounted directly on finished wall with hinges secured to wall framing.

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## Finishing Touches

### Interior Trim

A variety of moldings are available to provide a finished trim around doors and windows and at the intersection of walls with the floor or the ceiling. Typical molding patterns are shown in figures 171 to 174. Moldings that receive a natural finish are often oak or other hardwood species. The usual softwood molding is ponderosa pine. It is used where the finish is to be painted, but sometimes it is stained and given a natural finish. Molded particleboard with a wood grain vinyl overlay is also used in some cases.

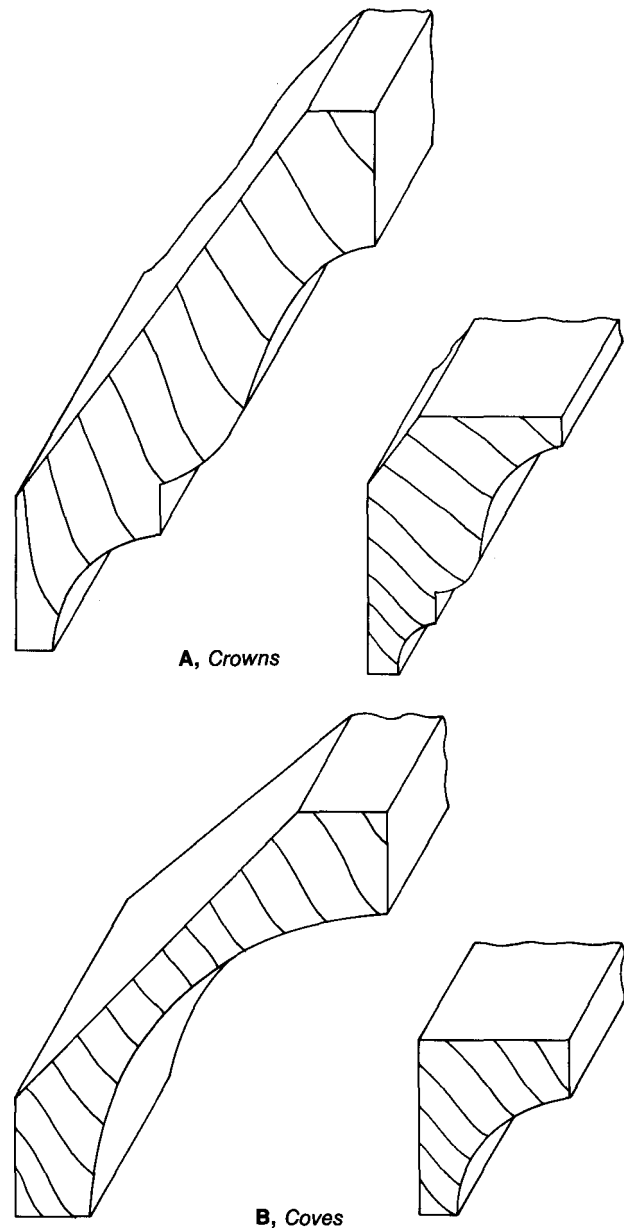
#### Casing

The casing is the edge trim around interior door openings and is also used to finish the room side of exterior door frames. Casing varies in width, being usually from  $2\frac{1}{4}$  to  $3\frac{1}{2}$  inches, depending on the style. Casing may be obtained in thicknesses from  $\frac{1}{2}$  to  $\frac{3}{4}$  inch, although  $\frac{11}{16}$  inch is standard in many of the narrow-line patterns. Door casings are nailed to the jamb and to the framing studs or header, allowing about a  $\frac{3}{16}$ -inch edge distance from the face of the jamb (see fig. 169). Finish or casing nails, size 6d or 7d depending on the thickness of the casing, are used to nail into the stud. Finishing nails, size 4d or 5d, or  $1\frac{1}{2}$ -inch brads are used to fasten the thinner edge of the casing to the jamb. In hardwood, it is usually advisable to predrill to prevent splitting. Nails in the casing are located in pairs (fig. 175) and spaced about 16 inches apart along the full height of the opening and at the head jamb.

Casing with any form of molded shape must have a mitered joint at the corners (fig. 175A). When casing is squared-edged, a butt joint may be made at the junction of the side and head casing (fig. 175B). If the moisture content of the casing is well above that recommended, a mitered joint may open slightly at the outer edge as the material dries. This can be minimized by using a small glued spline at the corner of the mitered joint. Actually, use of a spline joint under any moisture condition is considered good practice, and some prefitted jamb, door, and casing units are provided with splined joints. Nailing the joint after drilling aids in retaining a close fit (fig. 175).

The casing around the window frames on the interior of the house should be the same pattern as that used around the interior door frames. Other trim that is used for a double-hung window frame includes the sash stops, stool, and apron (fig. 176A). Another method of using trim

Figure 171—Moldings for intersection of walls and ceilings:

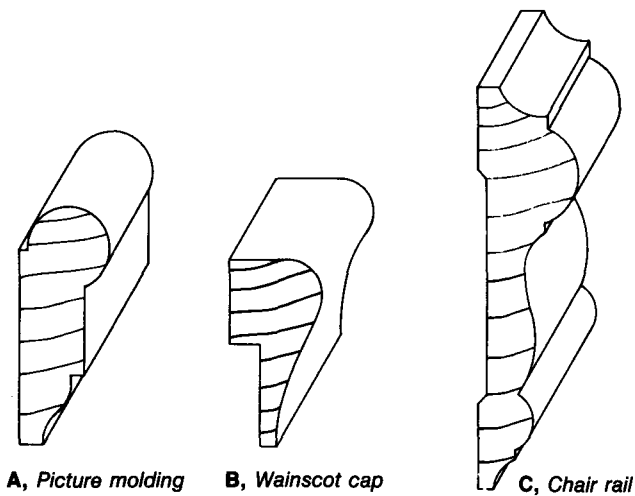


around windows has the entire opening enclosed with casing (fig. 176B). The stool is then a filler member between the bottom sash rail and the bottom casing.

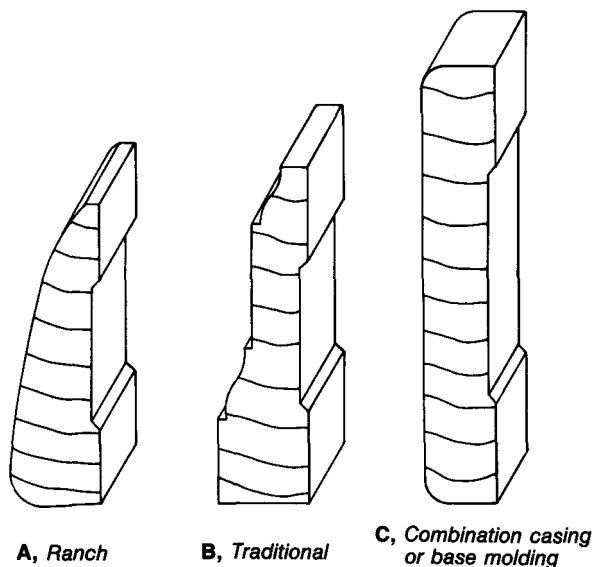
#### Window stool and apron

The stool is the horizontal trim member that laps the window sill and extends beyond the casing at the sides,

**Figure 172 – Wall moldings:**

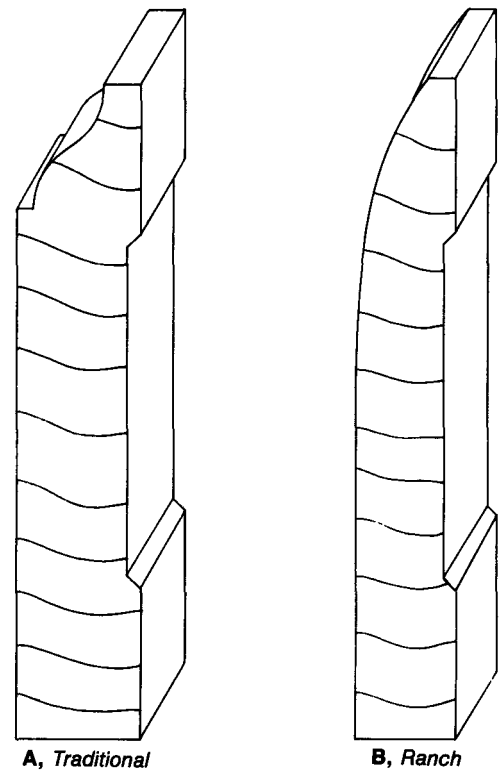


**Figure 173 – Casings:**

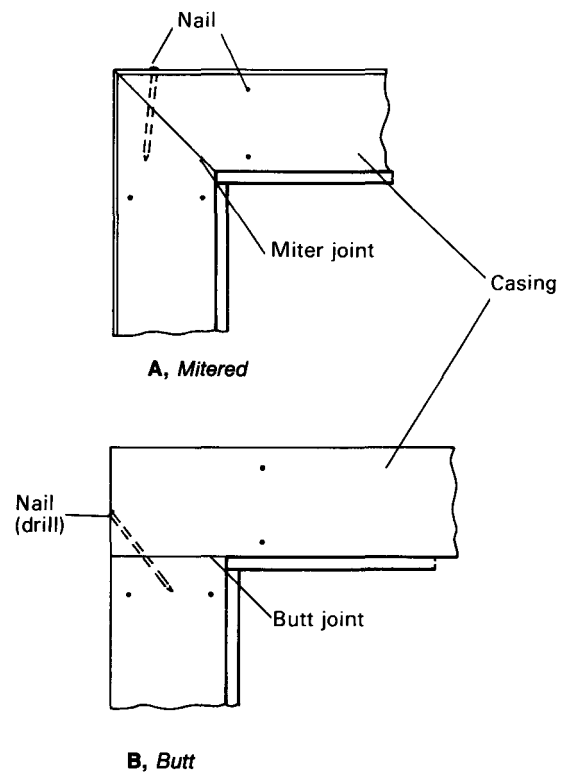


with each end notched against the wall. The apron serves as a finish member below the stool. The window stool is the first piece of window trim to be installed and is notched and fitted against the edge of the jamb and the gypsum board, with the outside edge flush against the bottom rail of the window sash (fig. 176A). The stool is blind-nailed at the ends so that the casing and the stop cover the nailheads. Predrilling is usually necessary to prevent splitting. The stool should also be nailed at mid-point to the sill and to the apron with finishing nails. Facenailing to the sill is sometimes used instead of, or in combination with, toenailing of the outer edge to the sill.

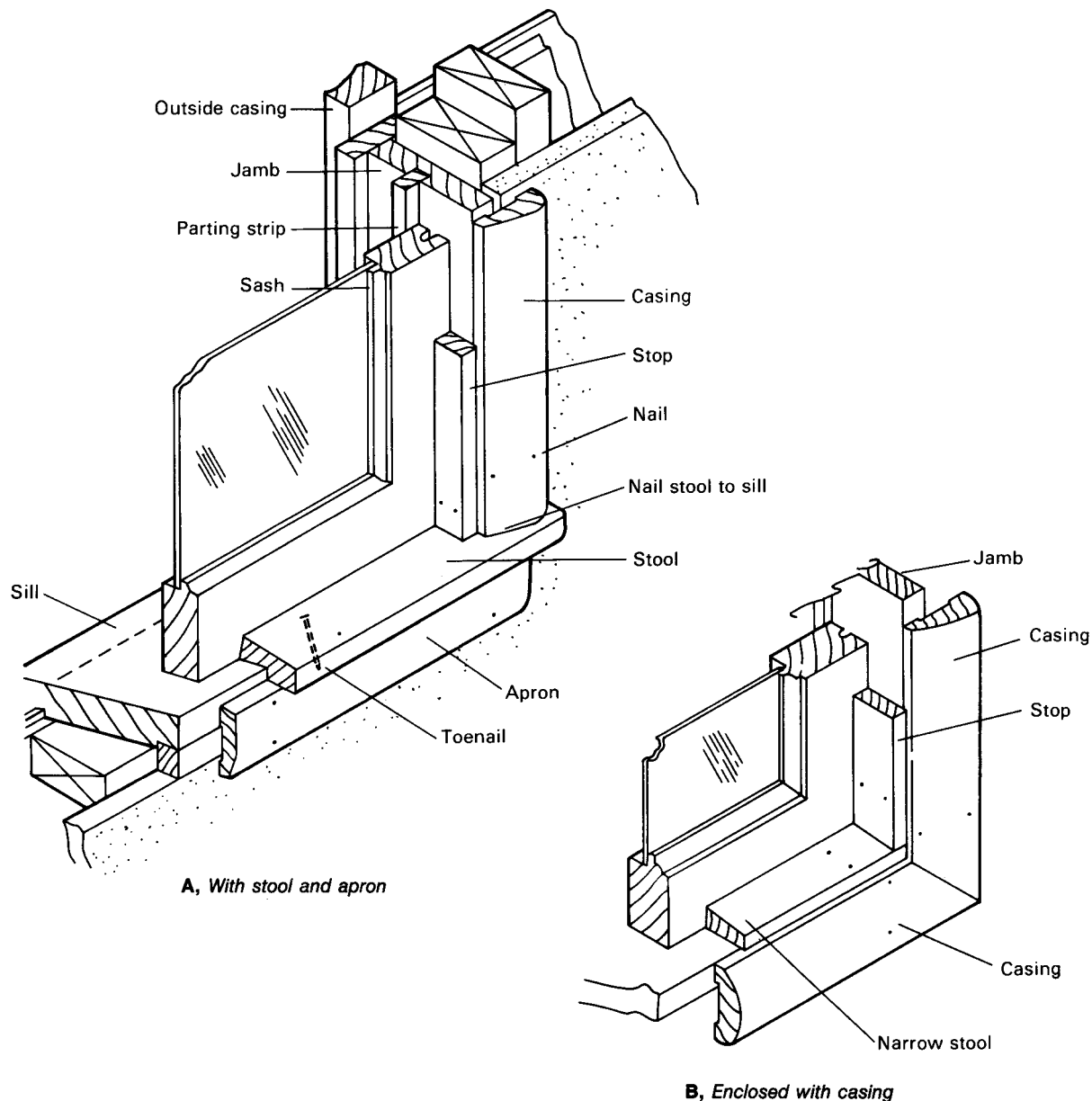
**Figure 174 – Base moldings:**



**Figure 175 – Casing joints:**



**Figure 176 – Installation of window trim:**



The casing is applied and nailed as described for door frames (fig. 175), except that the inner edge is flush with the inner face of the jambs so that the stop covers the joint between the jamb and casing. The apron is cut to a length equal to the outer width of the casing line. It is nailed to the window sill and to the 2- by 4-inch framing sill below.

When casing is used to finish the bottom of the window frame as well as the sides and top, the narrow stool butts against the side window jamb. Casing is then mitered at the bottom corners (fig. 176B) and nailed as previously described.

### ***Base molding and base shoe***

Base molding serves as a finish between the finished wall and the floor. It is available in several widths and forms. Two-piece base consists of a baseboard topped with a small base cap (fig. 177A). When the wall finish is not straight and true, the small base molding will conform more closely to the variations than will the wider base alone. A common size for this type of baseboard is  $\frac{5}{8}$  by  $3\frac{1}{4}$  inches or wider. One-piece base (fig. 177B and C) varies in size from  $\frac{7}{16}$  by  $2\frac{1}{4}$  inches to  $\frac{1}{4}$  by  $3\frac{1}{4}$  inches and wider. Although a wood member is desirable at the junction of the wall and carpeting to serve as a protective “bumper,” wood trim is sometimes eliminated entirely.

Most baseboards are finished with a base shoe  $\frac{1}{2}$  by  $\frac{3}{4}$  inch in size (fig. 177D). A single-base molding without the shoe is sometimes placed at the wall-floor junction, especially where carpeting might be used.

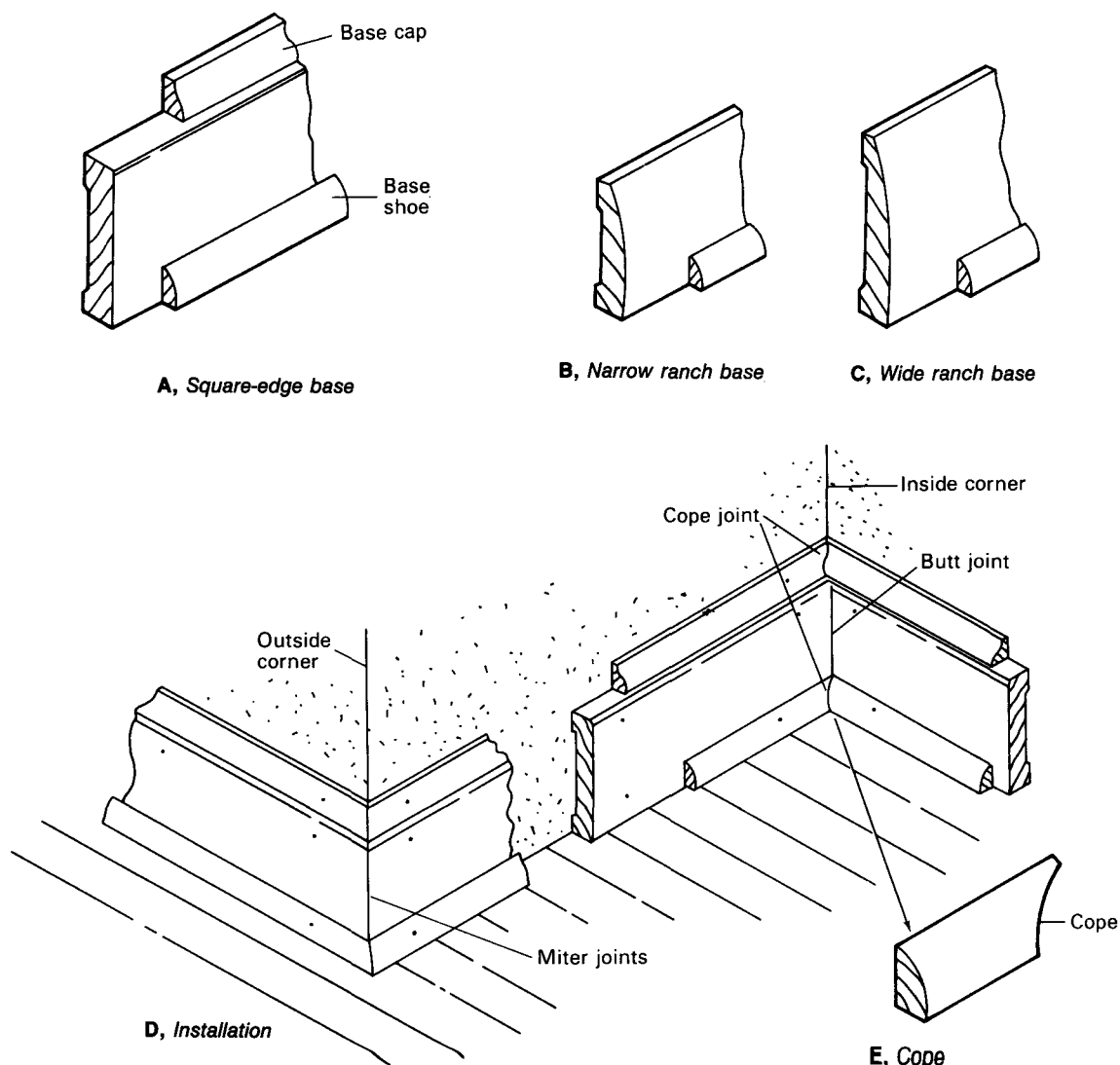
Square-edged baseboard should be installed with a butt joint at inside comers and a mitered joint at outside comers (fig. 177). It should be nailed to each stud with two 8d finishing nails. Molded single-piece base, base moldings, and base shoe should have a coped joint at inside comers and a mitered joint at outside comers. A coped joint is one in which the first piece is square-cut against the wall or base and the second molding coped. This is accomplished by sawing a  $45^\circ$  miter cut and with a coping saw trimming the molding along the inner line

of miter (fig. 177). The base shoe should be nailed into the subfloor with long slender nails and not into the base-board itself. Then no opening occurs under the shoe if there is a small amount of wood shrinkage.

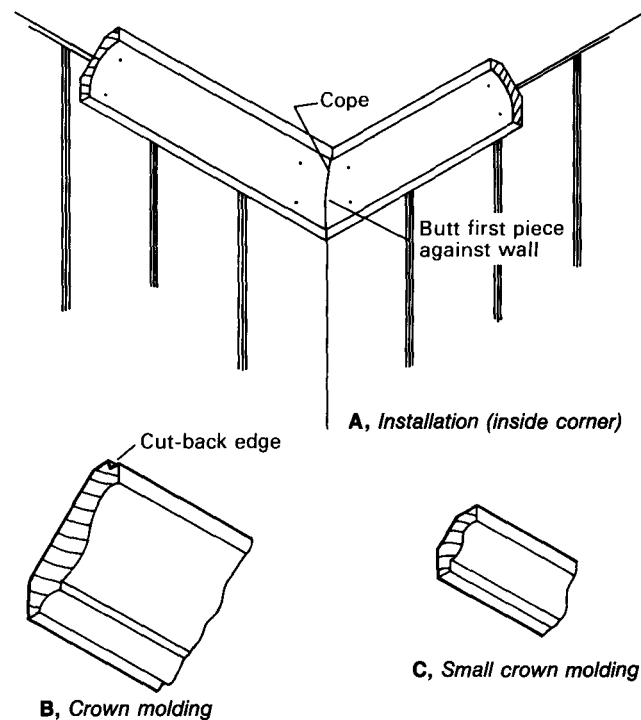
### Ceiling moldings

Ceiling moldings (fig. 171) are sometimes used at the junction of wall and ceiling for an architectural effect or to terminate paneling, gypsum board, or wood (fig. 178). As with base moldings, the inside corners should be cope jointed. This insures a tight joint and retains a good fit if there are minor moisture changes.

**Figure 177 – Base molding:**



**Figure 178 – Ceiling moldings;**



A cutback edge at the outside of the molding partially conceals any unevenness of the finish and makes painting easier where there are color changes (fig. 178). Finish nails should be driven and set into the upper wall plates and, for large moldings, also into the ceiling joists, when possible.

### **Cabinets and Other Millwork**

Millwork, as a general term, usually includes most wood materials and house components that require manufacturing. This covers not only the interior trim, doors, and other items previously described, but also such items as kitchen cabinets, fireplace mantels, built-in china cabinets, bookcases, and similar units. Most of these units are produced in a millwork manufacturing plant and are ready to install in the house. They differ from some other items because they usually require only fastening to the wall or floor.

While many units are custom made, others can be ordered directly from stock. For example, kitchen cabinets are often stock items, obtainable at widths of 12 or 15 inches and wider by 3-inch increments up to 48 inches wide.

Like interior trim, cabinets, shelving, and similar items can be made of various wood species. If the millwork is to be painted, ponderosa pine, southern pine, Douglas-fir, gum, and similar softwood species may be used. Birch,

oak, redwood, and knotty pine, and other woods with attractive surface variations, are finished with varnish or sealers.

Recommended moisture content for interior millwork may vary from 6 to 11 percent in different parts of the country.

### **Kitchen cabinets**

The kitchen usually contains more millwork than the rest of the rooms combined. This millwork is in the form of wall and base cabinets, broom closets, and other items. An efficient plan with properly arranged cabinets not only reduces work and saves steps but also often reduces costs because the area occupied is smaller. Location of the refrigerator, sink, dishwasher, and range, together with the cabinets, is important also from the standpoint of plumbing and electrical connections. In the design of a pleasant kitchen, good lighting, both natural and artificial, plays a significant part.

Kitchen cabinets, both base and wall units, should be constructed to specific standards of height and depth. Figure 179 shows common base cabinet counter heights and depths as well as clearances for wall cabinets. While the range of counter heights is from 30 to 38 inches, the standard height is 36 inches. Wall cabinets vary in height depending on the type of installation at the counter. The tops of wall cabinets are located at the same height, either free or under a 12- to 14-inch drop ceiling or storage cabinet. Wall cabinets are normally 30 inches high, but not more than 21 inches when a range or sink is located under them. Wall cabinets can also be obtained in 12-, 15-, 18-, and 24-inch heights. The shorter wall cabinets are usually placed over refrigerators.

Narrow wall cabinets are furnished with single doors and the wider ones with double doors. Base cabinets may be obtained in full-door or full-drawer units or with both drawers and doors. Sink fronts or sink-base cabinets, corner cabinets, broom closets, and desks are some of the special units that may be used in planning the ideal kitchen. Cabinets are fastened to the wall through cleats located at the back of each cabinet. It is good practice to use long screws to penetrate well into each wall stud.

### **Kitchen layout**

Four basic layouts are commonly used in the design of a kitchen.

**U-type.** This layout (fig. 180A) is very efficient, having the sink at the bottom of the U and the range and refrigerator on opposite sides.

**L-type.** This layout (fig. 180B), with the sink and refrigerator on one leg and the range on the other, is sometimes used with a dining space in the unoccupied corner.

**Galley kitchen plan.** This layout (fig. 180C) is often used in narrow kitchens and can be quite efficient with a sink near the center of one side and the range and refrigerator near opposite ends of the other side.

**Sidewall type.** This layout (fig. 180D) is usually preferred for small apartments. All cabinets, the sink, range, and refrigerator are located along one wall. Counter space is usually somewhat limited when kitchens are small.

Countertops are often plastic laminate and are available in a wide range of colors and textures. The countertop is usually purchased with the laminate already applied. Where ceramic tile is used, it must be applied on site after the top is installed. Another popular countertop is molded plastic that simulates marble.

### Bathroom cabinets

Cabinets are frequently used in the bathroom and are purchased built to a number of standard sizes just as they are for the kitchen. Countertops are similar, but where molded plastic is used, the sink may also be molded as an

integral part of the countertop. While natural wood cabinets are available, plastic laminates are often used because of the severe exposure to moisture. These cabinets are usually purchased as complete units for either one or two sinks.

### Closet shelving and rod

Shelving can be simple 1-inch boards supported at their ends by 1- by 2-inch cleats; however, manufactured units are often used to save installation time. Metal shelves and clothes rods that telescope allow adjustment to fit any space. Another very popular shelving is fabricated from steel rod welded to form an open mesh and in a configuration to be self supporting. The entire assembly is then coated with vinyl. These units are easy to install and have the advantage of not collecting dust as the solid shelves do.

### Mantels

The type of mantel used for a fireplace depends on the style and design of the house and its interior finish. The contemporary fireplace may have no mantel at all or at best a simple wood molding used as a transition between the masonry and the wall finish. However, the colonial or formal interior usually has a well-designed mantel framing the fireplace opening. This may vary from a simple mantel to a more elaborate unit combining paneling and built-in cabinets along the entire wall. In each design, however, it is important that no wood or other combustible material be placed within  $3\frac{1}{2}$  inches of the edges of the fireplace opening. Furthermore, any projection more than  $1\frac{1}{2}$  inches in front of the fireplace, such as the mantel shelf, should be at least  $12\frac{1}{2}$  inches above the opening. Mantels are fastened to the header and framing studs above and on each side of the fireplace.

### Finishes for Interior Walls, Ceilings, and Trim

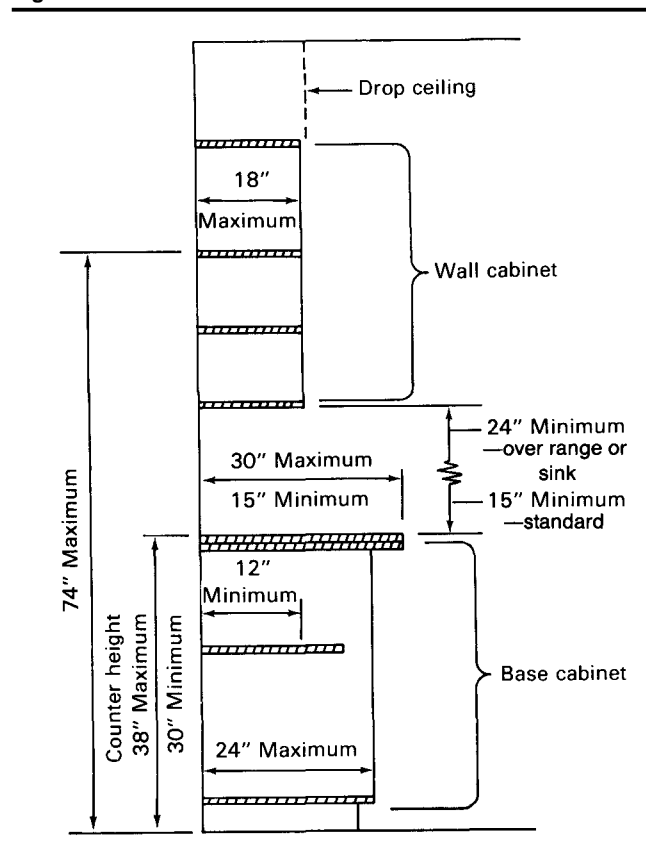
Interior wood is finished for appearance and cleanability. A wide variety of finishes can be used indoors. Veneered panels and plywood can present special finishing problems because these wood constructions may develop lathe checks.

### Opaque finishes (paints)

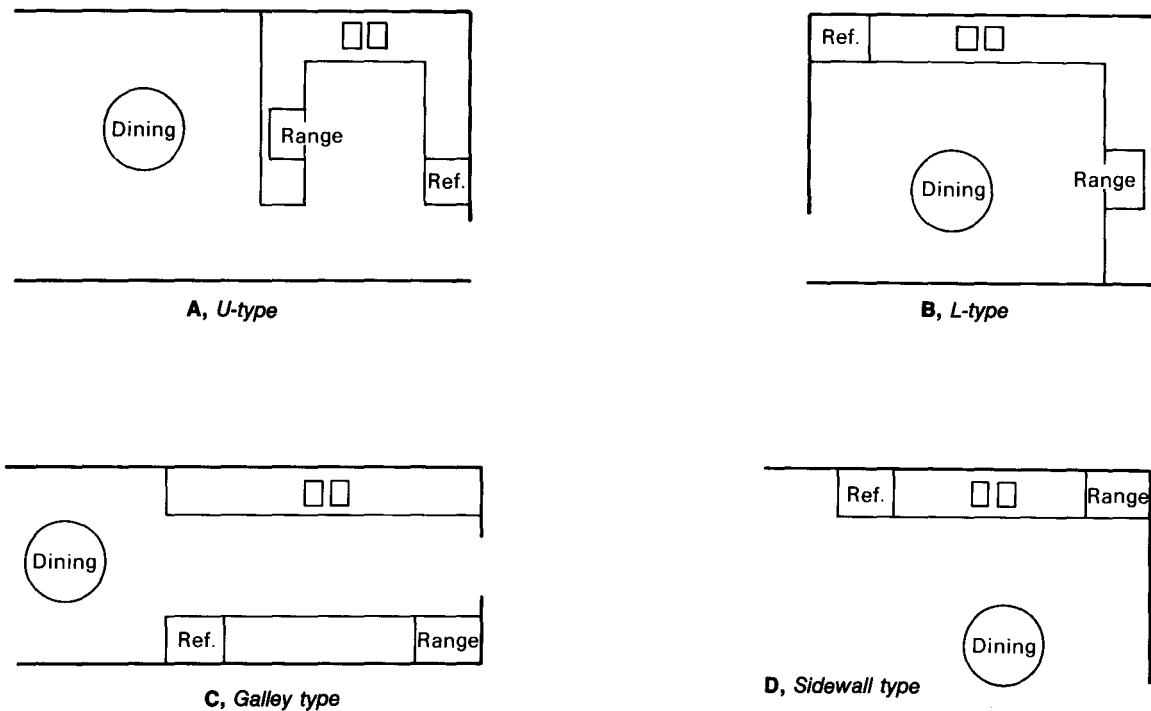
Interior surfaces are often painted. Smooth surfaces, different colors, and a lasting sheen are often demanded for interior woodwork, especially wood trim; therefore, enamels or semigloss enamels are used rather than flat paints.

Before enameling, the wood surface should be sanded extremely smooth and the surface dust removed by a tack

Figure 179 – Kitchen cabinet dimensions.



**Figure 180 – Kitchen layouts:**



cloth. Imperfections such as planer marks, hammer marks, and raised grain are accentuated by enamel finish. Raised grain is especially troublesome on flat-grained surfaces of the denser softwoods because the hard bands of latewood are sometimes crushed into the softer earlywood in planing, and later expand when the wood changes moisture content. For the smoothest surface, it is helpful to sponge softwoods with water, allow them to dry thoroughly, and then sand them lightly with new sandpaper before enameling. In new buildings, woodwork should be allowed adequate time to come to its equilibrium moisture content in the heated building before finishing.

To finish hardwoods that have large pores, such as oak and ash, the pores must be filled with wood filler (see section on fillers). After filling and sanding, make successive applications of interior primer and sealer, undercoat, and enamel.

Knots in the white pines, ponderosa pine, or southern pine should be sealed with shellac or a special knot sealer before priming. A coat of pigmented shellac or a special knot sealer is also sometimes necessary over white pines and ponderosa pine to retard discoloration of light-colored enamels by colored matter present in the resin of the heartwood of these species.

One or two coats of enamel undercoat are next applied; this should completely hide the wood and also present a surface that can be easily sandpapered smooth. For best results, the surface should be sanded just before applying the finish enamel; however, this step is sometimes omitted. After the finishing enamel has been applied, it may be left with its natural gloss or rubbed to a dull finish. When wood trim and paneling are finished with a flat paint, the surface preparation need not be as exacting.

### *Transparent finishes*

Transparent finishes are used on most hardwood and some softwood trim and paneling, according to personal preference. Most finishing consists of some combination of the fundamental operations of sanding, staining, filling, sealing, surface coating, or waxing. Before applying the finish, planer marks and other blemishes on the wood surface that would be accentuated by the finish should be removed.

**Stains.** Both softwoods and hardwoods are often finished without staining, especially if the wood has a pleasing and characteristic color. When stain is used, however, it often accentuates color differences in the wood surface because of unequal absorption into different parts of the grain pattern. With hardwoods, such emphasis of the grain is usually desirable; the best stains for the purpose are dyes dissolved in either water or solvent. The water stains give the most pleasing results, but raise the grain of

the wood and require an extra sanding operation after the stain is dry.

The stains most commonly used are in solvents that dry quickly. These do not raise the grain, and often approach the water stains in clearness and uniformity of color.

Stains on softwoods color the earlywood more strongly than the latewood, reversing the natural gradation in color unless the wood has been sealed first. Pigment-oil stains, which are essentially thin paints, are less subject to this problem and are therefore more suitable for softwoods. Alternatively, the softwood may be coated with penetrating clear sealer before any type of stain is applied in order to produce more nearly uniform coloring.

**Fillers.** In hardwoods with large pores, the pores must be filled if a smooth coating is desired. This is done usually after the wood is stained and before varnish or lacquer is applied. The filler may be transparent and without effect on the color of the finish or may be colored to contrast with the surrounding wood.

For finishing purposes, the hardwoods may be classified as follows:

***Hardwoods with  
large pores***

Ash  
Butternut  
Chestnut  
Elm  
Hackberry  
Hickory  
Lauans  
Mahogany  
Mahogany, African  
Oak  
sugarberry  
Walnut

***Hardwoods with  
small pores***

Alder, red  
Aspen  
Basswood  
Beech  
Cherry  
Cottonwood  
Gum  
Magnolia  
Maple  
Sycamore  
Yellow-poplar

Birch has pores large enough to take wood filler effectively when desired, but small enough as a rule to be finished satisfactorily without filling.

Hardwoods with small pores may be finished with paints, enamels, or varnishes in exactly the same manner as softwoods.

A filler may be a paste or liquid, natural or colored. It is applied by brushing first across the grain and then brushing with the grain. Surplus filler must be removed immediately after the glossy wet appearance disappears. First, the filler should be packed into the pores by wiping across the grain; then wiping should be completed with a few light strokes along the grain. Filler should be allowed to dry thoroughly and be sanded lightly before the finish coats are applied.

**Sealers.** Sealers are thinned varnish or lacquer and are used to prevent absorption of surface coatings and also to prevent the bleeding of some stains and fillers into surface coatings, especially lacquer coatings. Lacquer sealers have the advantage of drying very rapidly.

**Surface coats.** Transparent surface coatings over the sealer may be gloss varnish, semigloss varnish, shellac, nitrocellulose lacquer, or wax. Wax provides protection without forming a thick coating and without greatly enhancing the natural luster of the wood. Coatings of a more resinous nature, especially lacquer and varnish, accentuate the natural luster of some hardwoods and seem to permit the observer to look down into the wood. Shellac applied by the laborious process of French polishing probably achieves this impression of depth most fully, but the coating is expensive and easily marred by water. Rubbing varnishes made with resins of high refractive index for light (ability to bend light rays) are nearly as effective as shellac. Lacquers have the advantages of drying rapidly and forming a hard surface, but require more applications than varnish to build up a lustrous coating.

Varnish and lacquer usually dry with a highly glossy surface. To reduce the gloss, the surfaces may be rubbed with pumice stone and water or with polishing oil. Water-proof sandpaper and water may be used instead of pumice stone. The final sheen varies with the fineness of the powdered pumice stone; coarse powders make a dull surface and fine powders produce a bright sheen. For very smooth surfaces with high polish, the final rubbing is done with rottenstone and oil. Varnish and lacquer made to dry to semigloss or satin finish are also available.

Flat oil finishes commonly called Danish oils are also very popular. This type of finish penetrates the wood and forms no noticeable film on the surface. Two or more coats of oil are usually applied, which may be followed by a paste wax. Such finishes are easily applied and maintained but are more subject to soiling than a film-forming type of finish. Simple boiled linseed oil or tung oil are also used extensively as wood finishes.

## **Finishes for Floors**

The natural color and grain of wood floors make them inherently attractive and beautiful. In addition to enhancing the natural beauty of wood, floor finishes should protect the surface from excessive wear and abrasion, and make it easier to clean. As with other transparent finishes, the complete finishing process consists of four steps: sanding the surface, applying a filler for open-grain woods, applying a stain to achieve a desired color effect, and finally applying a finish. The choice of detailed procedures and specific materials depends largely on the species of wood used and individual preference in type of finish.

## Finishes for Exterior Surfaces

Careful sanding to provide a smooth surface is essential for a good finish because any irregularities or roughness in the wood surface are magnified by the finish. Development of a top-quality surface requires sanding in several steps with progressively finer sandpaper, usually with a machine unless the area is small. The final sanding is usually done with a 2/0 grade paper. When sanding is complete, all dust must be removed with a vacuum cleaner and then a tack rag. Steel wool should not be used on floors unprotected by finish because minute steel particles left in the wood may later cause staining or discoloration.

A filler is required if a smooth, glossy, varnish finish is desired on a wood that has large pores, such as oak or walnut.

Stains are sometimes used to obtain a more nearly uniform color when individual boards vary too much in their natural color. Stains may also be used to accent the grain pattern. If the natural color of the wood is acceptable, staining is omitted. The stain should be oil-based or a type that does not raise the grain. Stains penetrate wood only slightly; therefore, the finish should be carefully maintained to prevent wearing through the stained layer. It is difficult to renew the stain at worn spots in a way that matches the color of the surrounding area.

Finishes commonly used for wood floors are classified either sealers or varnishes. Sealers, which are usually thinned varnishes, are widely used in residential flooring. They penetrate the wood just enough to avoid formation of a surface coating of appreciable thickness. Wax is usually applied over the sealer; however, if greater gloss is desired, the sealed floor makes an excellent base for varnish. The thin surface coat of sealer and wax needs more frequent attention than do varnished surfaces. However, rewaxing or resealing and waxing of high-traffic areas is a relatively simple maintenance procedure—much simpler than the maintenance of varnish coatings.

Varnish may be based on phenolic, alkyd, epoxy, or polyurethane resins. Varnish forms a distinct coating over the wood and gives a lustrous finish. The kind of service expected usually determines the type of varnish, and varnishes are available especially designed for houses or for schools, gymnasiums, and other public buildings. Information on types of floor finishes can be obtained from the flooring associations or the individual flooring manufacturers.

Durability of floor finishes can be improved by keeping them waxed. Paste waxes generally give the best appearance and durability. Two coats are recommended, and if a liquid wax is used, additional coats may be necessary to get an adequate film for good performance.

The primary function of any wood finish (paint, varnish, wax, stain, oil, etc.) is to protect the wood surface, help maintain appearance, and provide cleanability. Wood surfaces exposed to the weather without any finish quickly change; they need finishing both for appearance and protection.

Many different methods are effective for finishing wood and wood-based products of various species, grain patterns, textures, and colors. Selection of a particular exterior finish depends on the appearance and degree of protection desired, and on the substrates used. Because different finishes give varying degrees of protection, the type of finish, its quality, quantity, and method of application must be considered in planning the finishing or refinishing of wood and wood products used outdoors.

### *Finishing characteristics of wood products*

Three general categories of wood products are commonly used in exterior construction: (1) lumber, (2) plywood, and (3) reconstituted wood products such as hardboard and particleboard. Each product has unique characteristics that affect the durability of any finish applied to it.

**Lumber.** Many older houses have wood siding. The ability of lumber to retain and hold a finish is affected by species (table 17), by smoothness, and by ring direction with respect to the surface (vertical versus flat grain). Wood shrinks less across annual rings than in the direction of the rings. For this reason, vertical- or edge-grained surfaces (fig. 181) are better than flat-grained surfaces.

The weight of wood varies tremendously between species. Some common construction woods such as southern pine are dense and heavy compared with such lighter species as redwood and cedar. The weight of wood is important because heavy woods shrink and swell more than light ones. This dimensional change in lumber occurs as the wood gains or loses moisture. Excessive dimensional change in wood constantly stresses a paint film and may result in its early failure.

Some species have wide bands of earlywood and latewood. Wide prominent bands of latewood are characteristic of southern pine and most Douglas-fir, and paint does not hold well on these species. By contrast, redwood and cedar do not have wide latewood bands, and these species are preferred when paint is to be used.

Ring direction also affects paint-holding characteristics and is determined at the time lumber is cut from a log. Most standard grades of lumber contain a high percentage

**Table 17—Characteristics of woods for painting and weathering** (omissions in the table indicate inadequate data for classification)

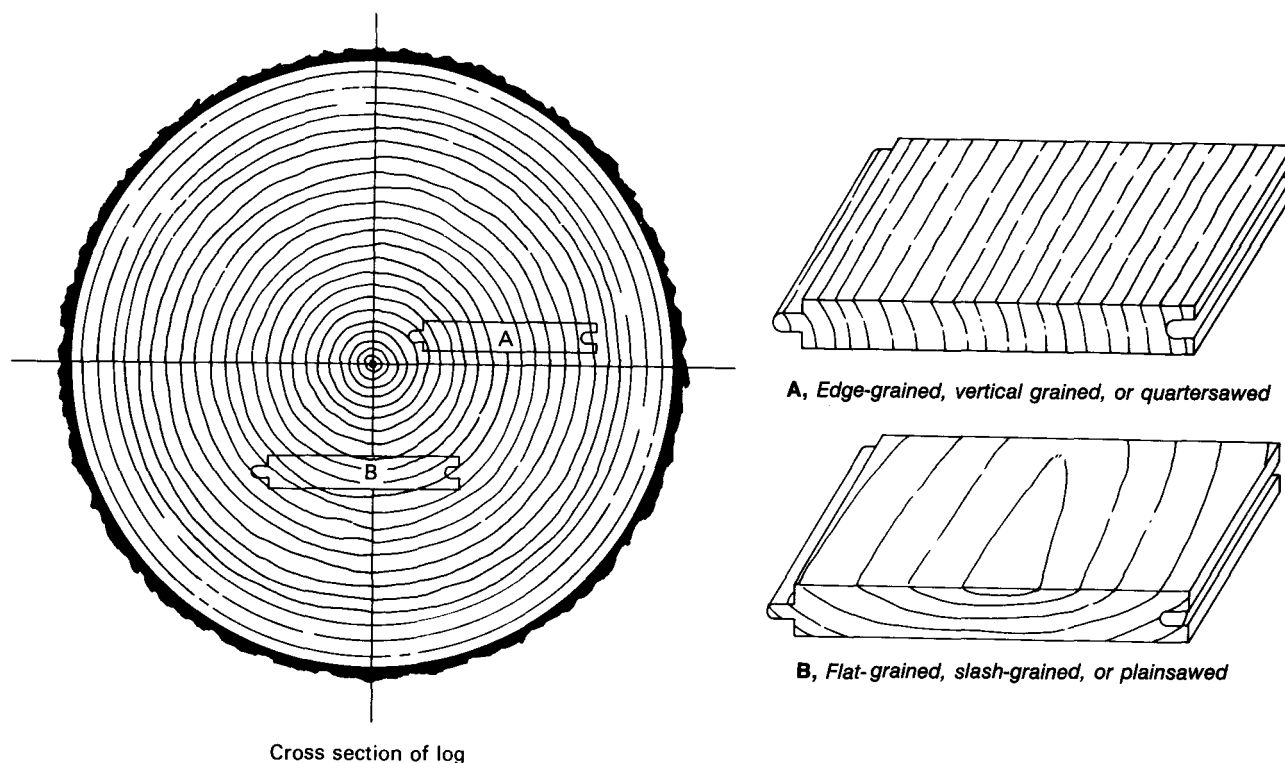
Wood	Ease of keeping well painted (I = easiest, V = most exacting <sup>a</sup> )	Weathering		Appearance	
		Resistance to cupping (1 = best, 4 = worst)	Conspicuousness of checking (1 = least, 2 = most)	Color of heartwood <sup>b</sup>	Degree of figure on flat-grained surface
softwoods					
Cedars					
Alaska-cedar	I	1	1	Yellow	Faint
(California) incense-cedar	I	—	—	Brown	Faint
Port-Orford-cedar	I	—	1	Cream	Faint
Western redcedar	I	1	1	Brown	Distinct
White-cedar	I		—	Light brown	Distinct
Cypress	I	1	1	Light brown	Strong
Redwood	I	1	1	Dark brown	Distinct
Products <sup>c</sup> overlaid with resin-treated paper	I	—	1	—	—
Pine					
Eastern white	II	2	2	Cream	Faint
Sugar	II	2	2	Cream	Faint
Western white	II	2	2	Cream	Faint
Ponderosa	III	2	2	Cream	Distinct
Fir, commercial white	III	2	2	White	Faint
Hemlock	III	2	2	Pale brown	Faint
Spruce	III	2	2	White	Faint
Douglas-fir (lumber and plywood)	IV	2	2	Pale red	Strong
Larch	IV	2	2	Brown	Strong
Lauan (plywood)	IV	2	2	Brown	Faint
Pine					
Norway	IV	2	2	Light brown	Distinct
Southern (lumber and plywood)	IV	2	2	Light brown	Strong
Tamarack	IV	2	2	Brown	Strong
Hardwoods					
Alder	III	—	—	Pale brown	Faint
Aspen	III	2	1	Pale brown	Faint
Basswood	III	2	2	Cream	Faint
Cottonwood	III	4	2	White	Faint
Magnolia	III	2	—	Pale brown	Faint
Yellow-poplar	III	2	1	Pale brown	Faint
Beech	IV	4	2	Pale brown	Faint
Birch	IV	4	2	Light brown	Faint
Cherry	IV	—	—	Brown	Faint
Gum	IV	4	2	Brown	Faint
Maple	IV	4	2	Light brown	Faint
Sycamore	IV	—	—	Pale brown	Faint
Ash	V/III	4	2	Light brown	Distinct
Butternut	V/III	—	—	Light brown	Faint
Chestnut	V/III	3	2	Light brown	Distinct
Walnut	V/III	3	2	Dark brown	Distinct
Elm	V/IV	4	2	Brown	Distinct
Hickory	V/IV	4	2	Light brown	Distinct
Oak, white	V/IV	4	2	Brown	Distinct
Oak, red	V/IV	4	2	Brown	Distinct

<sup>a</sup>Woods ranked in group V for *ease of keeping well painted* are hardwoods with large pores that must be filled with wood filler for durable painting. When so filled before painting, the second classification in the table applies.

<sup>b</sup>Sapwood is always light.

<sup>c</sup>Plywood, lumber, and fiberboard with overlay or low-density surface.

Figure 181—Wood grain in lumber:



of flat grain. Lumber used for board-and-batten siding, drop siding, or shiplap is frequently flat-grained. Bevel siding is commonly produced in several grades. In some cases, the highest grade is required to be vertical-grained and all heartwood over most of the width for greater paint durability. Other grades may contain lumber with flat grain, or vertical grain, or mixed grain, without requirements as to heartwood.

**Plywood.** Exterior plywood with a rough-sawn surface is commonly used for siding. Smooth-sanded plywood is *not recommended* for siding, but it is often used in soffits. Both sanded and rough-sawn plywood develops surface checks, especially when exposed to moisture and sunlight. These surface checks can lead to early paint failure with oil-based or alkyd paint systems. Quality acrylic latex primer and topcoat paint systems generally perform better. The flat-grained pattern present in nearly all plywood can also contribute to early paint failure. Therefore, if smooth or rough-sawn plywood is to be painted, special precautions should be exercised. Penetrating stains are often more appropriate for rough-sawn exterior plywood surfaces, but good-quality acrylic latex paints also perform very well.

**Reconstituted wood products.** Reconstituted wood products are those made by forming small pieces of wood into large sheets, usually 4 by 8 feet or as required for a specialized use such as beveled siding. These products are

classified as fiberboard or particleboard, depending upon the nature of the basic wood component.

Fiberboards are produced from mechanical pulps. Hardboard is a relatively heavy type of fiberboard, and its tempered or treated form designed for outdoor exposure is used for exterior siding. It is often sold in 4- by 8-foot sheets but is also available in narrow strips as a substitute for solid-wood beveled siding.

Particleboards are manufactured from whole wood in the form of splinters, chips, flakes, strands, or shavings. Waferboard and flakeboard are two types of particleboard made from relatively large flakes or shavings.

Some fiberboards and particleboards are manufactured for exterior use. Film-forming finishes such as paints and solid-color stains will give the most protection to these reconstituted wood products. Some reconstituted wood products may be factory-primed with paint, and some may even have a factory-applied topcoat. Also, some may be overlaid with a resin-treated paper to provide a superior surface for paint.

#### *Types of exterior wood finishes*

The outdoor finishes described in this section, their properties, treatment, and maintenance, are summarized in

table 18. The suitability and expected life of the most commonly used finishes on several wood and wood-based products are summarized in table 19. Information in tables 18 and 19 should be considered as general guidelines only. Many factors affect the performance and life-time of wood finishes, as described earlier.

**Paint.** Paints are coatings commonly used on wood and provide the most protection. They come in a wide

range of colors and may have either oil or latex base. Latex-based paints and stains are waterborne, and oil-based or alkyd paints are carried by organic solvents. Paints are used for esthetic purposes, to protect the wood surface from weathering, and to conceal certain defects.

Paints are applied to the wood surface and do not penetrate it deeply. The wood grain is completely obscured, and

**Table 18—Exterior wood finishes: types, treatment, and maintenance**

Finish	Initial treatment	Appearance of wood	cost of initial treatment	Maintenance procedure	Maintenance period of surface finish	Maintenance cost
Preservative oils (creosotes)	Pressure, hot and cold tank steeping	Grain visible. Brown to black in color, fading slightly with age	Medium	Brush down to remove surface dirt	5–10 yr only if original color is to be renewed; otherwise no maintenance is required	Nil to low
	Brushing	Brown to black in color, fading slightly with age	Low	Brush down to remove surface dirt	3–5 yr	Low
Waterborne preservatives	Pressure	Grain visible. Greenish in color, fading with age	Medium	Brush down to remove surface dirt	None, unless stained, painted, or varnished as below	Nil, unless stains, varnishes, or paints are used. See below
	Diffusion plus paint	Grain and natural color obscured	Low to medium	Clean and repaint	7–10 yr	Medium
Organic solvents preservatives.	Pressure, steeping, dipping, brushing	Grain visible. Colored as desired	Low to medium	Brush down and reapply	2–3 yr or when preferred	Medium
Waterrepellent†	One or two brush coats of clear material or, preferably, dip applied	Grain and natural color visible, becoming darker and rougher textured	Low	Clean and apply sufficient material	1–3 yr or when preferred	Low to medium
Stains	One or two brush coats	Grain visible. Color as desired	Low to medium	Clean and apply sufficient material	3–6 yr or when preferred	Low to medium
Clear varnish	Four coats (minimum)	Grain and natural color unchanged if adequately maintained	High	Clean and stain bleached areas, and apply two more coats	2 yr or when breakdown begins	High
Paint	Water repellent, prime, and two topcoats	Grain and natural color obscured	Medium to high	Clean and apply topcoat; or remove and repeat initial treatment if damaged	7–10 yr‡	Medium to high

Source: This table is a compilation of data from the observations of many researchers.

\*Pentachlorophenol, bis (tri-n-butyltin oxide), copper naphthenate, copper-8-quinolinolate, and similar materials.

†With or without added preservatives. Addition of preservative helps control mildew growth and gives better performance.

‡Using to-p-quality acrylic latex topcoats.

**Table 19—Suitability of finishing methods for exterior wood surfaces**

Type of exterior wood surfaces	Water-repellent preservative		Stains		Paints	
	Suitability	Expected life* (yr)	Suitability	Expected life† (yr)	Suitability	Expected life‡ (yr)
Siding						
Cedar and redwood						
Smooth (vertical grain)	High	1–2	Moderate	2–4	High	4–6
Rough sawn or weathered	High	2–3	Excellent	5–8	Moderate	3–5
Pine, fir, spruce, etc.						
Smooth (flat grain)	High	1–2	Low	2–3	Moderate	3–5
Rough (flat grain)	High	2–3	High	4–7	Moderate	3–5
Shingles						
Sawn	High	2–3	Excellent	4–8	Moderate	3–5
Split	High	1–2	Excellent	4–8	—	—
Plywood (Douglas-fir and southern pine)						
Sanded	Low	1–2	Moderate	2–4	Moderate	3–5
Rough sawn	Low	2–3	High	4–8	Moderate	3–5
Medium-density overlay§	—	—	—	—	Excellent	6–8
Plywood (cedar and redwood)						
Sanded	Low	1–2	Moderate	2–4	Moderate	3–5
Rough sawn	Low	2–3	Excellent	5–8	Moderate	3–5
Hardboard, medium density¶						
Smooth						
Unfinished	—	—	—	—	High	4–6
Preprimed	—	—	—	—	High	4–6
Textured						
Unfinished	—	—	—	—	High	4–6
Preprimed	—	—	—	—	High	4–6
Millwork (usually pine)						
Windows, shutters, doors, exterior trim	High¶	—	Moderate	2–3	High	3–6
Decking						
New (smooth)	High	1–2	Moderate	2–3	Low	2–3
Weathered (rough)	High	2–3	High	3–6	Low	2–3
Glued-laminated members						
Smooth	High	1–2	Moderate	3–4	Moderate	3–4
Rough	High	2–3	High	6–8	Moderate	3–4
Waferboard	—	—	Low	1–3	Moderate	2–4

Source: This table is a compilation of data from the observations of many researchers. Expected life predictions are for an average continental U.S. location; expected life will vary in extreme climates or exposure (desert, seashore, deep woods, etc.).

\* Development of mildew on the surface indicates a need for refinishing.

† Smooth, unweathered surfaces are generally finished with only one coat of stain, but rough-sawn or weathered surfaces, being more absorptive, can be finished with two coats, with the second coat applied while the first coat is still wet.

‡ Expected life of two coats, one primer and one topcoat. Applying a second topcoat (three-coat job) will approximately double the life. Top-quality acrylic latex paints will have best durability.

§ Medium-density overlay is generally painted.

¶ Semitransparent stains are not suitable for hardboard. Solidcolor stains (acrylic latex) will perform like paints. Paints are preferred.

¶ Exterior millwork, such as windows, should be factory treated according to Industry Standard IS4-81. Other trim should be liberally treated by brushing before painting.

a surface film is formed. Paints perform best on smooth, edge-grained lumber of lightweight species. The surface film can blister or peel if the wood is wetted or if inside water vapor moves through the house wall and wood siding because of the absence of a vapor-retarding material.

Latex paints are generally easier to use because water is used in cleanup. They are also porous and allow some moisture movement. In comparison, oil-based paints require organic solvent for cleanup, and some are resistant to moisture movement.

Of all the finishes, paints provide wood with the most protection against surface erosion and offer the widest selection of colors. A nonporous paint film retards penetration of moisture and reduces the problem of discoloration by wood extractives and warping of the wood. However, *paint is not a preservative. It will not prevent decay if conditions are favorable for fungal growth.* Original and maintenance costs are often higher for a paint finish than for a water-repellent preservative or penetrating stain finish.

**Solid-color stains.** Solid-color stains are opaque finishes (also called hiding or heavybodied); they come in a wide range of colors and are made with a much higher concentration of pigment than the semitransparent penetrating stains. As a result, they totally obscure the natural wood color and grain. Oil-based solid-color stains tend to form a film much like paint and as a result may also peel loose from the substrate. Latex-based solid-color stains are also available, and like the oil-based solid-color stains, they form a surface film. Both these stains are similar to thinned paints and can usually be applied over old paint or stain.

**Semitransparent penetrating stains.** Semitransparent penetrating stains are only moderately pigmented and do not totally hide the wood grain. These stains penetrate the wood surface, are porous, and do not form a surface film like paints. As a result, they do not blister or peel even if moisture moves through the wood. Penetrating stains have alkyd or oil base, and some may contain a fungicide as well as a water repellent. Moderately pigmented latex-based (waterborne) stains are also available, but they do not penetrate the wood surface like oil-based stains.

Stains are most effective on rough lumber or rough-sawn plywood surfaces, but they also provide satisfactory performance on smooth surfaces, although they require frequent renewal. They are available in a variety of colors and are especially popular in the brown or red earth tones because they give a “natural” or rustic wood appearance. They make an excellent finish for weathered wood. *Semitransparent stains are not effective when applied over a solid color stain or over old paint.*

**Water repellents and water-repellent preservatives.** A water-repellent preservative may be used as a natural finish. It contains a fungicide or mildewcide, a small amount of wax as a water repellent, a resin or drying oil, and a solvent such as turpentine or mineral spirits. Water-repellent preservatives do not contain any coloring pigments. Therefore, the resulting finish varies in color depending upon the wood itself. The preservative also prevents wood from darkening (graying) as a result of mildew and mold growth.

The initial application to smooth surfaces is usually short-lived. When a surface starts to show a blotchy discoloration caused by extractives or mildew, it should be cleaned with liquid household bleach and detergent solution and retreated after drying. During the first few years, the finish may have to be applied every year or so. After the wood has gradually weathered to a uniform color, the treatments are more durable and need refinishing only when fungi start to make the surface color uneven.

**Caution:** *Because of the toxicity of some fungicides in water-repellent preservative solutions and some semitransparent stains, care should be exercised to avoid excessive contact with the solution or its vapor or with the treated wood. Shrubs and plants should also be protected from accidental contamination.*

Water-repellent preservatives may also be used as a treatment for bare wood before priming and painting or in areas where old paint has peeled, exposing bare wood, particularly around butt joints or in corners. This treatment keeps rain or dew from penetrating into the wood, especially at joints and end grain, and thus decreases the shrinking and swelling of wood. The fungicide inhibits decay.

Water repellents are also available. These are water-repellent preservatives with the preservative left out. Water repellents are not effective natural finishes by themselves because they do not control mildew. They can be used as a stabilizing treatment before priming and painting.

**Transparent coatings.** Clear coatings of conventional spar, urethane, or marine varnishes, which are film-forming finishes, are not generally recommended for exterior use on wood. Such coatings embrittle by exposure to sunlight and develop severe cracking and peeling, often in less than 2 years. Areas that are protected from direct sunlight by overhang or which are on the north side of the structure can be finished with exterior-grade varnishes. Even in protected areas, however, a minimum of three coats of varnish is recommended, and the wood should be treated with water-repellent preservative before finishing. The use of pigmented stains and sealers as undercoats also contributes to longer life of the clear finish. For best performance in marine exposures, six coats of varnish should be used.

### *Application of exterior finishes*

**Paint.** Proper surface care and preparation before applying paint to wood is essential for good performance. Wood and wood-based products should be protected from the weather and wetting, both on the jobsite and after they are installed. Surface contamination from dirt, oil, and other foreign substances must be eliminated. *It is most important to paint wood surfaces within 1 week after installation, weather permitting.* To achieve maximum paint life, follow these steps:

**Treat wood siding and trim.** Brush or dip exterior wood with a *paintable* water-repellent preservative or water repellent to protect the wood against the entrance of rain and dew and minimize swelling and shrinking. Treat lap and butt joints especially well and the edges of panel products such as plywood, hardboard, and particleboard,

because paint normally fails first in these areas. Allow at least 2 warm, sunny days for adequate drying before painting the treated surface. If the wood has been dip treated with a water repellent or water-repellent preservative, allow at least 1 week of favorable weather.

**Prime bare wood.** The primer coat is very important because it forms a base for all succeeding paint coats. For woods with water-soluble extractives such as redwood and cedar, the best primers are good-quality oil-based and alkyd-based paints or stain-blocking acrylic latex-based paints. The primer seals in the extractives so that they will not bleed through the topcoat. A primer should be used whether the topcoat is oil-based or latex-based. For species such as pine that are predominantly sapwood and free of extractives, a high-quality acrylic latex topcoat paint may be used both as primer and topcoat. Apply enough primer to obscure the wood grain and do not spread too thinly. Follow the application rates recommended by the manufacturer. A primer coat that is uniform and of the proper thickness distributes the swelling stresses resulting from moisture content changes in wood and thus helps to prevent premature paint failure. Brush application is always superior to roller or spray application, especially for the first coat.

**Apply paint.** Two coats of a good-quality acrylic latex house paint should be applied over the primer. Other paints that are used include the oil based, alkyd based, and vinyl acrylic. The quality of paint is usually, but not always, related to price. If it is not practical to apply two topcoats to the entire house, consider two topcoats for fully exposed areas on the south and west sides as a minimum for good protection. Areas fully exposed to sunshine and rain are the first to deteriorate and therefore should receive two coats. On those wood surfaces best suited for painting, one coat of a good house paint over a properly applied primer (a conventional two-coat paint system) should last 4 to 5 years, but two coats over the primer can last up to 10 years (table 19).

**Coverage.** One gallon of paint covers about 400 ft<sup>2</sup> of smooth wood surface area. However, coverage varies with different paints, surface characteristics, and application procedures. Research indicates that the optimum thickness for the total dry paint coat (primer and two topcoats) is 4 to 5 mils or about the thickness of a sheet of newspaper.

**Time between coats.** To avoid future separation between paint coats, apply the first topcoat within 2 weeks after the primer, and the second topcoat within 2 weeks of the first. As certain paints weather, they form a soaplike substance on their surface that may prevent proper adhesion of new paint coats. If more than 2 weeks elapse before applying another paint coat, scrub the old

surface with water using a bristle brush or sponge. If necessary, use a mild detergent to remove all dirt and deteriorated paint. Then rinse well with water, and allow the surfaces to dry before painting.

**Temperature blistering.** To avoid blistering, oil-based paints should not be applied on a cool surface that will be heated by the sun within a few hours. Temperature blistering is most common with thick coats of paint of dark colors applied in cool weather. The blisters usually show up in the last coat of paint and occur within a few hours or perhaps as much as 1 or 2 days after painting.

**Minimum temperatures.** Oil-based paint may be applied when the temperature is 40 °F or above. A minimum of 50 °F is desirable for applying latex-based waterborne paints. For proper curing of latex paint films, the temperature should not drop below 50 °F for at least 24 hours after paint is applied. Low temperatures result in poor coalescence of the paint film and early paint failure.

**Avoid dewfall.** To avoid wrinkling, fading, or loss of gloss of oil-based paints and streaking of latex paints, the paint should not be applied in the evenings of cool spring and fall days when heavy dew forms during the night before the surface of the paint has thoroughly dried. Serious water absorption problems and major finish failure can also occur with some latex paints when applied under these conditions.

**Solid-color stains.** Solid-color stains may be applied to a smooth surface by brush, spray, or roller application, but brush application is best. These stains act much like paint. One coat of solid-color stain is considered adequate for siding, but two coats provide significantly better protection and longer service. These stains are not generally recommended for horizontal wood surfaces such as decks and window sills.

With a solid-color stain, in contrast to paint, lap marks may form. Latex-based stains are particularly fast-drying and are more likely to show lap marks than those with an oil base. To prevent lap marks, follow the procedures suggested under application of semitransparent penetrating stains.

**Semitransparent penetrating stains.** Semitransparent penetrating oil-based stains may be brushed, sprayed, or rolled on. Brushing gives the best penetration and performance. The stains are generally thin and runny, so application can be messy. Lap marks may form if stains are improperly applied but can be prevented by staining only a small number of boards or one panel at a time. This method prevents the front edge of the stained area from drying out before a logical stopping place is reached. It is desirable to work in the shade because the drying rate is slower. One gallon usually covers about 200 to 400 ft<sup>2</sup> of

smooth wood surface and from 100 to 200 ft<sup>2</sup> of rough or weathered surface.

For long life with penetrating oil-based stain on rough-sawn or weathered lumber, use two coats and apply the second coat before the first is dry. (If the first coat dries completely, it may seal the wood surface so that the second coat cannot penetrate into the wood.) Apply the first coat to a panel or area in a manner to prevent lap marks. Then work on another area so that the first coat can soak into the wood for 20 to 60 minutes. About an hour after applying the second coat, use a cloth, sponge, or dry brush lightly wetted with stain to wipe off the excess stain that has not penetrated into the wood. Otherwise areas of stain that did not penetrate may form an unsightly surface film and glossy spots will appear. Avoid intermixing different brands or batches of stain. Stir stain occasionally and thoroughly during application to prevent settling and color change.

**CAUTION:** *Sponges or cloths that are wet with oil-based stain are particularly susceptible to spontaneous combustion. To prevent fires, bury them, immerse them in water, or seal them in an airtight metal container immediately after use.*

A two-coat system on rough wood may last as long as 6 to 8 years in certain exposures because of the large amount of stain absorbed. By comparison, if only one coat of penetrating stain is used on new smooth wood, its life expectancy is 2 to 4 years; however, succeeding coats will last longer.

**Water repellents and water-repellent preservatives.** The most effective method of applying a water repellent or water-repellent preservative is to dip the entire board into the solution. However, brush treatment is also effective. When wood is treated in place, liberal amounts of the solution should be applied to all lap and butt joints, edges and ends of boards, and edges of panels where end grain occurs. Other areas especially vulnerable to moisture, such as the bottoms of doors and window frames, should not be overlooked. One gallon covers about 250 ft<sup>2</sup> of smooth surface or 150 ft<sup>2</sup> of rough surface. The life expectancy is only 1 to 2 years as a natural finish, depending upon the wood and exposure. Treatments on rough surfaces are generally longer lived than those on smooth surfaces. Repeated brush treatment to the point of refusal will enhance durability and performance. Treated wood that is painted will not need retreating unless the protective paint layer weathers away.

### *Special applications*

**Finishing porches and decks.** Exposed flooring on porches and decks is sometimes painted. The recommended procedure for treating with water-repellent preservative and primer is the same as for wood siding. After the primer, an undercoat (first topcoat) and matching second topcoat of porch and deck enamel should be applied. These paints are especially formulated to resist abrasion and wear.

Many fully-exposed decks are more effectively finished with a water-repellent preservative or a penetrating-type semitransparent pigmented stain alone. These finishes need more frequent refinishing than painted surfaces, but are easy to refinish because no such laborious surface preparation is needed as when painted surfaces start to peel. Solid-color stains should not be used on any horizontal surface such as decks because early failure may occur.

**Finishing treated wood.** Wood pressure-treated with waterborne chemicals that react with the wood or form an insoluble residue, for example, copper, chromium, and arsenic salts (CCA-treated wood), presents no major problem in finishing if the wood is properly redried and thoroughly cleaned after treating. Wood treated with solventborne or oilborne preservative chemicals, such as pentachlorophenol, is not considered paintable until all the solvents have evaporated. Solvents such as methylene chloride or liquified petroleum gas evaporate readily. Successful painting is usually impossible, however, when heavy oil solvents with low volatility are used to treat wood under pressure. Even special drying procedures for wood pressure-treated with the water-repellent preservative formulas that employ highly volatile solvents do not restore complete paintability.

Woods that have been pressure-treated for decay or fire resistance sometimes have special finishing requirements. None of the common *pressure* preservative treatments (creosote, pentachlorophenol, water-repellent preservatives, and waterborne) significantly change the weathering characteristics of woods. Certain treatments such as waterborne treatments containing chromium reduce the degrading effects of weathering. Except for esthetic or visual reasons, there is generally no need to apply a finish to most preservative-treated woods. If needed, oil-based, semitransparent penetrating stains can be used, but only after the preservative-treated wood has weathered for 1 to 2 years depending on exposure. The only preservative-treated woods that can be painted or stained immediately after treatment and without further exposure are CCA-treated woods, but only if they are dry and clean. Since CCA is waterborne, the wood must be dried after treatment. Manufacturers generally have specific recommendations for good painting and finishing practices for fire-retardant and preservative-treated woods.

## Maintenance of Finishes

Exterior wood surfaces need to be refinished only when the old finish has worn thin and no longer protects the wood. In repainting with oil-based paint, one coat may be adequate if the old paint surface is in good condition. Dirty paint can often be freshened by washing with detergent. Repainting too frequently with oil-based systems produces an excessively thick film that is likely to crack abnormally across the grain of the wood. Complete paint removal and repainting is the only cure for cross-grain cracking.

### *Paint and solid-color stains*

In refinishing an old paint coat (or solid-color stain), proper surface preparation is essential if the new coat is to give the expected performance. First, all loose paint should be scraped away. Any remaining paint should be sanded to feather the edges smooth with the bare wood. Any remaining old paint should be scrubbed with a brush or sponge and water. The scrubbed surface should be rinsed with clean water. If the surface is still dirty or chalky, it needs to be scrubbed again using a detergent. Mildew should be removed with a dilute liquid household bleach solution. After rinsing the cleaned surface thoroughly with fresh water, it should be allowed to dry before repainting. Areas of exposed wood should be treated with a water-repellent preservative, or water repellent, and allowed to dry for at least 2 days, and then primed. Topcoats can then be applied.

It is particularly important to clean areas protected from sun and rain such as porches, soffits, and side walls protected by overhangs. These areas tend to collect dirt and water-soluble materials that interfere with adhesion of the new paint. It is probably adequate to repaint these protected areas every other time the house is painted.

Latex paint can be applied over freshly primed surfaces and on weathered paint surfaces if the old paint is clean and sound. Where old sound paint surfaces are to be repainted with latex paint, a simple test should be conducted first. After cleaning the surface, a small, inconspicuous area is repainted with latex paint and allowed to

dry at least overnight. Then, to test for adhesion, one end of an adhesive bandage is pressed firmly onto the painted surface and pulled off with a snapping action. If the tape comes away free of paint, the latex paint is well bonded and the old surface does not need priming or additional cleaning. If the new latex paint adheres to the tape, the old surface is too chalky and needs more cleaning or the use of an oil-based primer. If both the latex paint and the old paint coat adhere to the tape, the old paint is not well bonded to the wood and must be removed before repainting.

### *Semitransparent penetrating stains*

Semitransparent penetrating oil-based stains are relatively easy to refinish. Heavy scraping and sanding are generally not required. Simply use a stiff-bristle brush to remove all surface dirt, dust, and loose wood fibers, and then apply a new coat of stain. The second coat of penetrating stain often lasts longer than the first because it penetrates into small surface checks that open up as wood weathers.

### *Water-repellent preservatives*

Water-repellent preservatives used for natural finishes can be renewed by a simple cleaning of the old surface with a bristle brush and an application of a new coat of finish. For determining if a water-repellent preservative has lost its effectiveness, a small quantity of water is splashed against the wood surface. If the water beads up and runs off the surface, the treatment is still effective. If the water soaks in, the wood needs to be refinished. Refinishing is also required when the wood surface shows signs of graying. Gray discoloration can be removed by using liquid household bleach.

**NOTE:** Steel wool and wire brushes should not be used to clean surfaces to be finished with semitransparent stains or water-repellent preservatives because small iron deposits may be left behind. The small iron deposits can react with certain water-soluble extractives in woods like western redcedar, redwood, Douglas-fir, and the oaks to yield dark blue-black stains on the surface.



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## Special Topics

### Protection Against Decay and Termites

Wood used in conditions where it is always dry, or even where it is wetted briefly and then redries rapidly, does not decay. However, all wood and wood products used in construction are susceptible to decay if kept wet for long periods under temperature conditions favorable to the growth of decay organisms. Most of the wood used in a house is not subjected to such conditions. There are places where water can work into the structure, but such places can be protected. Protection is accomplished by methods of design and construction, by use of suitable materials, and in some cases by using treated material.

Wood is also subject to attack by termites and some other insects. Termites can be grouped into two main classes—*subterranean* and *dry-wood*. In northern states, subterranean termites are confined to scattered, localized areas of infestation (fig. 182). In several locations in the South the Formosan subterranean termite has recently (1966) been discovered. It is a serious pest because its colonies contain large numbers of the worker caste and cause damage rapidly. Though presently localized in a few areas, this species could spread to other areas. Controls are similar to those for other subterranean termites. Dry-wood termites are found principally in Florida, southern California, and the Gulf Coast States. They are more difficult to control but cause less serious damage than subterranean termites.

Wood has proved itself through the years to be a desirable and satisfactory building material. Damage from decay and termites has been small in proportion to the total value of wood in residential structures, but it has been troublesome to many homeowners. Moreover, changes in features of building design and use of new building materials call for a restatement of the basic safeguards to protect buildings against both decay and termites.

### Decay

Wood decay is caused by certain fungi that can utilize wood for food. These fungi, like the higher plants, require air, warmth, food, and moisture for growth. Early stages of decay caused by these fungi may be accompanied by a discoloration of the wood. Paint may also become discolored where the underlying wood is rotting. Advanced decay is easily recognized because the wood has undergone definite changes in properties and appearance. In advanced stages of building decay, the affected wood generally is brown and crumbly but sometimes may

be comparatively white and spongy. These changes may not be apparent on the surface, but the loss of sound wood inside is often reflected by sunken areas on the surface or by a “hollow” sound when the wood is tapped with a hammer. Where the surrounding atmosphere is very damp, the decay fungus may grow out on the surface—appearing as white or brownish growths in patches or strands or in special cases as vinelike structures.

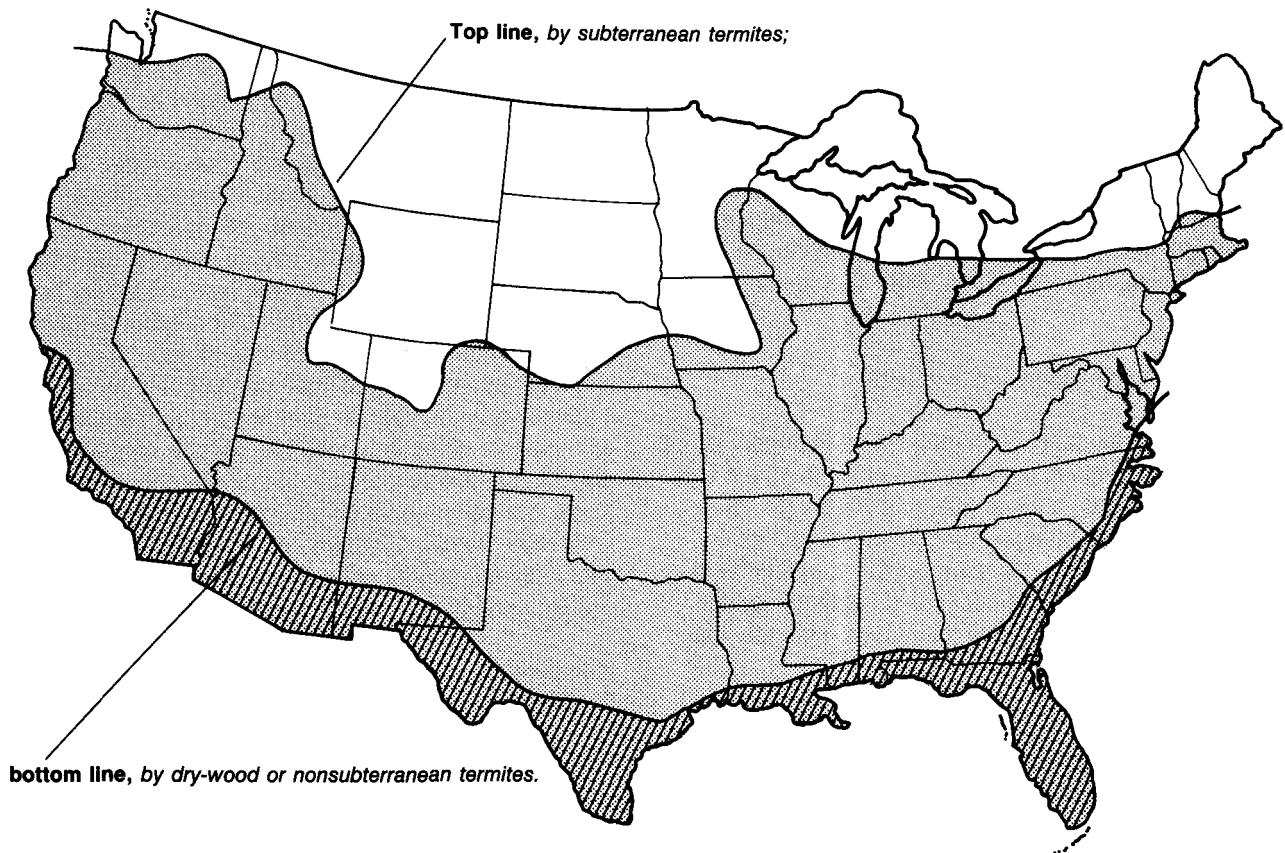
Fungi grow most rapidly at temperatures of about 70 to 85 °F. Elevated temperatures such as those used in kiln-drying of lumber kill fungi, but low temperatures, even far below zero, merely allow them to remain dormant.

Moisture requirements of fungi are within definite limitations. Wood-destroying fungi do not become established in dry wood. A moisture content of 20 percent (which can be determined with an electrical moisture meter) is safe. Moisture content greater than this is practically never reached in wood sheltered against rain and protected, if necessary, against wetting by condensation or fog. Decay can be permanently arrested simply by taking measures to dry out the infected wood and to keep it dry. Brown, crumbly decay, in the dry condition, is sometimes called “dry rot,” but this is a misnomer. Such wood must necessarily have been damp when the rotting occurred.

The presence of mold or stain fungi should serve as a warning that conditions are or have been suitable for growth of decay fungi. Heavily molded or stained lumber, therefore, should be examined for evidence of decay. Furthermore, such discolored wood may not be entirely satisfactory for exterior millwork because it frequently has greater water absorptiveness than bright wood.

The natural decay resistance of all common native species of wood lies in the heartwood. When untreated, the sapwood of all species has low resistance to decay and usually has short life under decay-producing conditions. Of the species of wood commonly used in house construction, the heartwood of redwood and the cedars is classified as being highest in decay resistance. All-heartwood lumber is becoming more and more difficult to obtain, however, as increasing amounts of timber are cut from the smaller trees of second-growth stands. In general, when substantial decay resistance is needed in load-bearing members that are difficult and expensive to replace, wood appropriately treated with preservative is recommended.

**Figure 182 – Northern limits of termite damage in the United States:**



### *Subterranean termites*

Subterranean termites are the most destructive of the insects that infect wood in houses. The chance of infestation is great enough to justify preventive measures in the design and construction of buildings in areas where termites are common.

Subterranean termites are common throughout the southern two-thirds of the United States except in mountainous and extremely dry areas.

One of the requirements for subterranean termite life is the moisture available in the soil. Termites become most numerous in moist, warm soil containing an abundant supply of food in the form of wood, scraps of lumber for example, or other cellulosic material. In their search for additional food (wood), they build earthen shelter tubes over foundation walls or in cracks in the walls, or on pipes or supports leading from the soil to the house. These tubes are from  $\frac{1}{4}$  to  $\frac{1}{2}$  inch or more in width and flattened, and serve to protect the termites in their travels between food and shelter.

Because subterranean termites eat the interior of the wood, they may cause much damage before they are discovered. They honeycomb the wood with definite tunnels that are separated by thin layers of sound wood. Decay fungi, on the other hand, soften the wood and eventually cause it to shrink, crack, and crumble without producing anything like these continuous tunnels. When both decay fungi and subterranean termites are present in the same wood, even the layers between the termite tunnels are softened.

### *Dry-wood termites*

In contrast to the subterranean tunnel-building termites, dry-wood termites fly directly to and bore into the wood. Dry-wood termites are common in the tropics, and damage has been recorded in the United States in a narrow strip along the Atlantic Coast from Cape Henry, VA, to the Florida Keys, and westward along the coast of the Gulf of Mexico to the Pacific Coast as far as northern California (fig. 182). Serious damage has been noted in southern California and in localities around Tampa, Miami, and Key West, FL. Infestations may be found in structural

timber and other woodwork in buildings, and also in furniture, particularly where the surface is not adequately protected by paint or other finishes.

Dry-wood termites cut across the grain of the wood and excavate broad pockets, or chambers, connected by tunnels about the diameter of the termite's body. They destroy both springwood and the usually harder summerwood, whereas subterranean termites principally attack springwood. Dry-wood termites remain hidden in the wood and are seldom seen, except when they make dispersal flights.

### *Safeguards against decay*

Except for special cases of wetting by condensation or fog, a dry piece of wood stays dry and never decays if it is placed off the ground under a tight roof with wide overhang. It is a good precaution to design and construct a house to comply with these conditions of "umbrella protection." The use of dry lumber in designs that keep the wood dry is the simplest way to avoid decay in buildings.

Most of the details regarding wood decay have been included in earlier chapters, but they are given here as a reminder of their relationship to protection from decay and termites.

Untreated wood should not come in contact with the soil. It is desirable that the foundation walls have a clearance of at least 8 inches above the exterior finish grade, and that the floor construction has a clearance 18 inches or more from the bottom of the joists to the ground in basementless spaces. The foundation should be accessible at all points for inspection. Porches that prevent access should be isolated from the soil by concrete or from the building proper by metal flashing or aprons (fig. 183).

Exterior steps and stair carriages, posts, wall plates, and sills should be isolated from the ground by concrete or masonry. Sill plates and other wood in contact with concrete near the ground should be separated from the concrete by a moistureproof membrane, such as heavy roll roofing or 6-mil polyethylene. Girder and joint openings in masonry walls should be big enough to assure an air space around the ends of these members.

**Design details.** Surfaces like steps, porches, door and window frames, roofs, and other projections should be sloped to promote runoff of water. Noncorroding flashing should be used around chimneys, windows, doors, or other places where water might seep in. (See section on flashing and other sheet metal in chapter 4.) Roofs with considerable overhang give added protection to the siding and other parts of the house. Gutters and downspouts should be placed and maintained to divert water away from the buildings. Porch columns and screen rails should

be shimmed above the floor to allow quick drying or posts should slightly overhang raised concrete bases.

Exterior steps, rails, and porch floors exposed to rain need protection from decay, particularly in warm, damp parts of the country. Pressure treatment of the wood provides a high degree of protection against decay and termite attack. In geographic areas where the likelihood of decay is relatively small, on-the-job application of water-repellent preservative by dipping or soaking has been found to be worthwhile. The wood should be dry, cut to final dimensions, and then dipped or soaked in the preservative solution. Soaking is the best of these nonpressure methods, and the ends of the boards should be soaked for a minimum of 3 minutes. It is important to protect the end grain of wood at joints, because this area absorbs water easily and is the most common infection point. These treatments work because they provide a treated layer near the wood surface. Any saw-cut made after treatment will expose unprotected wood. Let treated wood dry for several days before painting or staining.

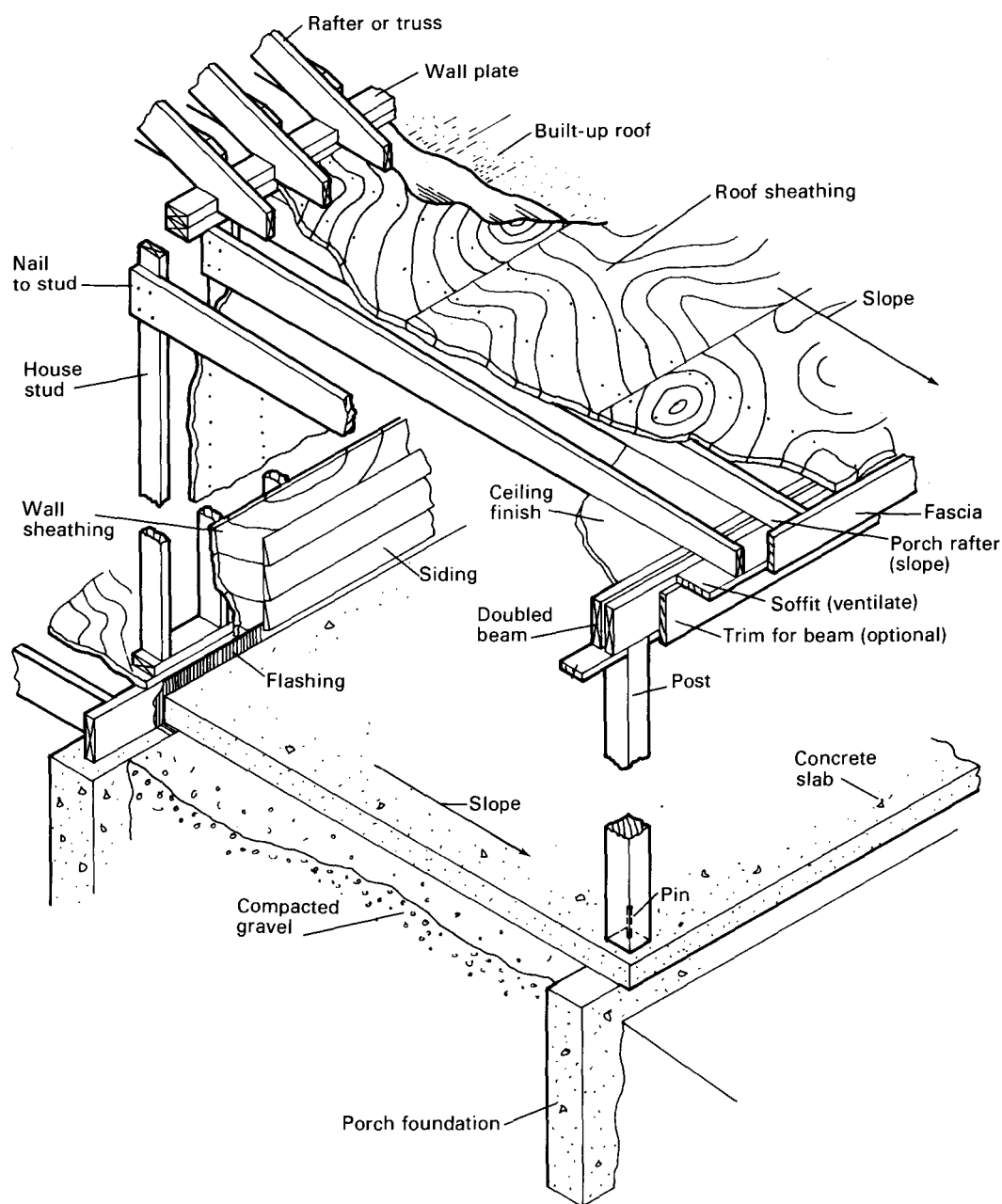
Remember, water-repellent treatments are only effective for wood used above ground.

**Green or partially seasoned lumber.** Construction lumber that is green or partially seasoned should be avoided; it may be infected before it comes to the job site with one or more of the staining, molding, or decay fungi. Such wood may contribute to serious decay both in the structural frame and exterior parts of buildings. If wet lumber must be used, or if wetting occurs during construction, the wood should not be fully enclosed or painted until thoroughly dried.

**Water vapor from the soil.** Crawl spaces of houses built on poorly drained sites may be subjected to high humidity. During the winter when the sills and outer joists are cold, moisture condenses on them and, in time, the wood absorbs so much moisture that it is susceptible to attack by fungi. Unless this moisture dries out before temperatures become favorable for fungus growth, considerable decay may result. However, the decay may progress so slowly that no weakening of the wood becomes apparent for a few years. Placing a layer of 45-pound or heavier roll roofing or a 6-mil sheet of polyethylene over the soil to keep the vapor from getting into the crawl space would prevent such decay. This precaution can be recommended for all sites where, during the cold months, the soil is wet enough to be compressed in the hand.

If the floor is uninsulated, some fuel savings can be made by closing the foundation vents during the coldest months. However, unless the crawl space is used as a heat plenum chamber, insulation is usually located between floor joists, and the vents can remain open.

**Figure 183—Metal shield used to protect wood at porch slab.**



When soil covers are used, crawl space vents can be very small, needing only 10 percent of the area required without covers. (See section on crawl space foundations in chapter 2.)

**Water vapor from household activities.** Water vapor is also given off during cooking, washing, and other household activities. This vapor can pass through walls and ceilings during very cold weather and condense on sheathing, studs, and rafters, causing condensation problems. A vapor retarder of an approved type is needed on

the warm side of walls. (See section on vapor retarders in chapter 6.) It is also important that the attic space be well ventilated. (See section on ventilation in chapter 4.)

**Water supplied by the fungus itself.** Some substructure decay is caused, principally in the warmer coastal areas, by a fungus that provides its own needed moisture by conducting it through a vinelike structure from moist ground to the wood. The total damage caused by this water-conducting fungus is not large, but in individual instances it tends to be unusually severe. Preventive and

remedial measures depend on getting the soil dry and avoiding bridges of untreated wood such as posts connecting the ground to sill or beams.

### ***Safeguards against termites***

The best time to provide protection against termites is during the planning and construction of the building. The first requirement is to remove all wood debris like stumps and discarded form boards from the soil at the building site before and after construction. Steps should also be taken to keep the soil under the house as dry as possible.

Next, the foundation should be made impervious to subterranean termites to prevent them from crawling up through hidden cracks to the wood in the building above. Properly reinforced concrete makes the best foundation, but unit-construction walls or piers capped with at least 4 inches of reinforced concrete are also satisfactory. No wood member of the structural part of the house should be in contact with the soil.

The best protection against subterranean termites is by treating the soil near the foundation or under an entire slab foundation with an approved termiticide. Any wood used in secondary appendages, such as wall extensions, decorative fences, and gates, should be treated under pressure with a good preservative.

In regions where dry-wood termites occur, the following measures should be taken to prevent damage:

1. All lumber, particularly secondhand material, should be carefully inspected before use, and any infected piece discarded.
2. All doors, windows (especially attic windows), and other ventilation openings should be screened with metal wire with not less than 20 meshes to the inch.
3. Preservative-treated lumber can be used to prevent attack in construction timber and lumber.
4. Several coats of house paint can provide considerable protection to exterior woodwork in building. All cracks, crevices, and joints between exterior wood members should be filled with a mastic caulking or plastic wood before painting.
5. The heartwood of foundation-grade redwood, particularly when painted, is more resistant to attack than most other native commercial species.

### ***Pressure-treated wood***

Wood treated under pressure with chemicals to resist decay and insect attack is called pressure-treated wood. This type of wood is classified as a permanent building material by such authorities as the Federal Housing Administration (FHA) and the Forest Products Labora-

tory. Properly treated wood members can be expected to last almost indefinitely in most applications.

Pressure-treated wood products can be cut or drilled. Because the treating chemicals may not penetrate completely through thick materials, the cut ends or holes must receive brush treatment with a suitable preservative.

**Types of preservatives.** There are three general classifications of pressure treatments based on the type of preservative: creosote solutions, pentachlorophenol (penta), and waterborne preservatives.

Creosote and solutions of the heavier, less volatile petroleum oils help protect wood from weathering outdoors, but they have an odor, lack cleanliness, and are not readily paintable. Volatile oils or solvents with oil-borne preservatives, if removed after treatment, leave the wood cleaner than the heavier oils do. Pentachlorophenol may be carried in any of four mixtures—with heavy oil, mineral spirits, methylene chloride, or liquefied petroleum gas. Wood treated with pentachlorophenol dissolved in methylene chloride or liquefied gas has a dry, paintable, and glueable surface.

Creosote and penta treatments are used widely in farm, ranch, and marina applications. Penta in liquid petroleum gas (LPG) or in light petroleum solvent is also used for fencing and other exterior applications.

Waterborne preservatives provide a clean and paintable wood surface, free from objectionable odor. Because water is added during treatment, the wood must be dried after treatment to the moisture content required for use. The waterborne preservatives are used widely to pressure-treat lumber and plywood for use in decks, fences, marinas, and all-weather wood foundations. The waterborne salts are more commonly used for pressure-treating materials to be used for outdoor residential purposes; they are ammoniacal copper arsenate (ACA), chromated copper arsenate (CCA), acid copper chromate (ACC), chromated zinc chloride (CZC), and fluor chrome arsenate phenol (FCAP).

**Treatment codes.** The color of the wood does not show the quality of treatment. Wood treated with an oil-based preservative such as pentachlorophenol is usually light-to-dark brown. Most of the waterborne-salt treatments leave a greenish color because they contain copper or chromium salts. Sometimes lumber receives a brightly colored coating that prevents fungus stain during shipment. These coatings are not pressure treatments. They are only surface treatments and give no long-term protection against decay or termites. *When buying preservative-treated wood, pay close attention to the stamps, labels, or certifications on them.*

Each piece of pressure-treated wood or plywood should bear a quality mark. Such marks indicate that the technical requirements of a treating standard have been met or exceeded. Examples of quality marks of the AWPB are shown (fig. 184). Codes designating AWPB quality standards that are commonly used in residential construction are given in table 20. The placing of these code designations in the AWPB quality marks is shown in figure 184.

Products marked for ground contact are treated to a higher degree of chemical retention than those marked for above-ground applications. In some instances, the above-ground marking may indicate the use of a preservative not permitted for ground or fresh-water contact. In all cases, materials marked for ground contact are suitable for fresh-water installation. Materials marked for ground contact may be used safely above ground. Materials marked for above-ground use should not be used for ground or water contact.

#### Precautions in use of pressure-treated wood

The following precautions should be taken when handling wood pressure-treated with creosote, pentachlorophenol, or preservatives that contain inorganic arsenicals, and in determining where to use and dispose of the treated wood. When buying preservative-treated lumber, ask for EPA-approved consumer information sheets.

**On site.** Wood pressure-treated with waterborne arsenical preservative may be used inside residences as long as all sawdust and construction debris are cleaned up and disposed of after construction.

Logs treated with pentachlorophenol should not be used for log homes.

Wood treated with creosote or pentachlorophenol should not be used where it will be in frequent or prolonged contact with bare skin (for example, chairs and other outdoor furniture and decks), unless effective sealer has been applied.

Creosote-treated wood should not be used in residential interiors.

Pentachlorophenol-treated wood should not be used in residential, industrial, or commercial interiors except for laminated beams or other building components that have two coats of an appropriate sealer applied. Sealers may be applied at the installation site. Urethane, shellac, latex epoxy enamel, and varnish are acceptable sealers for pentachlorophenol-treated wood.

Do not use treated wood under circumstances where the preservative may become a component of food. Do not use treated wood for cutting boards or countertops.

Only treated wood that is visibly clean and free of surface residues should be used for patios, decks, and walkways.

**Handling.** Dispose of treated wood by ordinary trash collection or burial at a suitable waste disposal facility. Burial at a house construction site encourages termites. Treated wood should not be burned in open fires or in stoves, fireplaces, or residential boilers because toxic chemicals may be produced as part of the smoke and ashes. Treated wood from commercial or industrial use (e.g., construction sites) may be burned only in commercial or industrial incinerators or boilers in accordance with State and Federal regulations.

Avoid frequent or prolonged inhalations of sawdust from treated wood. When sawing and machining treated wood, wear a dust mask. Whenever possible these operations should be performed outdoors to avoid indoor accumulations of airborne sawdust from treated wood. When power-sawing and machining, wear goggles to protect eyes from flying particles.

Avoid frequent or prolonged skin contact with creosote-treated wood and with pentachlorophenol-treated wood; when handling the treated wood, wear long-sleeved shirts and long pants and use gloves impervious to the chemicals (for example, vinyl-coated gloves).

Wash exposed areas thoroughly after working with the wood, before eating, drinking, or use of tobacco products.

If oily preservatives or sawdust accumulate on clothes, launder before reuse. Wash work clothes separately from other household clothing.

#### Energy Conservation

Energy can be saved by reductions in heat gain or loss as well as through the use of efficient appliances and lighting. Reduction of heat transfer rate is accomplished by reducing conduction through the house shell, convection or air infiltration through cracks in the shell, and radiation of heat directly to or from the house. The installation of an efficient heating, ventilating, and air-conditioning (HVAC) system plays a major role in energy conservation. The type of lighting fixture used also has a major impact on energy conservation. Principles of passive solar energy can be applied in the design either to supplement heat or provide cooling, depending on the climate.

#### Reducing conduction

Conduction is the movement of heat directly through materials. Every material has a resistance to heat flow, referred to as its R-value. A vacuum stops conduction entirely; materials containing air layers, pockets, or bub-

**Table 20**—*AWPB quality standards codes*

Preservative	Above-ground standard	Ground contact standard
<b>General-purpose applications</b>		
Waterborne preservatives	LP-2	LP-22
Light-hydrocarbon solvent/penta	LP-3	LP-33
Volatile-hydrocarbon-solvent (LPG)/penta	LP-4	LP-44
Creosote or creosote/coal-tar solutions	LP-5	LP-55
Heavy-hydrocarbon-solvent/penta	LP-7	LP-77
<b>Special-purpose applications</b>		
Waterborne preservatives for use in residential and light commercial foundations	—	FDN
Nonstructural landscape timbers from peeled cores	—	LST
All preservatives for use in marine (saltwater) exposure	—	MLP

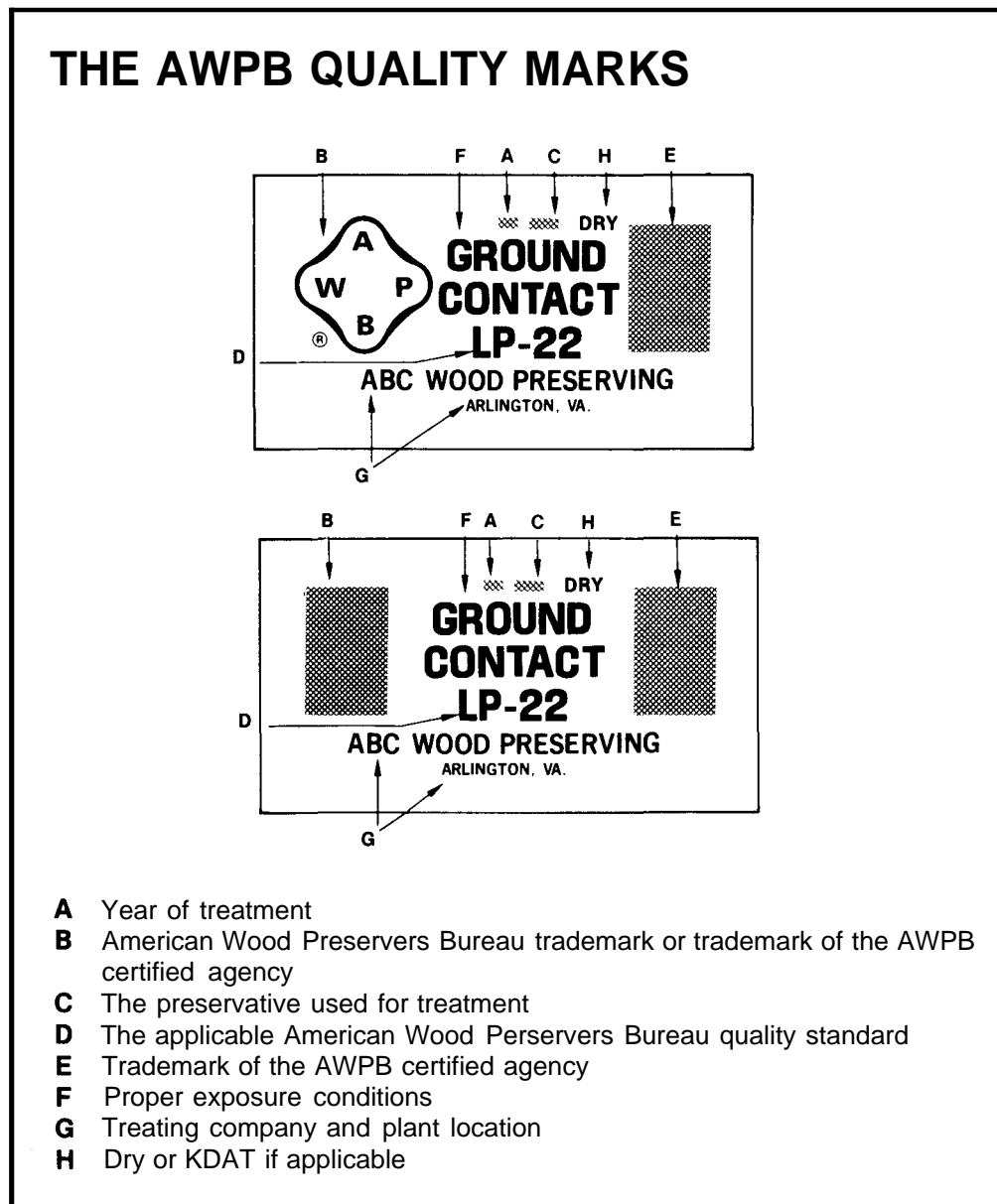
bles have substantial resistance. Dense materials such as metal, glass, and concrete have little resistance and are poor insulators.

- Insulation in walls makes a large reduction in heat loss. Installing R-11 insulation, rather than none, in the wall cavities of a typical 1,600-ft<sup>2</sup>, one-story, single-family, detached house in an area where the indoor-outdoor temperature difference is 70 °F, reduces total heat loss and gain by nearly 20 percent.
- Installing R-13 rather than R-11 insulation in the wall cavities of this house results in an extra 2-percent savings.
- An additional 5-percent savings is possible by installing 1-inch-thick polystyrene rigid foam sheathing instead of the usual ½-inch insulating board sheathing.
- If the walls of the house are constructed with 2- by 6-inch studs placed 24 inches on center, there is space in the wall cavity for R-19 insulation. Installation of R-19 instead of R-11 insulation increases the savings by another 6 percent.
- If the roof of the house is constructed with engineered roof trusses spaced 24 inches on center, installing R-19 instead of R-11 ceiling insulation reduces the heat loss through the ceiling by an additional 8 percent, and using R-30 rather than R-19 ceiling insulation saves an additional 4 percent.
- Good insulation installation practice reduces heat loss and heat gain. To do so, cover all insulated areas completely; extend ceiling insulation over the top of the top plate; insulate behind the band joist; insulate soffits of cantilevered floor construction; cut insulation batts to fit narrow stud spaces and leave enough surplus to staple the flanges; butt the ends of insulation batts tightly against one another; shove batts tightly against the top and bottom plates in the wall cavities; put insulation behind pipes, wires, and electrical outlet

boxes in exterior walls; and stuff insulation into all cracks around door and window frames and into all other areas with odd shapes, and staple polyethylene over these areas to form a vapor retarder.

- Reducing the ratio of exterior wall area to floor area reduces energy demand. Theoretically, a two-story square house (approximately a cube) has the least heat loss. However, when R-11 and R-19 insulation is used in walls and ceilings, a one-story house relatively deep front to back has essentially the same heat loss as a two-story house, all other factors being equal.
- Assuming R-11 wall insulation, a one-story house, 32 feet deep by 50 feet long, would have 2 percent less heat loss than one 24 feet deep by 66½ feet long. The two houses have the same area. The difference in their heat loss is caused by the difference in the ratios of their exterior wall area to floor area.
- Avoiding L-, T-, and H-shaped floor plans conserves energy. A 24- by 50-foot house with a 20- by 20-foot “L” has the same area as a 32- by 50-foot rectangular house, but may have about 3 percent more heat loss.
- In the 1,600-ft<sup>2</sup> one-story house described above, reducing the wall height from 8 feet to 7 feet 6 inches could save another 1 percent of the total energy consumption, even with insulation filling the full thickness of the wall.
- Glass is a poor insulator. Reducing window area can substantially reduce conduction and related heating and cooling costs. The window area of the typical dwelling is probably equal to about 15 percent of the wall area. Under most codes this can be reduced to 10 percent. In the 1,600-ft<sup>2</sup> house, the reduction of glass could mean a reduction of between 9 and 18 percent in energy consumption if double glazing is used, or between 5 and 10 percent with triple glazing (or double glazing in either window or storm sashes). But this

Figure 184—Examples of quality marks of the American Wood Preservers Bureau (AWPB).



strategy must be tempered depending on window orientation, shading, and climate.

- When reducing window area, it is preferable to raise the sill height rather than lower the top of the window opening. This has two advantages. First, it retains the height of the upper portion of the window, which provides better natural illumination. Second, it helps to reduce heat gain in the summer because the upper portion of the window is more easily shaded by the roof overhang.
- In a house with 200 ft<sup>2</sup> of window area equally distributed on all four sides of the dwelling, heat

gain is 2,000 British thermal units per hour (Btu/h) less with double glazing or storm windows than with single glazing.

- Assuming that the 1,600-ft<sup>2</sup> house has two standard-size exterior doors, the addition of two wood storm doors may save 2 percent of the heating energy in winter, and two metal storm doors may save 1 percent.
- The use of 24-inch on-center wall framing and the adoption of the wall framing techniques set forth in *Manual of Lumber and Plywood Saving Techniques for Residential Light-Frame Construction* (NAHB Research Foundation 1971) allows about 2 percent less heat loss

than traditional framing techniques. This is because more heat is lost through the wood section than through the fully insulated cavity. This calculation assumes that 1/2-inch insulating board is used for sheathing and that the siding is 5/8-inch wood or plywood.

- Assuming that a 1,600-ft<sup>2</sup> house has a full basement and that the average basement wall exposure above grade is 2 feet, the heat loss through the typical 8-inch block wall and basement floor may be more than 20 percent of the total for the building. Adding furring strips and R-3 or masonry wall insulation covered with either gypsum board or 3/8-inch plywood reduces heat loss by about 10 percent. If 2- by 3-inch boards, 24 inches on center, are placed 1 inch inside the wall and R-11 insulation is used with 3/8-inch gypsum board or 1/4-inch plywood, about another 6 percent can be saved.
- For a slab-on-grade house with 1-inch by 12-inch-wide R-4 slab edge insulation, the heating load is 14 percent less than with no edge insulation. The use of 2-inch by 24-inch-wide R-8 slab edge insulation can save an additional 8 percent.
- Grading so that the ground surface around the house slopes away from the house allows surface water to drain away from the dwelling. This helps to keep the earth next to the foundation wall drier (and thus warmer), which reduces heat loss through that wall.
- If the house is built on an unheated crawl space, vents that can be closed in winter and a vapor-retarding ground cover will reduce heat loss even when the floors are insulated.
- A heated crawl space plenum is a more economic design and preferable to the unheated crawl space. Use a vapor retarder on the ground and insulation on the perimeter walls rather than in the floor.

Although earth is a poor insulator, in great enough thicknesses it can save energy. Earth-bermed or “basement” houses with subgrade living space are inexpensive to heat and cool.

### ***Reducing convection (air infiltration)***

Convection is the movement of warm air. In a house, pressure differentials force warm air out from cracks in the ceiling and on one side of the house while drawing cold drafts into the house through cracks on the other side. In an old house the air can be completely replaced in half an hour, 48 times a day. In a reasonably tight new house, the air may change once every 2 hours. Convection heat losses and summer heat gains can be reduced by installing caulking, weatherstripping, and other physical barriers to seal up the cracks.

- Use sill sealer between the top of the foundation wall and the band joist or sill plate in frame construction, to reduce air infiltration. Use sill sealer or flexible caulking between the bottom exterior wall plate and the floor sheathing in western or platform framing.
- Use a 1- by 4-inch board for the bottom wall plate (rather than a 2 by 4), because a 1 by 4 is flexible enough in most cases to conform to irregularities in the floor surface. This reduces air infiltration and also cuts heat loss through the framing material.
- Caulk outside cracks at doors, windows, around other openings or penetrations of the wall, and at corners.
- Pay special attention to avoiding, eliminating, or sealing cracks that can allow air to enter the house or structure including cracks around pipe or wire penetrations of the exterior walls.
- Nail sheathing tightly to the framing to minimize air infiltration into the stud space. Even if the stud space is filled with insulation, air leakage increases losses by convection and conduction that reduce the thermal efficiency of the wall.
- For the same reasons, replace wall sheathing damaged during construction.
- The quality of windows greatly influences the amount of air infiltration. A window fitting poorly without weatherstripping allows about 5½ times more air infiltration than an average window with weatherstripping.
- Storm windows not only reduce heat loss, they also reduce air infiltration. For best results, they need to be tightly fitted.
- Exterior doors are a major source of air infiltration. Even when fitted well, a door allows as much air infiltration as a double-hung window that is poorly fitted. This estimate should be doubled for wood doors because they tend to warp. Storm doors reduce this air infiltration by half.
- Weatherstrip attic access doors and apply one or more pieces of rigid insulation, cut to size, to the attic side of the door. This insulation can improve the thermal characteristics of panel or hollowcore doors.
- Weatherstrip the attic access hole and insulate the back of the scuttle closure panel.
- Stuff mineral wool insulation around pipes, flues, or chimneys penetrating into the attic space, especially in cold climates.
- Even if the ceiling insulation has a vapor retarder, good practice calls for 1 ft<sup>2</sup> of attic ventilation area for each 300 ft<sup>2</sup> of ceiling area. Increased ventilation of the attic space can reduce air temperatures during the

summer and thereby decrease air-conditioning loads. Insufficient data are available to pinpoint the effect of ventilation on the heating load. Further, the actual reduction is affected to a great extent by the amount of attic insulation used. At the R-19 level of insulation use, the reduction of attic temperature resulting from increased ventilation reduces heat gain only to a minor extent. Climate also is an important determination of heat gain. Except in the hottest climates, mechanical attic ventilation (fans) may well use more energy than it saves. This occurs because of the flow of conditioned air from the house into the attic space, which is induced by the slightly lower air pressure in the attic when the exhaust fan is running.

- If a range hood is installed, use the recirculating type in cold climates and the exhaust-to-outside-air type in warm climates where the air-conditioning load is more important than the heating load. To use the recirculating type of hood, local regulations may require a window in the kitchen.
- In cold climates, minimize the use of exhaust fans. Research has shown that fans can be the source of very large amounts of infiltrating air. When they are necessary, a model with a positive damper closure is recommended.
- If a fireplace is installed, it should be equipped with a damper to cut heat loss when the fireplace is not in use. A removable sheet metal closure or glass doors for the opening will cut heat loss even more when the fireplace is not in use.
- Garages and carports can help reduce the heating load. In cold climates, attached garages or carports should be placed on the north, northeast, or northwest sides of the house to block the wind and to permit full access to the low winter sun.

### ***Reducing radiation***

Radiation is the movement of heat through space and air. It can be stopped by reflectance or by shading with solid objects. Short-wavelength ultraviolet light rays from the sun, which can penetrate glass, change to long-wavelength infrared heat waves when they strike a dark color. The infrared rays are trapped inside the structure because they do not readily pass through glass. In passive solar heating, ultraviolet rays from the sun pass through windows, are absorbed by dark surfaces, and are reemitted as infrared heat rays which are trapped inside the house. This is the "greenhouse effect."

- Shading glass having southern exposure with a roof overhang reduces heat gain in the summer without impairing heat gain in the winter. At the 35° latitude (North Carolina, Oklahoma, Las Vegas), a 28-inch overhang provides complete shading in the summer for

floor to ceiling glass having a southern exposure. This shading reduces summer heat gain through the glass by 50 percent.

- The area, location, and shading of windows and the use of double glazing or storm sash have important effects in reducing cooling loads for air-conditioning.
- Occasionally, it is possible to locate the dwelling or windows to take advantage of the shadow cast by existing trees to reduce solar heat gain in the summer. During landscaping appropriate trees can be selected and planted to shade the house during summer.
- In hot climates, garages or carports attached to the east side or west side of the dwelling shade glazing on east or west walls, thereby reducing solar heat gain.
- Even with a well-insulated ceiling, the color of the roof makes a difference in heat gain. A light-colored roof surface lowers the design load requirement for cooling.

### ***Efficiency of HVAC and appliances***

Use of efficient heating, ventilating, and air-conditioning (HVAC) equipment, and appliances, as well as efficient installation techniques, can save energy.

- Avoid oversized heating and cooling equipment. One of the most important energy conservation measures is to determine carefully the heat loss and heat gain requirements of the dwelling and to install equipment no larger than is required. Oversized equipment results in short periods of operation, higher first cost, higher operating costs, poor comfort conditions, and lower seasonal efficiency. Specify air conditioners having high Seasonal Energy Efficiency Ratios (SEER). In areas of high humidity consider SEERs ranging from 8.0 to 10.0.
- If electricity is to be the source of energy for heating and the dwelling is to be air-conditioned, consider using a heat pump. Heat pumps use about one-third to one-half the energy of electric resistance heating. In extreme climates, hot or cold, check with the local power supplier for applicability of heat pumps.
- Heat pumps should be sized by a professional engineer, based on analysis of both the heating load and the cooling load. Somewhat more weight should be given to the dominant load, but with careful attention to the heating load output of the heat pump at average outdoor temperatures for the local climate.
- The HVAC subcontractor should install warm-air furnaces with filters that can be changed easily by the homeowner. Clogged filters reduce fuel efficiency both for heating and cooling.

- Consider installing a clock thermostat so that the thermostat can be set back at night and the furnace started automatically in the morning. Reducing the temperature by 5° for 8 hours at night in Chicago saves 7 percent of the annual heating bill; setting the thermostat back 7½° saves 9 percent; and setting it back 10° saves 11 percent. In warm climates like that of Los Angeles, the percentage savings are more (12, 14 and 16 percent, respectively) but the total dollar savings are less than in colder climates. These figures may not be applicable when heat pumps are used.
- Where possible, avoid putting heating and cooling ducts in nonconditioned space such as attics; otherwise, insulate the ducts. Wrap metal duct joints in nonconditioned spaces with duct tape to minimize heat leakage, even when they are to be wrapped with insulation. Heat loss through poorly fit unwrapped duct joints located in nonconditioned spaces can be as high as 25 percent of the total demand.
- Locating air-conditioning condensers where they receive afternoon shade from the house, trees, garage, or carport increases condenser efficiency and slightly reduces energy.
- Locate the water heater as close as possible to the area of greatest demand for hot water. This is usually the kitchen and laundry area. Avoid placing hot water pipes in unheated areas such as attics or crawl spaces if possible; otherwise, use pipe insulation.
- Set the water heater temperature to 120 or 125 °F. If the temperature settings are not marked on the thermostat, 120 °F may be estimated by assuming the middle setting is equal to a temperature of about 140 to 150 °F. For bathing, washing, clothes washing, and dishwashing 120 °F is hot enough. (The 150 °F setting is not high enough to sanitize dishes or clothes; to sanitize, 180 °F is required for at least 2 min.) A setting of 120 °F instead of 150 °F can save as much as half the energy required for water heating—very important saving because heating water frequently uses more energy than anything in the house except heating (or cooling) air.
- Install a shower head with low water consumption. Studies show that bathing accounts for about 40 percent of the hot water used in the typical household.
- Some appliances and mechanical electrical equipment are more energy efficient than others. Consider comparative energy usage when selecting these items.
- A side-by-side refrigerator-freezer may use up to 45 percent more energy than the over-under refrigerator-freezer.
- Some frostless refrigerators use up to 50 percent more energy than the regular defrost type. This means an

average use of perhaps 350 Btu more energy every hour all year long.

- Microwave ovens use less energy than conventional gas or electric ovens. Self-cleaning ovens reportedly require less energy for cooking but have a high energy consumption for cleaning.

### *Reducing lighting*

- In the typical dwelling, lighting is the fourth largest energy user, requiring about 3.4 percent of the total energy bill. During the winter, heat loss from lighting is gained by the structure, so it is not lost. In summer, however, it is estimated that lighting adds about 600 to 700 Btu/h to the average cooling requirement in a dwelling of medium size. Not much can be done about this in terms of installed capacity, but the total energy use for lighting can be cut back somewhat by using less general purpose lighting and more task lighting.
- Use fluorescent lights when possible because they produce nearly four times more light per watt than the typical incandescent light bulbs.
- Fixtures that use one large bulb are substantially more efficient than those that use several smaller bulbs.
- Pale finishes for walls, ceilings, and floor enhance the level of natural light. Paints that have a high light-reflectance value are available, even in colors.
- Do not use recessed or "bullet" lamps that penetrate into nonconditioned space such as an attic. All heat from such lamps is lost. Also, the fixture can be a major channel for air and acoustical infiltration for outdoors.

### *Passive solar energy*

In addition to the energy-efficient features already discussed, the use of passive solar heating and natural cooling can reduce energy costs. In a completely passive solar home that is carefully designed and thermally protected, heating costs may be one-half to two-thirds less than those for a house without solar heating, depending on the climate, location, and other factors. Such saving is accomplished by proper design and appropriate use of south glazing and of heat storage materials.

Passive solar heating of houses requires careful attention to design. One important design factor is the orientation of the house. If there is a choice, solar gain can be maximized by aligning the ridge of the house on an approximately east-west axis. Perpendiculars to the house ridge may have an azimuth angle 25° east or 25° west of south without greatly reducing the potential solar gain.

Another factor is the amount and location of glass. It is easy to provide an excessive amount of glass with improper

orientation, which may result in wintertime overheating and increased Summertime air-conditioning loads. Likewise, improper designs can add to cost without yielding appropriate benefits. It is recommended that professional assistance be obtained when considering passive solar designs. The three most common passive solar systems are called direct gain, sunspace, and Trombe wall.

There are two kinds of direct gain systems, one sometimes called sun tempering and the other called direct gain. In sun tempering, additional south-facing glazing is added along with a proper overhang or shading system to prevent excessive heat gain in the summertime. In this system, the amount of additional south-facing glazing is limited to the amount that will not cause overheating without the addition of concrete, brick, block, slate tile or other heat-absorbent or heat-storage material. In the direct gain system, south-facing glazing, properly shaded against heat gain in the summer, is added along with additional thermal storage, mass, water, or phase-change materials to store the extra heat and slowly release it when the sun is not shining.

In the sunspace or sunroom design, substantial amounts of glazing and heat-storage material are provided along with a system for transferring excessive heat from the sunroom to the adjacent room or rooms. In most instances, it has been found that overhead glazing or sloped glazing admits too much unwanted heat.

The Trombe wall system typically consists of a masonry wall inside the dwelling, sometimes vented and sometimes not, close to a large span of exterior glazing. The wall, warmed by the sun in the daytime, gradually loses the excess heat to the dwelling during the night. Shading is essential to prevent heat from being absorbed by the wall and then diffused into the house during the summer.

All these systems have advantages and disadvantages, but the sun tempering, direct gain, and sunroom designs are more popular than the Trombe wall.

Natural cooling is another method using architectural and mechanical techniques to conserve energy in the summertime. Summer energy consumption is reduced by use of shading, dehumidification, natural and mechanical ventilation, and increased air motion (i.e., with overhead fans).

### **Noise Control**

Little attention has been given to noise control in most single-family houses, but increasing noise pollution indicates a need for considering some control measures. Control measures may include planning to keep out outdoor noise, planning interior separation of noisy from quiet areas, placing sound absorbers in living spaces, and con-

struction that reduces sound transmission. Many of the construction features that enhance energy conservation are also beneficial for noise control.

#### ***Exterior planning***

Noise absorption is affected by the shape and orientation of a house. If the narrow dimension faces the exterior noise source, there is much less sound transmission to the inside than if the long dimension faces the source. Courtyards facing the noise source not only provide more area for sound transmission, but also provide surfaces for sound to be reflected and amplified. Landscaping can be used effectively to deflect and absorb sound, but requires more than a hedge or scattered shrubs and trees. A dense forest at least 25 to 50 feet deep or a solid fence can noticeably reduce noise. A more extreme measure, but quite effective, is a berm between the noise source and the house. Special attention should be given to providing tightly sealed doors and windows on the side facing the noise source. Double walls, triple glazing, and good weatherstripping are all effective in reducing sound transmission.

#### ***Interior planning***

Interior noise control basically involves separating quiet spaces from those containing noisy equipment. Spaces with mechanical equipment are best located on an outside wall. Kitchens, bathrooms, and utility rooms can be located on the noisy side of the house or near mechanical equipment. Closets can be effectively used as buffers between bedrooms and noise-producing areas. They can also be used between two bedrooms to provide sound insulation. Back-to-back closets are even better. Doors must be kept closed for closets to be effective. A bookcase or storage wall also helps isolate two adjoining rooms. Doors opening to hallways should be staggered rather than located opposite each other. Special attention should be given to vertical separation. Do not locate mechanical equipment in the basement directly under bedrooms.

#### ***Sound absorbers***

Some materials absorb sound and change it to heat rather than reflect it. Sound absorption is often desirable except in the case of music, which often needs reflection to avoid the feeling of a "dead" space. Common absorptive materials in residential spaces are carpet, furniture, drapes, and acoustical ceiling tile. Kitchens, whose hard surfaces result in a lot of sound reflection, cannot be as conducive to quiet conversation as living rooms that have many sound absorbers. Surface-mounted acoustical panels on the walls and ceiling can reduce some of the noise in such areas as kitchens. Absorptive material placed in the

heating ducts can reduce sound transmission between connected spaces or the transmission of noises from the heating system.

*Construction to reduce sound transmission*

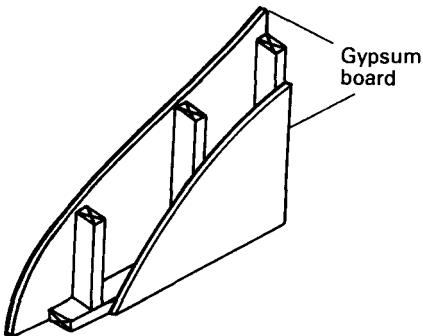
The effectiveness of various wall, floor, and ceiling construction in reducing sound transmission is rated by Sound Transmission Class (STC). The lower the STC, the less effective the construction is in stopping sound transmission to neighboring rooms. The approximate effectiveness of walls with varying STC numbers is shown in the following tabulation:

STC number	Effectiveness
25	Normal speech can be understood quite easily
35	Loud speech audible but not intelligible
45	Must strain to hear loud speech
48	Some loud speech barely audible
50	Loud speech not audible

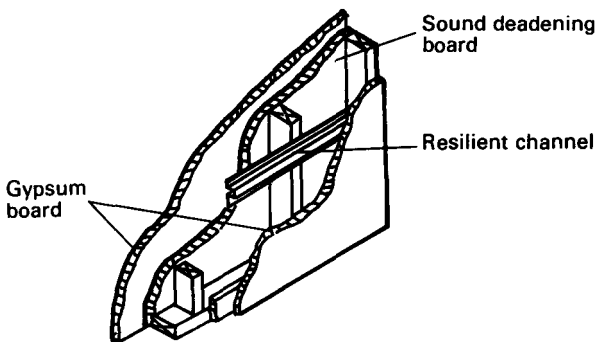
Some alternatives in construction that improve STC include the use of resilient channels, staggered studs, and combinations of sound-deadening board. The addition of insulation to wall cavities may also add to their resistance to sound transmission. Some examples of wall constructions and their range of STC ratings are shown in figures 185 through 188. Floor-to-ceiling constructions that provide sound insulation are shown in figures 189 and 190.

Even though the constructions shown resist sound transmission, sound may take a route around these barriers. Sound can travel through cracks at the top or bottom of a wall. It may also travel through electrical outlets or

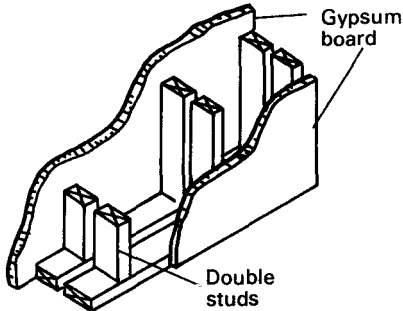
**Figure 185**—A plain stud wall with gypsum board on both sides has an STC rating of 32 to 36. Adding a second layer of gypsum board to each side increases the STC rating of 38 to 41.



**Figure 186**—A single-stud wall with gypsum board on both sides has an STC rating of 32 to 36. Adding a second layer of gypsum board to each side increases STC rating of 44 to 47.



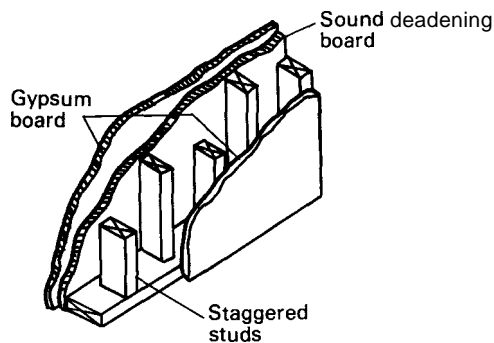
**Figure 187**—A double-stud wall on separate plates has an STC rating of 42 to 44. If insulation is added to the stud cavities on one side, the STC rating is increased to 50 to 53.



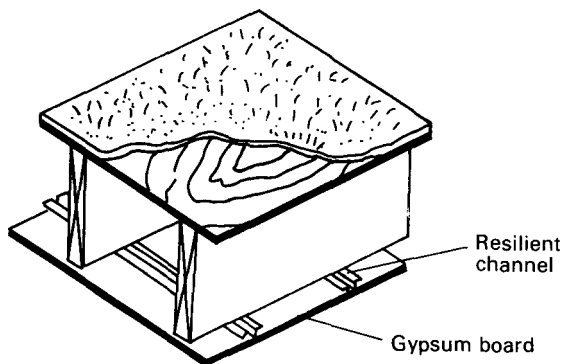
recessed cabinets in opposite faces of the wall placed in the same stud space. Sound may travel around a wall by passing through a floor into a basement or crawl space and back through the floor into an adjoining room. Doors, even tightly sealed, provide a better path for sound than the wall systems designed for sound isolation, and a very small crack under or around a door increases the sound transmission significantly.

Heating and cooling equipment can be a major noise source. If the furnace is located in a closet in the living area, the walls should be masonry, or gypsum drywall should be mounted on resilient channels over wood studs. A solid-core wood or insulated metal door should be used, and it should be tightly weatherstripped. Combustion air should be taken from the attic or crawl space, not through wall or door louvers from the living area. The return air duct and plenum should be lined with acoustic material to absorb the fan noise. Duct openings to different rooms should not be directly opposite each other. Ducts should be sized to avoid air velocities of more than 1,000 feet per minute, which create noise in the ducts and at the outlet grilles.

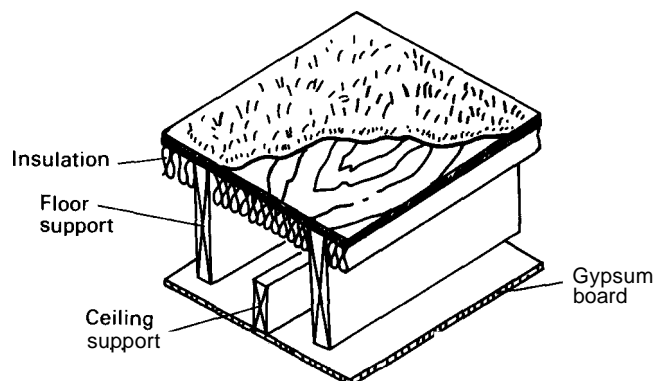
**Figure 188**—A staggered-stud wall on a single plate with sound-deadening board under gypsum board on one side has an STC rating of 44 to 46. Adding insulation to the stud cavities increases the STC rating to 46 to 50.



**Figure 189**—A floor-ceiling structure having carpet, pad, plywood subfloor, and ceiling gypsum board supported on resilient channels has an STC rating of 46 to 48.



**Figure 190**—A floor-ceiling structure having carpet, pad, plywood subfloor, and ceiling gypsum board supported on separate ceiling joists has an STC rating of 51 when 2 to 3 inches of insulation are installed beneath the plywood subfloor.



Piping for hydronic-heating systems should be wrapped with insulating material to reduce vibration. Pipes should be sized to limit the speed of flow, and provision must be made for venting any air that gets into the system.

## Wind, Snow, and Seismic Loads

Some geographic locations have loading requirements beyond those expected in the usual conventional construction. These loads are considered in the local building codes and appropriate structural design is required. Wind loads are critical in coastal areas of the Southeast because of the frequent hurricanes. Some areas of the country have heavy snow loads. This is particularly true in high mountain areas. Seismic loads are critical on the West Coast, where earthquakes are a constant threat. This section is not intended to provide engineering design for these extreme loads, but presents some general considerations for good performance.

Wood construction generally performs well when subjected to natural disasters. Two reasons for good performance are that wood members can resist short-term loads considerably above working stresses and that the large number of mechanically fastened joints make the structure ductile.

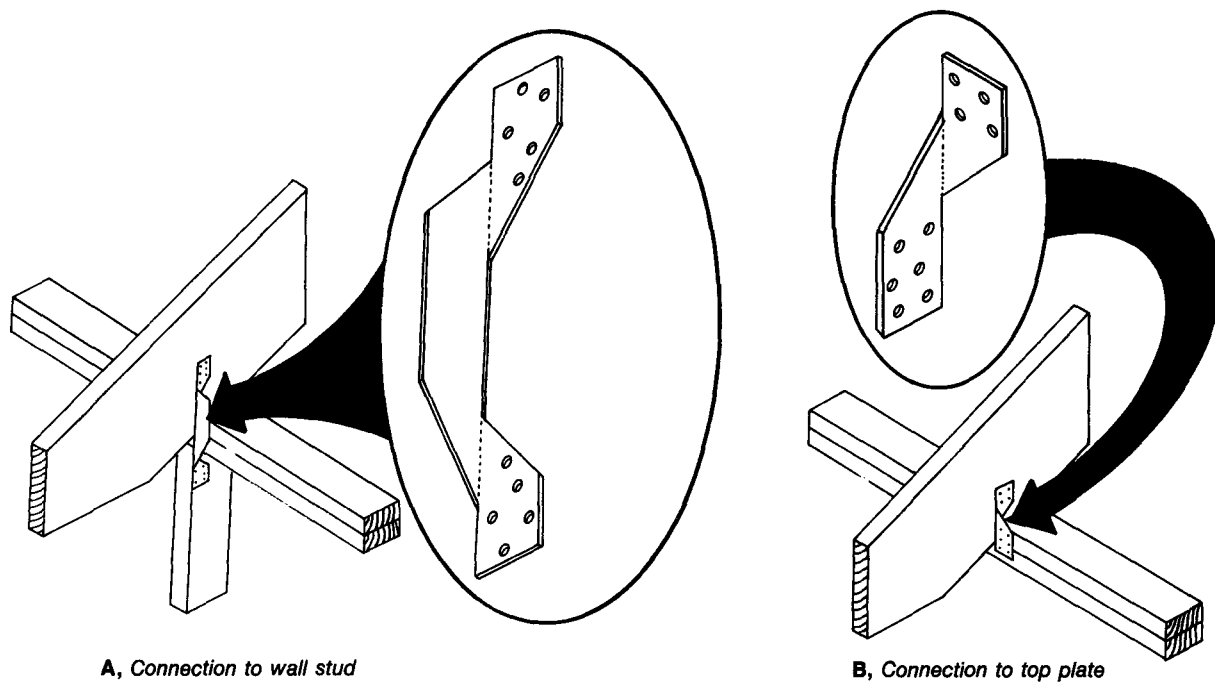
### Wind load

The primary consideration for good performance under extreme wind load is that all members of the structure be tied together. The roof is most vulnerable and should be well secured to the walls. The walls must also be secured to the floor and foundation system. A good connection to the foundation is necessary; do not depend on the weight of the house to hold it in place. Wide roof overhangs, carports, and porches need to be well anchored because of the large area for uplift. Connectors should load nails laterally rather than in withdrawal. In order to accomplish this, sheet metal connectors or straps are often required.

Instead of depending on toenailing to the top plate, use commercially available connectors for connecting roof trusses or rafters to the wall (fig. 191). Where a rafter and joist system is used, collar beams or gussets are important to hold the roof together at the ridge (fig. 192). Metal straps or plates can be used to tie the wall to the floor and sill plate (fig. 193). This tie can also be accomplished with structural wall sheathing that extends down over the floor framing and is well nailed (fig. 194). Finally the sill plate has to be anchored to the foundation (fig. 195). These connections are further discussed in chapter 3.

The principle of tying all components of the structure together is often best accomplished with engineered components such as roof trusses. Connectors are specifically

**Figure 191**—Connectors used to attach trusses or rafters to the wall:



engineered to hold all the parts together. The truss concept is carried a step further in a structure called the truss-frame. It combines roof truss, floor truss, and studs into a unified structural component. The studs extend into both the roof and floor trusses resulting in rigid joints completely tied together with metal plate connectors (fig. 196). The truss-frame is designed as an engineered component and fabricated in a truss plant. If the frame is tied to the foundation, it will have great resistance to wind loads. Rigidity perpendicular to the frames is provided by the diaphragm action of roof and wall sheathing and the subfloor. The truss-frames are hauled to the building site and placed by a crane in the same manner as roof trusses. The building can be very quickly enclosed using this system because, once the frames are set, enclosure with sheathing is all that is required. The truss-frame has been accepted by major model building codes and has been successfully used in all parts of the country.

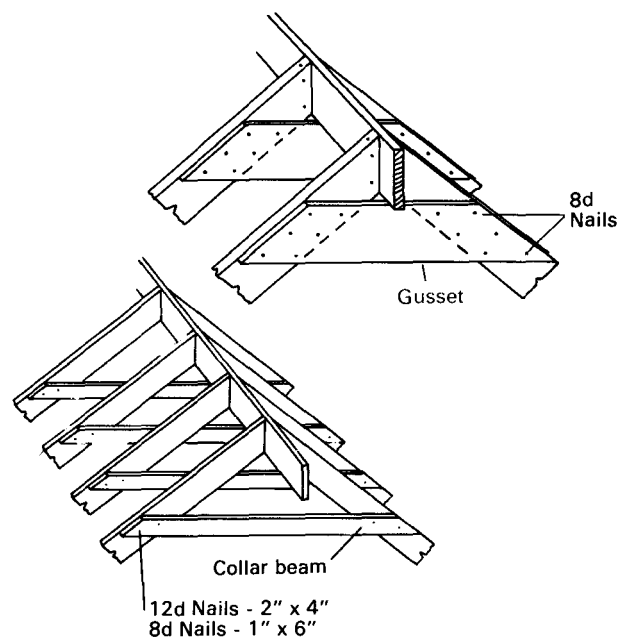
Observation of wind damage has shown that building shape has some influence on overall damage. Hip roofs sustain less shingle damage than gable roofs because turbulence around the gable end starts the removal of shingles at the edge.

#### ***Snow load***

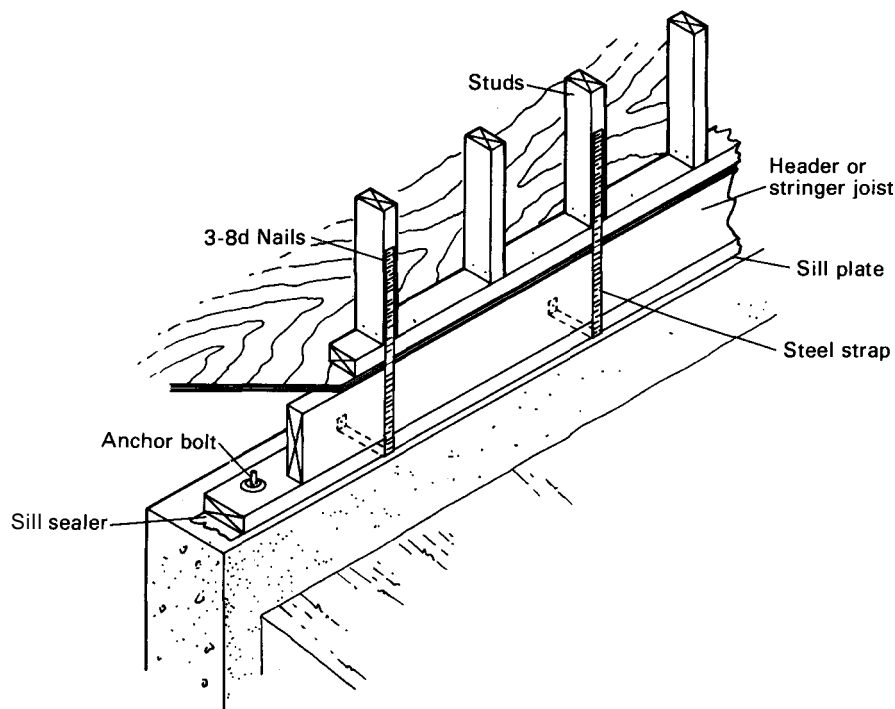
The major preparation for snow load is simply the use of larger structural members. The size of structural members is usually specified by the local building code.

Rafters and beams in particular are designed for maximal snow load conditions. Observations have shown little evidence of failures in light-frame houses. Failures reported are generally in commercial buildings with long spans over large open spaces.

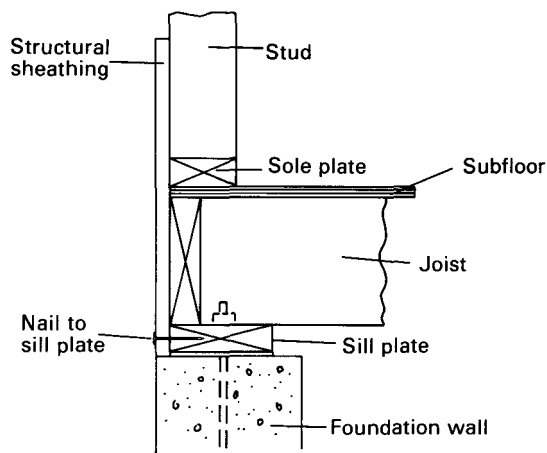
**Figure 192**—Collar beam or gusset required at ridge in a rafter framed roof system.



**Figure 193**—Steel strap for connecting the wall to the sill plate.



**Figure 194**—Structural sheathing nailed to sill plate for tying the wall to the foundation wall.



There are some general considerations of shape that may influence snow load. Snow usually slides off steep sloping roofs. It often blows from flat roofs where the roof is all at one elevation. The problem of snow buildup develops on sloped roofs when the wind is perpendicular to the ridge. Turbulence at the ridge causes drifting on the downwind side, resulting in an unbalanced loading on the roof structure. Another drift problem develops where two building sections of different heights join. Snow

blows off the higher section onto the lower section, resulting in a deep drift. This is particularly critical when the lower section is a flat roof.

In a joist-and-rafter roof, it is particularly important that the joists be well nailed to the rafters to prevent rafters from spreading as a result of outward thrust from the snow load. Bracing the center of the rafters to a center bearing partition may also prevent sag in the rafter caused by a heavy snow load (fig. 197). The best resistance to snow loads is often accomplished with engineered components such as roof trusses.

### *Seismic load*

The major items needed to provide earthquake resistance are adequate lateral bracing, shear resistance in walls, and good connections between all major components. Buildings that have performed best have had simple rectangular configurations, continuous floors, and small window and door openings. They may be described as having a symmetric box-like lateral resistive system. In addition to the building acting as a unit, anchorage to the foundation is particularly important to avoid having the foundation move out from under the house.

The primary cause of failure observed following earthquakes been inadequate lateral bracing in walls. The best

Figure 195 —Anchorage of the sill plate to the foundation wall.

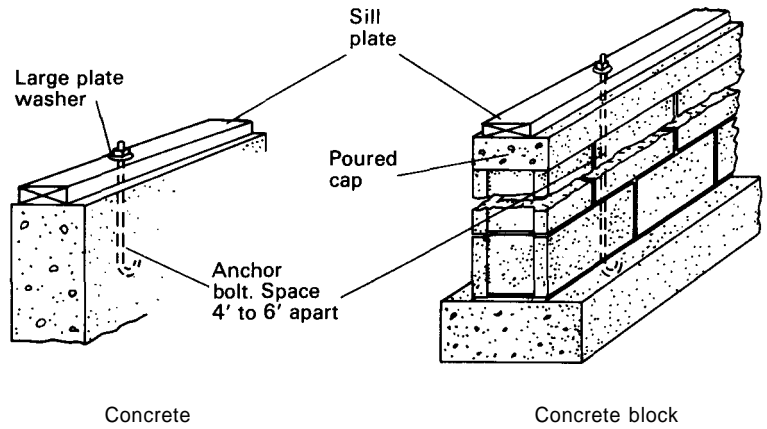


Figure 196 —The truss-framed system combines floor, walls, and roof into a unitized frame for structural continuity from the foundation to the ridge.

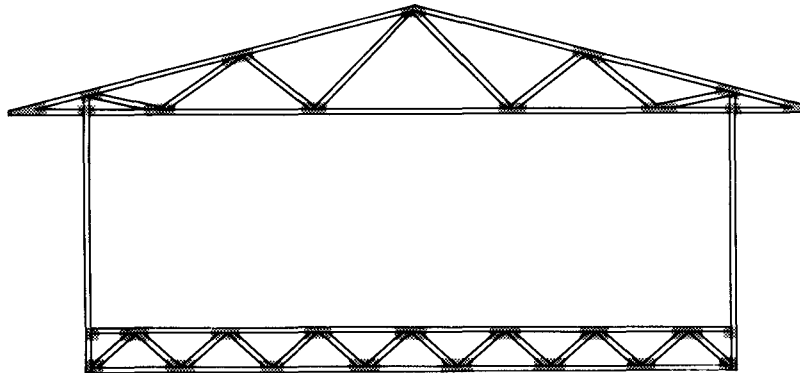
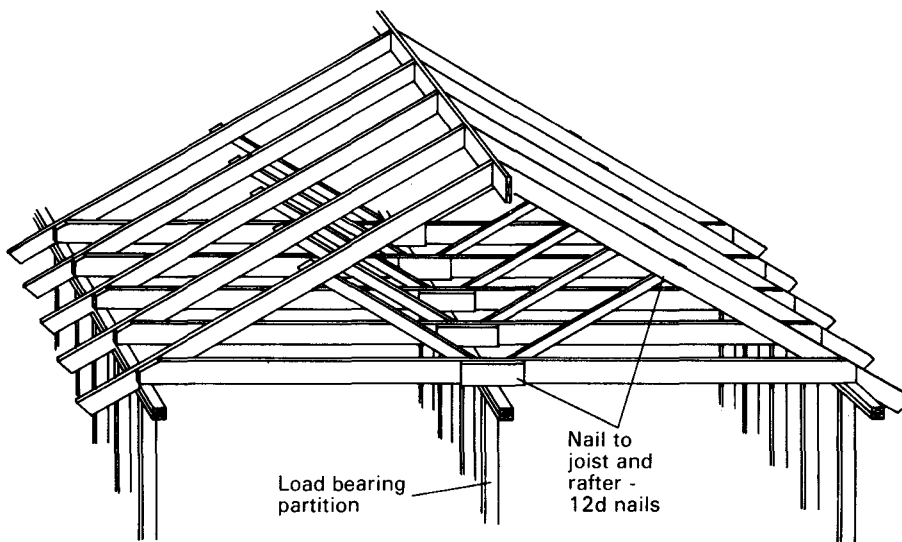


Figure 197 —Bracing of rafters to a center load-bearing partition to prevent sag from a heavy snow load.



bracing is provided by well-nailed structural wall sheathing. Good diagonal bracing is also acceptable. Where wood diagonals are used, they must be high-quality material. Major failures have occurred where wood bracing had large knots. Another problem is racking walls that are not arranged symmetrically. This may result in rotation of the building, which can cause collapse.

Large openings in walls have been a major cause of failure observed in earthquakes. The openings appear to be more critical when they are near a corner. Particular danger of failure exists where large openings have a second story over them, as do some garage doors, because of the weight of the second story added to the lack of racking resistance.

The joining of two elements of a building of different height (e.g., in a split-level house) can also cause problems. The two sections have different frequencies of vibration, and so may not move together.

### ***Summary***

Natural forces such as high wind, excessive snow load, and earthquake can exert forces on the wood-frame house beyond normal design loads. However, wood can generally resist short-term loads beyond its working stresses, and the resilience of the structure and redundancy of the large number of connectors adds to the ability of the house to support excessive loads. Structural adequacy is improved by good connections between all components and good lateral bracing. A simple, unified shape is an added plus. Engineered components such as roof trusses or the truss-frame perform particularly well when subjected to severe structural loads.

### **All-Weather Construction**

It is not always possible to avoid construction when at times weather conditions are too cold, too wet, or too hot and dry. There are steps that can be taken to overcome these obstacles. The objective of the discussion presented in the following paragraphs is to highlight the major concerns when building under adverse weather conditions. The details of the methods and materials are the subject of other publications such as the *All-Weather Home Building Manual* (NAHB Research Foundation 1975), which are cited in the section on additional readings.

### ***Cold weather***

Builders in cold weather areas plan for winter construction by preparing access roads by late fall. They excavate for and pour foundations before heavy frost sets in. The completed foundation is protected by decking the first floor and by covering the bottom of the foundation with straw.

Builders that do excavate in winter use a big backhoe with heavy ripper teeth or a big bulldozer with a ripper attachment to break up frozen earth. Scheduling is important when excavating in winter. Builders look for a 2- or 3-day break in severe weather before they schedule a foundation excavation. Excavation is often done and foundation walls poured or laid in 3 days. The hole for the foundation is ripped and dug the first day, except for the last 12 inches. On the second day, the last 12 inches are excavated and footings are formed and poured. On the third day, the foundation walls are formed and poured or the masonry block is laid.

Concrete for footings and foundation walls comes heated from the supplier after November 15. Canadian and some U.S. builders pour concrete in temperatures below zero, but most prefer to pour foundation walls in temperatures not much lower than 10 °F. Builders order from 1 to 2 percent calcium chloride in the mix to help the concrete set quickly, and they protect the pour by placing insulation around and on top of the wall forms. Heated mortar with 1 or 2 percent calcium chloride is used by masons to lay concrete block walls in winter.

Some form of insulation is used around the concrete footings and on the bottom of the foundation to keep frost from getting under the footings and causing them to heave. Builders use straw, hay, or blankets of fiberglass backed with polyethylene. Straw or hay is spread from 12 to 24 inches thick over the footings and the bottom of the foundation. The plastic insulating blankets are designed to cover the footing or the entire foundation hole.

Temporary or permanent heat is hooked up as soon as the house is enclosed, and is left on until the house is complete. If the hookup is permanent, the furnace is often hung by metal straps from the first floor joists until the basement floor is poured. Temporary heat is usually provided by propane or oil-fired portable heating units called salamanders.

Protective enclosures are used in both the United States and Canada. The windbreaks or lean-tos not only protect brick masons from windchill and low temperatures but also keep the mortar from freezing before it sets. Often, masons place one or two portable heaters inside a plastic-enclosed scaffolding to insure that the masonry wall will set and cure properly.

The treated wood foundation system discussed in the section on foundations offers an alternative to concrete or masonry that is less susceptible to damage from cold weather conditions, eliminates the problem of scheduling concrete delivery and the masonry subcontractor, and allows work to proceed on the upper floor and wall framing immediately after the foundation is in place.

### ***Wet weather***

Builders in wet weather areas maintain their production volume despite the rain and the mud. Their primary problems include site drainage, site preparation, material delivery, material storage, excavating, and getting the roof on as quickly as possible to keep the rain out.

The builder's first move in wet weather is to drain the building site and keep it drained of surface water. Careful grading of the lot is the first step in disposing of surface water. This is accomplished by rough-grading the site so that water flows away from the foundation area. Hand-dug, small surface drains also remove excess surface water from the foundation area. Slot trenches and drainage pipes work well to drain surface and subsurface water on rolling terrain where the water can be channeled down the hill, but they are less effective in flat swampy areas where the natural grade is slight. In flat swampy areas, builders frequently rely on well points to drain subsurface water.

The next step is preparing the driveway for wet weather construction. After the driveway has been fully or partially paved, material deliveries are easier, hand labor is saved, and concrete trucks can get to the foundation area without getting stuck. Framing and other heavy materials can be delivered or moved from storage to the working area without bringing in special equipment. Builders in the Northeastern and North Central States use crushed stone or pea gravel on the driveway, along with heavy planks and timbers, to ease material delivery and to keep concrete trucks from getting stuck. Some builders pour the driveways before foundation work begins. This provides a solid area for delivery of materials and for working, and a dry area for temporary storage of heavy materials.

Wet weather excavating problems are most difficult in areas on silts and clay soils. Not only does it take longer to excavate muddy clay, but gumbo clays and marine clays clog the trenchers. Rubber-tired equipment is all but impossible to use in mud. Excavators in all parts of the country use sand and gravel on muddy sites to overcome loss of traction and soil load-bearing problems. Builders in some parts of the South where gumbo clay is prevalent spread sand over the entire construction site to provide better soil workability and for landscaping after construction is completed.

Builders in wet weather areas such as the Gulf Coast States and Middle Southern States design their schedules around two important factors: site access and "blackening-in" or closing-in under roofing. Framing is often not begun until driveways and sidewalks are poured. Once the slab is poured or the foundation is installed, the important thing is to black-in the roof as quickly as possible to keep

out the rain. To accomplish this, scheduling the roofing subcontractor to come in and lay the asphalt felt is critical. Many builders in the Gulf Coast States have the framing carpenters do the blackening-in so they do not have to rely on the roofing subcontractor to do that job.

### ***Hot and dry weather***

Building conditions in the Southwestern United States are unlike any other in the country. The climate in parts of southern California, west Texas, New Mexico, Arizona, and Nevada is hot and dry. Much of the area is desert. Temperatures in the summer soar to more than 120 °F in some places, while humidity is less than 5 percent. The high temperatures and low humidity, along with wind and dust storms, combine to make building conditions difficult.

Because of the extreme heat, builders start work early in the morning and quit early in the afternoon. Roofers, framers, and masons are often on site before 5 a.m., and they don't work much after 1 or 2 p.m. Concrete subcontractors usually don't work after 12 noon.

Concrete pouring begins around 5 a.m. and is completed by 9:30 or 10 a.m. Very little concrete is poured after 10 a.m. because the mix gets too hot. The subcontractors use a wet finish and saturate the soil and gravel under the slab with water before they pour. They also spray the finished concrete with a petroleum-base solution or cover the slab with plastic to prevent moisture from evaporating. Special additives are rarely used when pouring concrete in desert areas.

### ***Maintenance and Repair***

A well-constructed house requires relatively little maintenance if adequate attention is given at the planning stage to details and to choice of materials, as presented in this handbook. Many small expenses initially added to cost more than pay for themselves in later maintenance savings. For example, the extra expense of corrosion-resistant nails for siding and trim saves many times that much annually because of the less frequent need for painting. Also the use of edge-grained rather than flat-grained siding provides a longer paint life and thus justifies the higher cost.

The following sections outline some factors relating to maintenance of the house and how to reduce or eliminate conditions that may be harmful as well as costly. These suggestions can apply to both new and old houses.

### ***Basement***

The basement of a poured concrete or block wall may be damp for some time after a new house has been com-

pleted. However, after the heating season begins, most of this dampness from walls and floors gradually disappears if construction has been correct. If dampness or wet walls and floors persist, the owner should check various areas to eliminate any possibilities for water entry. Possible sources of trouble include:

1. Drainage at the downspouts. The final grade around the house should have a slope away from the building and provide a splash block or other means to drain water away from the foundation wall.
2. Soil settling at the foundation wall and resultant pockets in which water may collect. These areas should be filled and tamped so that surface water can drain away.
3. Leaking in a poured concrete wall at the form tie rods. The leaks usually seal themselves, but larger holes should be filled with a cement mortar or other sealer. Clean and slightly dampen the area first for good adhesion of mortar.
4. Concrete-block or other masonry walls exposed above grade often show dampness on the interior after a prolonged rainy spell. A number of waterproofing materials on the market provide good resistance to moisture penetration when applied to the inner face of the basement wall. If the outside of below-grade basement walls is treated correctly during construction, waterproofing the interior walls is not normally required.
5. There should be at least a 6-inch clearance between the bottom of the siding and the grass. This means that at least 8 inches should be allowed above the finish grade before sod is laid or foundation plantings made. This clearance minimizes the chance of moisture absorption by siding, sill plates, or other adjacent wood parts. Shrubs and foundation plantings should be kept away from the wall to improve air circulation and drying. In lawn sprinkling, it is poor practice to allow water to spray against the walls of the house.
6. Check areas between the foundation wall and the sill plate. Any openings should be filled with a cement mixture or a caulking compound. This filling decreases heat loss and prevents entry of insects into the basement, as well as reducing air infiltration.
7. Dampness in the basement in the early summer months is often augmented when windows are opened for ventilation during the day allowing warm, moisture-laden outside air to enter. The low temperature of the basement cools the incoming air and frequently causes condensation to collect and drip from cold-water pipes and collect on colder parts of the masonry walls and floors. To air out the basement, open the windows during the night and close them during the day.

Perhaps the most convenient method of reducing humidity in basement areas is with dehumidifiers. A mechanical dehumidifier is moderate in price and does a satisfactory job of removing moisture from the air during periods of high humidity. Basements containing living quarters and without air conditioners may require more than one dehumidifier unit. When dehumidifiers are in operation, all basement windows should be closed.

### *Crawl-space area*

Crawl-space areas should be checked as follows:

1. Inspect the crawl-space area annually for signs of termite activity such as termite tubes on the walls or piers. In termite areas, soil in the crawl space or under the concrete slab is normally treated with some type of chemical to prevent termite infestation. Examine the foundation walls for any cracks, as such cracks form good channels for termite entry.
2. While in the crawl space, check exposed wood joists and beams for indications of excessive moisture. In older houses where soil covers have not been used in the past, signs of staining or decay may be present. Use a penknife to test questionable areas. Decayed wood will be soft and will provide little resistance to prodding.
3. Soil covers should be used to protect wood members from ground moisture. These may consist of plastic films, roll roofing or other suitable materials. A small amount of ventilation (discussed in chapter 2) is desirable to provide some air movement. If the crawl space does not presently have a soil cover, install one for greater protection.

### *Roof and attic*

The roof and the attic area of both new and older houses may be inspected with attention to the following:

1. A dirty streak down the gable end of a house with a close rake section can often be attributed to rain entering and running under the edge of the shingles. This results from insufficient shingle overhang or the lack of a metal roof edge. The addition of a flashing strip to form a drip edge can usually minimize this problem.
2. In winters with heavy snows, ice dams may form at the eaves, often resulting in water entering the cornice and walls of the house. The immediate remedy is to remove the snow on the roof for a short distance above the gutters and, if necessary, in the valleys. Additional insulation between heated rooms and attic space and increased ventilation in the overhanging eaves to lower the general attic temperature will help to decrease the melting of snow on the roof and thus

minimize ice formation. Also, deep snow in the valleys sometimes forms ice dams that cause water to back up under shingles and valley flashing.

3. Roof leaks are often caused by improper flashing at the valley or ridge, or around the chimney. Observe these areas during a rainy spell to discover the source of a leak. Water may travel many feet from the point of entry before it drips off the roof members.
4. Attic ventilators are valuable year round; in summer, to lower the attic temperature and improve comfort conditions in the rooms below; in winter, to remove water vapor that may work through the ceiling and condense in the attic space and to minimize ice dam problems. The ventilators should be open in both winter and summer.

To check for sufficient ventilation during cold weather, examine the attic after a prolonged cold period. If nails protruding from the roof into the attic space are heavily coated with frost, ventilation is usually insufficient. Frost may also collect on the roof sheathing, first appearing near the eaves on the north side of the roof. Increasing the size of the ventilators or placing additional ventilation in the soffit area of the cornice will improve air movement and circulation.

### *Exterior walls*

One of the maintenance problems that sometimes occurs with a wood-sided house involves the exterior paint finish. Several reasons are known for peeling and poor adherence of paint. One of the major reasons perhaps can be traced to moisture in its various forms, including paint quality and method of application. Another factor involves the species of wood and the direction of grain. Some species retain paint better than others, and edge grain provides a better surface for paint than flat grain. Chapter 7 covers correct methods of application, types of paint, and other recommendations for a good finish. Other phases of exterior wall maintenance that homeowners may encounter are as follows:

1. If, instead of galvanized, aluminum, stainless steel, or other noncorrosive nails, bright steel nails have been used in applying the siding, rust spots may occur at the nailhead. The spots are quite common where nails are driven flush with the heads exposed. The spotting may be remedied somewhat, in the case of flush nailing, by setting the nailhead below the surface and puttying. The puttying should be preceded by a priming coat.
2. Brick and other types of masonry are not always waterproof, and continued rains may result in moisture penetration. Masonry veneer walls over a sheathed wood frame are normally backed with a waterproof sheathing paper to prevent moisture entry into the wall cavity. When walls do not have such protection and the moisture problem persists, a waterproof coating should be used over the exposed masonry surfaces. Transparent waterproof materials can be obtained for this purpose.
3. Caulking is usually required where a change of materials occurs along a vertical line (e.g., where wood siding abuts on brick chimneys or walls). The wood should normally have a prime coating of paint for proper adhesion of the caulking compound. Caulking guns with cartridges are the best means of waterproofing these joints. Many materials with a neoprene, elastomer, or other base are available for permanent caulking.
4. Rainwater may work behind wood siding through butt joint and sometimes up under the butt edge by capillary action when joints are not tight. Painting the siding board under the butt edges at the lap adds mechanical resistance to water ingress. However, moisture changes in the siding cause some swelling and shrinking that may break the paint film. Capillary action is effectively reduced by treating the siding with a water repellent before its application. For houses already built, the water repellent can be applied under the butt edges of bevel siding or along the joints of drop siding and at all vertical joints. Such water repellents, often combined with a preservative, can be purchased at local paint dealers as a water-repellent preservative. In-place application is often done with a plunger-type oilcan. Excess repellent on the face of painted surfaces should be wiped off.

### *Interior*

Gypsum board. The maintenance of gypsum board interior surfaces is no problem in a properly constructed house. However, damage to the wall surface may require repairs at times:

1. Cracks may develop caused by shrinkage of framing or movement of structural members. Structural problems should be solved before proceeding with repairs. Cracks can be filled with joint cement and sanded smooth as in the original process of treating joints between sheets.
2. Accidental damage may result in gouges or holes in the gypsum board. Gouges or relatively small holes can be filled with joint cement and sanded smooth. Larger holes may require cutting a section from the gypsum board and replacing it with a new section of board the size of the opening. Cut the section to extend between two studs so that the edges of the new section can be supported by the studs. Nail the new section in place and fill the joints around the perimeter with joint cement. Finish the joint by feathering edges and sanding smooth as in the original process of treating joints between sheets.

**Moisture on windows.** Moisture on inside surfaces of windows may often occur during the colder periods of the heating season. The following precautions and corrections should be observed during this time:

1. During cold weather and in cold climates, condensation or frost may collect on the inner face of single-glazed windows. Water from the condensation or melting frost runs down the glass and soaks into the wood sash to cause stain, decay, and paint failure. The water may rust a steel sash. To prevent such condensation, the window should be provided with a storm sash or double glazing, which also minimizes condensation. If condensation still persists on double-glazed windows, it usually indicates that the humidity within is too high. A humidifier, if used, should be turned off for a while or the setting lowered. If possible, other moisture sources such as house plants, showers, and cooking should also be reduced enough to remedy the problem. Also, increasing the inside temperature reduces surface condensation. If the problem persists, some type of mechanical ventilation may be necessary.
2. Occasionally, in very cold weather, frost may form on the inner surfaces of the storm windows. This may be caused by (a) a loose-fitting window sash that allows moisture vapor from the house to enter the space between the window and storm sash, (b) high relative humidity in the living quarters, or (c) a combination of both. Generally, the condensation on storm sash does not create a maintenance problem, but it may be a nuisance. Weatherstripping the inner sash offers resistance to moisture flow and may prevent this condensation. Lower relative humidities in the house are also helpful.

**Problems with exterior doors.** Condensation in the form of water or frost may occur on the glass or even on the interior surface of exterior doors during periods of severe cold. Furthermore, warping may result. The addition of a tight-fitting storm or combination door usually remedies both problems. To prevent or minimize warping as well as reduce heat loss, either a solid-core flush door or a panel door with solid stiles and rails is preferable to a hollowcore door.

**Openings in flooring.** Strip flooring finish that has been laid at too high a moisture content or with varying moisture contents may be a source of trouble to the homeowner. As the flooring dries out and reaches moisture equilibrium, spaces form between the boards. These openings are often very difficult to correct. If the floor has a few large cracks, one expedient is to fit matching strips of wood between the flooring strips and glue them in place. In severe cases, it may be necessary to replace sections of the floor or to refloor the entire house.

Another method is to cover the existing floor with a thin flooring,  $\frac{5}{16}$  or  $\frac{3}{8}$  inch thick. This requires removal of the base shoe, fitting the thin flooring around door jambs, and perhaps sawing off the door bottoms. New flooring can best be laid at right angles to original flooring. (For proper methods of laying floors to prevent open joints in new houses see chapter 6.)

**Unheated rooms.** To lower fuel consumption and for personal reasons, some homeowners close off unused rooms and leave them unheated during the winter months. Low temperatures, unfortunately, are conducive to condensation because surfaces may be below the dewpoint temperature of the air. Certain corrective or protective measures can be taken to prevent damage and subsequent maintenance expense, as follows:

1. Do not operate humidifiers or otherwise intentionally increase humidity in heated parts of the house.
2. Open the windows for ventilation of unheated rooms for several hours during bright sunny days. Ventilation helps draw moisture out of the rooms.
3. Install storm sash on all windows, including those in unheated rooms. This materially reduces heat loss from both heated and unheated rooms and minimizes the condensation on the inner glass surfaces.



## TECHNICAL NOTES



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## Technical Notes

### Concrete

Concrete consists of a mixture of Portland cement, sand, gravel, and various admixtures, combined in various proportions to meet specific conditions or requirements.

The most convenient way to obtain concrete is to order it from a local ready-mixed-concrete supplier. The ingredients for ready-mixed concrete are accurately measured, often in automated plants with computer equipment, and then mixed either at the plant or in a truck mixer, and delivered to the job site.

Producers of ready-mixed concrete can generally assist in the selection of appropriate mixes or in developing mixes to fulfill a builder's specific needs. Local practices in regard to ordering ready-mixed concrete vary, but usually ordering is either by performance or by prescription.

When concrete is ordered by performance, the builder specifies the strength level desired and the ready-mixed-concrete producer is responsible for proportioning and delivering a mixture that will yield the desired strength in a substantial majority of tests. For strength specifications to be meaningful, properly conducted strength tests are required.

When concrete is ordered by prescription, the builder specifies the weight of Portland cement per cubic yard, maximum amount of mixing water, admixtures required, and possibly their dosage rates. In essence, the builder accepts responsibility for the level of quality and performance.

### *Slump*

Slump is a measure of the consistency or stiffness of fresh concrete expressed in inches. It is influenced by the amount of water—more water means more slump—but water is not the only factor. The type of aggregate, the air content, and the proportions of the ingredients all affect slump.

The slump test is a method of measuring the workability of concrete when wet, and also a check of the concrete's consistency from batch to batch. The test consists of filling a cylindrical mold of standard diameter and height with concrete, removing the mold, and measuring the distance the concrete settles after a given period of time. For residential work, slumps range from 4 to 7 inches.

### *Air entrainment*

Air entrainment is essential for protecting concrete that is exposed to freezing, thawing, and the action of salts used for removing ice.

An air-entraining admixture or air-entraining cement causes microscopic air bubbles to form throughout the concrete, which acts as “relief” valves when the concrete freezes, helping to prevent scaling or spalling of the surface. (Scaling is a general crumbling of the surface cement layer of the concrete. Spalling is a form of chipping in which disc-like pieces loosen and pop out from the surface.) Resistance to deicers, which also cause scaling and spalling, is greater if the air-entrained concrete is dried for about 4 weeks after curing.

Air-entrained concrete is more watertight, more resistant to sulfate soils, and easier to work, particularly if the mixture is lean or has angular aggregates. Concrete strength is reduced somewhat by air entrainment, but a lower water/cement ratio is possible in an air-entrained mix and this can make up for any strength lost because of air entrainment.

### *Accelerators*

Accelerators speed up the setting time and strength development of concrete and are especially useful in cold weather. They can be combined with water-reducing admixtures.

Calcium chloride is the most commonly used accelerator. It is not an antifreeze, but it speeds up the set and makes freezing damage less likely, especially if the concrete is protected from low temperatures while it is curing.

Because calcium chloride must be carefully used and may increase shrinkage on drying, alternative solutions should be considered.

- There are five types of Portland cement, designated types I through V. They vary in their characteristics, including rate of strength gain. It is conventional practice to use type I in concrete mixes. If type II is specified, the resulting mix gains strength twice as quickly on the first day that the mixture is placed. However, the strengths of mixtures using type I and type II are approximately equal after 3 months.
- Reducing the amount of water relative to the amount of Portland cement can accelerate the rate of

strength gain. Too much cement, however, can increase susceptibility to cracking. Altering of the water/cement ratio should therefore be done by an experienced professional.

- Higher temperatures during curing speed up strength gain considerably.
- Warming the mix by using heated water can accelerate strength gain.

### ***Retarders***

Retarders are chemicals that can be added to the concrete mixture in hot weather when the concrete may set so quickly that it cannot be finished properly. Retarders are also useful when difficult placements require more time. Some retarders are water reducers or plasticizers. Called water-reducing retarders, they slow down the set while speeding up placement by plasticizing the concrete. Not all plasticizers retard the set.

In hot weather, concrete sets more slowly when the aggregate or water, or both, are cooled. One effective method is to use chipped ice for part of the mixing water.

### ***Plasticizers***

Plasticizers make the concrete more workable with less water. Strength is increased by the low water/cement ratio, and labor costs are reduced because the concrete is more workable.

Some water reducers may increase shrinkage on drying, and this may increase cracking. Other water reducers, however, reduce shrinkage cracks, according to the manufacturers.

Water reducers may be either accelerators or retarders. The type chosen should fit the circumstance. For example, an accelerating water reducer is suitable for cold weather; a retarding water reducer is suitable for hot weather.

Some water reducers also entrain air. One should allow for the extent of this entrainment when specifying amounts of air-entraining agent.

Water reducers are worth investigating if the concrete needs added strength without increasing labor costs.

### ***Superplasticizers***

An ordinary water reducer can reduce water requirement by 10 to 15 percent while slightly increasing slump. A superplasticizer can increase slump dramatically from an original 3 inches to 7 or 8 inches. Because concrete mixtures with superplasticizers are much easier to place, labor costs can be reduced.

A superplasticized concrete mix is easier to work because of the almost liquid slump, and because of the consistency of the concrete. Cement masons liken it to a temporary lubrication of the mix. It can be chuted more easily at a lower angle and is almost self-leveling.

## **Heat Flow and Insulation**

There are three primary mechanisms of heat transfer in building systems: conduction, convection, and radiation. By these mechanisms, heat flows from objects at higher temperatures to those at lower temperatures, that is, from hot to cold.

A common example of conduction is the metal handle on a frying pan. As the pan is heated, the handle becomes hot exclusively by the process of conduction. With most materials, the more dense the material, the higher its rate of heat flow by conduction. Metals transfer a great deal of heat this way, and so they are commonly used in electric transmission systems. Because they are excellent conductors, energy loss is at a minimum. Conversely, metal elements that extend through building sections are undesirable because of their high level of conduction.

In building material such as metal windows, heat flow by conduction can be reduced by use of a "thermal break." A casing of metal encloses a core of a material, such as wood, that has low thermal conductivity, and the casing itself is not continuous from the inside to the outside. The separation of the casing provides the thermal break.

Heat flow by convection can be observed in a house in that second-story rooms are warmer than first-story rooms. This difference in temperature occurs because heated air is less dense than cooler air. The heated air moves up to and across the ceilings of the first-story rooms and up the stairway to the second-story rooms. At the same time, the cooler air, which is more dense, settles to the floors of the upper-story rooms, and moves across the floors and down the stairway to the first-story rooms.

The warmth of the sun on the skin illustrates heat flow by radiation.

An old-fashioned steam or hot water radiator transfers heat by radiation, conduction, and convection simultaneously. The cast-iron structure conducts heat to the outside surface of the radiator. Air flowing between and around the radiator transfers heat by convection. At the same time, the warm surface of the radiator face transfers (radiates) additional heat and thus warms any nearby surface at a lower temperature, including surfaces of people, furnishings, and interior walls of the room.

## Measuring heat flow

Extensive measurements have been made of the heat flow characteristics of most building materials as well as entire building sections. Rating heat flow performance involves five forms of measurement—British thermal units (Btu's), thermal conductivity (k-value), conductance (C-value), thermal resistance (R-value), and the combined ability of a building section to retard heat flow (U-value).

**British thermal unit.** A Btu is defined as the amount of heat required to raise the temperature of 1 pound of water 1 °F. A Btu can be visualized as the amount of heat released by the burning of one wooden kitchen match from end to end. As a point of reference, a gallon of water weighs 8.33 pounds. Therefore, for example, it would take about 330 Btu's to raise the temperature of water 1 °F in a 40-gallon hot water heater. British thermal unit per hour (Btu/h) signifies the number of Btu's used per hour for a specified purpose.

**Thermal conductivity.** This measure, referred to as the k-value, introduces elements of size and time and may be applied only to homogeneous materials. The thermal conductivity of a given material is defined as the amount of heat that passes through a sample of the material 1 inch thick and 1 ft<sup>2</sup> in area, in 1 hour, with 1 °F difference in temperature between its two surfaces. The lower the k-value, the higher the insulating value. Insulation materials have k-values of 0.5 Btu/ft<sup>2</sup>/h/°F or less at temperatures normally encountered in building sections. Industrial insulations may have k-values of 1.0 or greater at the higher temperatures for which they are intended and used. The thermal conductivity of a material usually increases with mean temperature.

**Conductance.** The C-value is similar to conductivity but is a more flexible measurement unit. The thickness of the material is not confined to 1 inch. For example, a brick about 4 inches thick and nonhomogeneous materials such as concrete block can also be measured for C-values.

If the material is homogeneous, it is possible to determine the C-value if the k-value is known, and vice versa, using the relationship:

$$C\text{-value} \times \text{thickness} = k\text{-value}$$

For example, a homogeneous material with a C-value of 0.1 and a thickness of 3 inches has a corresponding k-value of 0.3. The lower the C-value, the higher the insulating value.

**Thermal resistance.** The R-value is a measurement of the ability of materials to retard heat flow rather than to transmit heat. Mathematically, R is the inverse of C or k. For example, a material with a C-value of 0.2 (1/5) has an R-value of 5.0.

The use of R-values makes it possible to add the thermal values of a whole series of materials. R-values have been measured for solid materials, nonhomogeneous materials, air spaces, and air films on both the inside and outside of building sections. Since R-values indicate the ability to retard heat flow, the higher the R-value, the higher the insulating value. Materials having the same R-value, regardless of thickness, weight, or appearance, are equal in insulating value. One should therefore specify insulation products by R-value rather than simply by thickness.

Table 21 lists R-values for some commonly available insulation materials.

**The U-value.** The sum of the conductances of all parts of a building section, including air films and air spaces adjacent to or a part of the building section, is called the U-value. Mathematically, it is defined as the number of Btu passing through 1 ft<sup>2</sup> of the combined building section in 1 hour for each degree Fahrenheit of temperature difference. The lower the U-value, the higher the insulating value. If an uninsulated frame wall has a U-value of about 0.25, a comparable insulated wall has reduced U-value of about 0.07.

**Table 21—R-values for commonly available insulation materials**

Material	Approximate R-value
Insulation, mineral wool blanket and batt	
Approximately 3 to 3½ inches thick	11.00
Approximately 5¼ to 6½ inches thick	19.00
Approximately 6 to 7 inches thick	22.00
Approximately 8½ to 9 inches thick	30.00
Approximately 12 inches thick	38.00
Insulation, board	
Glass fiber, organic bonded, 1 inch	4.00
Expanded polystyrene, extruded, cut cell, 1 inch	4.00
Expanded polystyrene, extruded, smooth, 1 inch	5.00
Expanded polystyrene, molded beads, 1 inch	3.57
Expanded polyurethane, 1 inch or more	6.25
Polyisocyanurate, 1 inch	7.20
Mineral fiber with resin binder, per inch	3.45
Insulation, blown loose fill	
Cellulosic, per inch	3.13–3.70
Perlite expanded, per inch	2.70
Mineral fiber (rock, slag, glass)	
3¼ to 5 inches	11.00
6½ to 8¾ inches	19.00
7½ to 10 inches	22.00
10¼ to 13¾ inches	30.00
13 to 17¼ inches	38.00
Vermiculite exfoliated, per inch	2.13–2.27

## Home insulating materials

Home insulating materials retard the flow of heat from the inside to the outside in the winter, and from the outside to the inside in the summer.

The most widely used home insulation material is called fiberglass or rock wool. It is composed of fine inorganic fibers made from rock, slag, or sand, with other material added to enhance service properties. Available forms include: flexible batts and blankets, with and without facings; semirigid and rigid boards, with and without facings; and a loose form for blowing or pouring.

Batt and blanket insulation often has a facing of kraft vapor-barrier paper with stapling flanges. Sometimes an enclosure of “breather” paper (paper that does not stop moisture movement) is used on the outer face for rock wool materials. Batts and blankets are also available with aluminum foil facings, and stapling flanges, and in an unfaced form held in place by pressure.

Blown mineral wool must be installed with pneumatic equipment and requires the service of an insulation contractor. Like faced or unfaced batts or blankets, pouring wool can be used by homeowners to increase the performance level of attic insulation.

Mineral wool board insulation can be used on the inside face of crawl-space walls and the outside of basement walls. Mineral wool blankets and boards are available for duct insulation; building blankets should not be used for this purpose. Preformed mineral wool pipe insulation is also available through industrial insulation contractors for both hot and cold water piping.

Other types of insulation used in residential construction include:

- Foamed plastic insulation boards or sheets, which are used as exterior wall sheathing, foundation insulation, and perimeter edge insulation for slab-on-grade construction.
- Cellulose fiber insulation, which is used primarily in ceilings and in walls of existing homes. It should be pneumatically installed by an insulation contractor.
- Multiple-layer aluminum foil insulation, which is sometimes used between furring strips on masonry wall construction. It is fragile and must be installed with great care if it is to be effective.

Combustible vapor-retarding facings on insulation should not be left exposed. They should be covered with materials having an acceptable flame spread or fire rating. Breather paper is combustible and, when exposed in accessible space, should be either covered or stripped off after the batts are in place.

## Lumber Grades

Softwood lumber is divided into three size categories. Finish grades nominally 1 inch thick and thicker are called *boards*. Pieces with nominal thickness ranging from 2 to 4 inches are called *dimension lumber*. Lumber 5 inches and thicker is called *timber*. Most framing materials used in light-frame construction are dimension lumber.

Dimension lumber is sold by grade, species (or species group), and size. Consider all grades and species suitable for the application and choose those that best meet the need. For economy in construction, it is recommended that the lowest grade suited to a job be used. Douglas-fir, hem-fir, or southern pine are good choices for longer spans because they are the stronger species, while other species may be more economical for shorter spans.

Lumber sizes in the United States are given as *nominal* dimensions (e.g., 2 by 4) in inches. At the time a piece of lumber is first sawn from a log it may approach those dimensions. Resawing, surfacing, and seasoning diminish the size considerably, resulting in an actual dimension that is less than nominal.

Dimension lumber is manufactured in lengths in 2-foot increments. The most common sizes are 8, 10, 12, 14, and 16 feet, but most lumberyards stock longer lengths. Actual lengths are usually slightly longer than nominal to allow for trimming. Most framing lumber is surfaced on four sides (S4S) and has eased edges (EE), although some square-edge stock is manufactured.

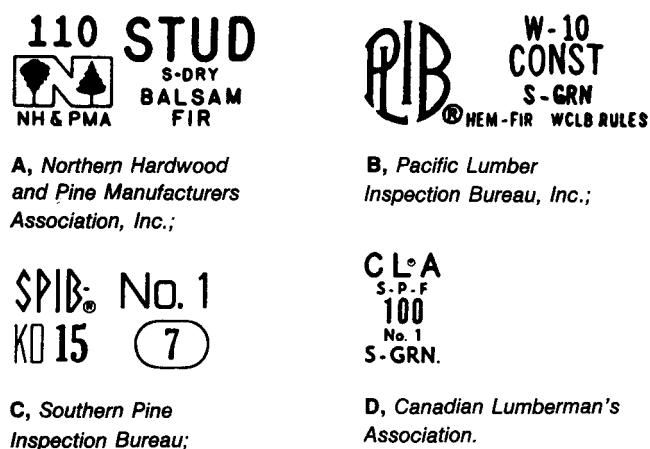
To assign lumber grades, a certified grader evaluates both natural and manufacturing characteristics. Unlike carpentry materials, framing lumber is graded primarily for strength rather than appearance. Lumber grading sets quality control standards among lumber mills manufacturing the same or similar products. An official grade stamp on a piece of lumber certifies its assigned grade.

All major building codes require that lumber used structurally be grade-stamped by an agency certified by the Board of Review of the American Lumber Standards Committee. The lumber standard requires that all grade stamps contain five basic elements: The symbol or lumber logo of the quality control agency; the mill number or name; the grade of the material; the species or species combination; the condition of seasoning at the time of manufacture. (Four examples are shown in figure 198.)

### Dimension lumber grades

Dimension lumber grades are standardized throughout North America, regardless of species or grading agency. Under the National Grade Rule for Dimension Lumber

**Figure 198**—Examples of symbols or lumber logos of quality control agencies:



promulgated by the American Lumber Standards Committee, there are four basic use categories, with one or more grades in each. The categories are light framing; stud; structural light framing; and structural joists and planks (table 22).

The grades of light framing lumber 2 to 4 inches thick and 2 to 4 inches wide are Construction, Standard, and Utility. Construction and Standard grades, produced primarily by Western and Canadian manufacturers, are commonly combined and sold as “Standard & Better.” They are use for general wall framing, regardless of species. Utility grade, often marketed as “Utility & Better,” can be used for interior framing, plates, blocking, cripples, etc. Economy grade is not accepted by building codes and is not recommended for construction.

Studs are marked in an all-purpose grade, called Stud grade. This grade designation encompasses lumber 2 to 4 inches thick and 2 to 6 inches wide, with a 10-foot length limit. It is most commonly found in 2 by 4 and 2 by 6 sizes, precision-trimmed to specific lengths. When length is not a factor, 2 by 4 Stud grade can be used interchangeably with Standard & Better.

The grades of structural light framing lumber 2 to 4 inches thick and 2 to 4 inches wide are Select Structural, No. 1, No. 2, and No. 3. Availability varies in different markets. The majority of southern pine is produced in these grades, which is not normally available at the retail level in the West. Select Structural and No. 1 are commonly used in engineered applications such as roof and floor trusses.

The grades of structural joist and plank lumber 2 to 4 inches thick and 6 or more inches wide are Select Structural, No. 1, No. 2, and No. 3. The first three, normally

sold together as “No. 2 & Better,” are used primarily for floor joists, ceiling joists, and roof rafters. Span and load-carrying requirements dictate the grade, specifics, and size. No. 3 grade is suitable for shorter spans.

### Moisture content

The portion of the grade stamp that designates the condition of seasoning at time of manufacture specifies one of three categories:

- S-GRN Unseasoned, with more than 19 percent moisture content
- S-DRY 19 percent or less moisture content
- MC-15 15 percent or less moisture content

Southern pine producers who kiln-dry their material may use a KD-19 or KD-15 designation to indicate 19-percent or 15-percent moisture content.

Availability of different levels of seasoning varies in local markets. Dimension lumber up to 2 inches thick is available “green” (unseasoned), “dry” (19 percent maximum), or in some areas, “MC-15” or “KD-15” (15 percent maximum). But even in a dry market, the maximum thickness structural grade available seasoned is 2 inches. Lumber thicker than 2 inches is shipped “green.”

The lumber industry produces two sizes of dimension lumber, depending on moisture content: a “dry” size and a slightly larger “green” size. Once the unseasoned size reaches 19-percent moisture content it will be the same size as the dry. “Green” and “dry” sizes should not be mixed during construction, even though their structural properties are identical.

### Design Values for Visually Graded Structural Lumber

Design values necessary for engineering calculations to determine the lumber size for specific spans are given in table 23. (Allowable spans are shown in tables 7 and 8.)

### Plywood Markings

Plywood products, whether construction or industrial, should be stamped with a marking indicating the intended use of the product. The most widely used markings are those of the American Plywood Association (APA). The markings provide assurance that the product conforms with APA performance standards and/or U.S. Product Standard PS 1–83 for Construction and Industrial Plywood. Typical APA markings are shown in figure 199. The top three markings appear on the face of the panel; the bottom marking is an edge stamp.

### ***Grade***

Panel grades are generally identified in terms of the veneer grade used on the face and back of the panel (A-B, B-C, etc.), by a name suggesting the panel's intended end use (APA Rated Sheathing, Underlayment, etc.). The highest quality veneer is "A," the lowest "D." The minimum grade of veneer in exterior plywood is "C." "D" veneer is used only in panels intended for interior use or for applications protected from exposure to weather or moisture.

### ***Span ratings***

Some APA trademarked panels, such as APA Rated Sheathing, APA Rated Sturd-I-Floor, and APA 303 Siding, carry numbers in their trademarks called span ratings. These denote the maximum recommended center-to-center spacing, in inches, of supports over which the panel should be placed in construction applications.

APA Rated Sheathing span ratings appear as a set of two numbers separated by a slash, such as 32/16 or 48/24. The first number in the set denotes the maximum recommended spacing of supports when the panel is used for roof sheathing with the long dimension of the panel across three or more supports. The second number indicates the maximum recommended spacing of supports when the panel is used for subflooring with the long dimension of the panel across three or more supports. Thus, panel marked 32/16 may be used for roof sheathing over supports 32 inches on center or for subflooring supports 16 inches on center.

APA Rated Sturd-I-Floor panels are designed for single-floor (combined subfloor-underlayment) applications under carpet and pad. The panels are manufactured with span ratings of 16, 20, 24, and 48 inches. As with APA Rated Sheathing, these are based on application of the panel with the long dimension across three or more supports.

APA 303 Siding is manufactured with span ratings of 16 and 24 inches. It can be applied directly to studs or over nonstructural wall sheathing (Sturd-I-Wall Construction), or over nailable panel or lumber sheathing (double-wall construction). Panels with a span rating of 16 inches may be applied vertically direct to studs spaced 16 inches on center. Panels bearing a span rating of 24 inches may be used vertically direct to studs 24 inches on center. All 303 Siding panels may be applied horizontally direct to studs 16 or 24 inches on center, provided that horizontal joints are blocked. When 303 Siding is used over nailable structural panel or lumber sheathing, the span rating refers to the maximum recommended spacing of vertical rows of nails rather than to stud spacing.

### ***Thickness***

This number gives the actual panel thickness.

### ***Species group number***

Plywood manufactured under U.S. Product Standard PS 1-83 may be made from over 70 species of wood. These species are divided according to strength and stiffness properties into five groups. Group 1 species are the strongest and stiffest, group 2 the next strongest and stiffest, and so on.

### ***Exposure durability***

Plywood panels are produced in four exposure durability classifications: Exterior, Exposure 1, Exposure 2, and Interior.

Exterior panels have a fully waterproof bond. They are designed for applications subject to continuous exposure to the weather or to moisture.

Exposure 1 panels are highly moisture resistant. They are designed to resist moisture during long construction

**Table 22—Dimension lumber grades and sizes**

Grades	Use Category	Description
Construction, Standard, & Utility	Light framing 2 by 2 through 4 by 4	For use where high strength values are not required (studs, plates, sills, cripples, blocking, etc.).
Stud	Studs 2 by 2 through 4 by 6 10 feet and shorter	An optional all-purpose grade limited to 10 feet and shorter. Characteristics affecting strength and stiffness values are limited so that the grade is suitable for all stud uses, including load-bearing walls.
Select Structural, No. 1, No. 2, & No. 3	Structural light framing 2 by 2 through 4 by 4	Designed to fit engineering applications where higher bending/strength ratios are needed in light framing sizes (for trusses, concrete pier wall forms, etc.).
Select Structural, No. 1, No. 2, & No. 3	Structural joists and planks 2 by 6 through 4 by 16	Designed especially to fit in engineering applications for lumber (joists, rafters and general framing uses)

**Table 23—Design Values for Visually Graded Structural Lumber**

	For material 2 to 4 inches thick by 2 to 4 inches wide				For material 2 to 4 inches thick by 5 inches or more wide			
	Extreme fiber in bending (9)		Modulus of elasticity (E)	Horizontal shear (H)	Extreme fiber in bending (9)		Modulus of elasticity (E)	Horizontal shear (H)
	Single member uses	Repetitive member uses			Single member uses	Repetitive member uses		
Southern pine (surfaced dry, used at 19% maximum moisture content)								
Select structural	2,000	2,300	1,400,000	90	1,700	1,950	1,400,000	90
No. 1	1,700	1,950	1,400,000	90	1,450	1,650	1,400,000	90
No. 2	1,400	1,600	1,300,000	90	1,200	1,350	1,300,000	90
No. 3	775	875	1,100,000	90	700	800	1,100,000	90
Appearance	1,700	1,950	1,400,000	90	1,450	1,650	1,400,000	90
Stud	775	875	1,100,000	90	700	800	1,100,000	90
Construction	1,000	1,150	1,100,000	90	—	—	—	—
Standard	550	650	1,100,000	90	—	—	—	—
Utility	275	300	1,100,000	90	—	—	—	—
Spruce–pine–fir(surfaced dry or green, used at 19% maximum moisture content)								
Select structural	1,450	1,650	1,500,000	70	1,250	1,450	1,500,000	70
No. 1	1,200	1,400	1,500,000	70	1,050	1,200	1,500,000	70
No. 2	1,000	1,150	1,300,000	70	875	1,000	1,300,000	70
No. 3	550	650	1,200,000	70	500	575	1,200,000	70
Appearance	1,200	1,400	1,500,000	70	1,050	1,200	1,500,000	70
Stud	550	650	1,200,000	70	500	575	1,200,000	70
Construction	725	850	1,200,000	70	—	—	—	—
Standard	400	475	1,200,000	70	—	—	—	—
Utility	175	225	1,200,000	70	—	—	—	—
Hem–fir(surfaced dry or green, used at 19% maximum moisture content)								
Select structural	1,650	1,900	1,500,000	75	1,400	1,650	1,500,000	75
No. 1	1,400	1,600	1,500,000	75	1,200	1,400	1,500,000	75
No. 2	1,150	1,350	1,400,000	75	1,000	1,150	1,400,000	75
No. 3	650	725	1,200,000	75	575	675	1,200,000	75
Appearance	1,400	1,600	1,500,000	75	1,200	1,400	1,500,000	75
Stud	650	725	1,200,000	75	575	675	1,200,000	75
Construction	825	975	1,200,000	75	—	—	—	—
Standard	475	550	1,200,000	75	—	—	—	—
Utility	225	250	1,200,000	75	—	—	—	—
Douglas–fir(south (surfaced dry or green, used at 19% maximum moisture content)								
Select structural	2,000	2,300	1,400,000	90	1,700	1,950	1,400,000	90
No. 1	1,700	1,950	1,400,000	90	1,450	1,650	1,400,000	90
No. 2	1,400	1,600	1,300,000	90	1,200	1,350	1,300,000	90
No. 3	775	875	1,100,000	90	700	800	1,100,000	90
Appearance	1,700	1,950	1,400,000	90	1,450	1,650	1,400,000	90
Stud	775	875	1,100,000	90	700	800	1,100,000	90
Construction	1,000	1,150	1,100,000	90	—	—	—	—
Standard	550	650	1,100,000	90	—	—	—	—
Utility	275	300	1,100,000	90	—	—	—	—

Source: National Forest Products Association. National Design Specification: Wood Construction, Supplement to the 1986 Edition. Table 4A.  
The species and grades selected from Table 4a and reproduced here reflect those most commonly used for framing.

delays, or exposure to similarly demanding conditions. However, only exterior panels should be used for permanent exposure to weather or moisture.

Exposure 2 panels are intended for protected construction applications involving only moderate delays in providing protection from moisture.

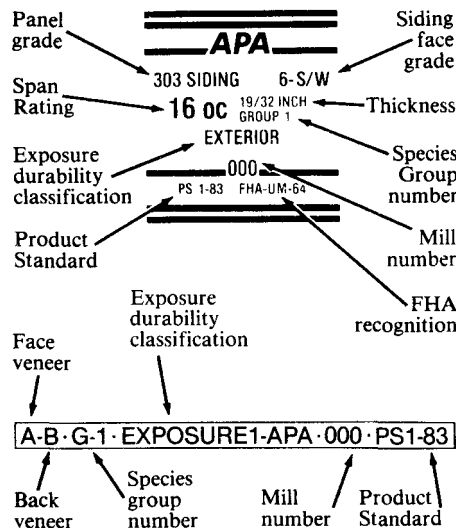
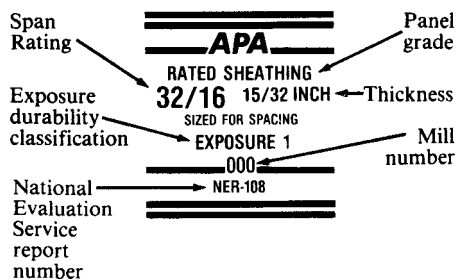
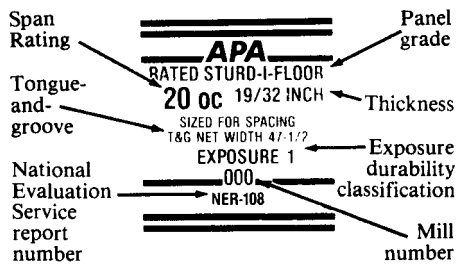
Interior panels which lack further glue-line information in their markings are manufactured with interior glue and are intended for interior applications only.

### **Mill number**

The mill number is the identification number assigned to the manufacturing facility in which the panel was produced.

**Figure 199—Typical American Plywood Association (APA) markings designating performance standards.**

### TYPICAL APA REGISTERED TRADEMARKS



Product standard

U.S. Product Standard PS 1-83 for Construction and Industrial Plywood is a voluntary commodity standard developed cooperatively by the U.S. Department of Commerce and the construction and industrial plywood industry.

APA performance standards are the result of new manufacturing technology that makes possible the manufacture of structural panel products from wood

byproducts and species not provided for in U.S. Product Standard PS 1-83.

Panels produced under APA performance standards are called APA Performance-Rated Panels.

In addition to conventional veneer plywood, APA performance standards encompass such panel products as composites, waferboard, oriented strand board, and structural particleboard.

### Finishing Pressure-Treated Wood

Wood that is pressure-treated with waterborne salts can be stained or painted in the same manner as untreated wood.

Wood that is treated with oilborne preservatives can be stained or painted if liquid petroleum gas (LPG), methylene chloride, or other light hydrocarbon solvent has been used as the preservative carrier. It should be specified when ordering that the material be suitable for staining or painting.

Wood that is treated with creosote, creosote solutions, or oilborne preservatives in heavy hydrocarbon solvent generally cannot be successfully stained or painted.

Prolonged exposure to wood-preserving chemicals may present a health hazard. To minimize exposure, one should: 1) wear protective gloves and clothing; 2) wear goggles and dust mask when sawing, machining, or sanding for prolonged periods of time; 3) perform all sawing, boring, planing, and sanding outdoors or in well ventilated areas; 4) wash exposed areas of body with soap and water after handling pressure-treated materials; 5) wash all clothing that was worn while the material was being handled; and 6) avoid burning scraps of pressure-treated lumber in open fires or in a fireplace, stove, or similar device. The preferred method of disposing of pressure-treated scrap pieces is to bury them at a suitable waste disposal facility.

### Nailing Schedules

Table 24 lists many of the components that are used in home construction and recommendations for how to join these components. The proper number and size of nails, and method of nailing are essential to ensure the structural integrity of a house. A nail should never be too big, too small, or placed improperly.

### Square Corners

Square corners in house construction ensure that all elements of the house fit together as planned, thus simplify-

**Table 24—Nailing schedules**

Materials being joined	Nailing method	No.	Nail size	Nailing procedures
Header to joists	Endnail	3	12d	Joist hangers advised
Joist to sill or girder	Toenail	2	8d	
Header and stringer joist to sill	Toenail		8d	24 inch on center
Subfloor, boards				
1 by 6 inch and smaller		2	8d	To each joist
1 by 8 inch		3	8d	To each joist
Subfloor, plywood				
At edges			8d	6 inch on center
At intermediate joists			8d	8 inch on center
Subfloor (2 by 6 inch, tongue and groove to joist or girder)	Blind-nail (casing) and facenail	2	12d	
Soleplate to stud, horizontal assembly	Endnail	2	12d	At each stud
Top plate to stud	Endnail	2	12d	
Soleplate to joist or blocking	Facenail		12d	24 inch on center maximum
Doubled studs	Facenail		12d	24 inch on center, staggered
End stud of intersecting wall to exterior wall stud	Facenail		12d	24 inch on center
Upper top plate to lower top plate	Facenail		12d	24 inch on center
Upper top plate, laps and intersections	Facenail		12d	
Header, two pieces			12d	12 inch on center, staggered
Ceiling joist to top wall plates	Toenail	2	8d	
Ceiling joist laps at partition	Facenail	3	12d	
Rafter to top plate	Toenail	2	8d	
Rafter to ceiling joist	Facenail	3	12d	
Rafter to valley or hip rafter	Toenail	3	8d	
Ridge board to rafter	Endnail	3	12d	
Rafter to rafter through ridge board	Toenail	3	12d	
Collar beam to rafter				
2-inch member	Facenail	2	12d	
1-inch member	Facenail	3	8d	
1-inch diagonal let-in brace to each stud and plate (4 nails at top)		2	8d	
Built-up corner studs				
Studs to blocking	Facenail	2	10d/12d	Each side
Intersecting stud to corner studs	Facenail	2	12d	24 inch on center
Built-up girders and beams, three or more members	Facenail		10d/12d	12 inch on center, staggered, each layer
			10d/12d	
Wall sheathing:				
1 by 8 inch or less, horizontal	Facenail	2	8d	At each stud
Wall sheathing, vertically applied plywood.				
$\frac{3}{8}$ inch and less thick	Facenail		6d	6 inch on center at edges
$\frac{1}{2}$ inch and over thick	Facenail		8d	12 inch on center intermediate
Wall sheathing, vertically applied fiberboard				
$\frac{1}{2}$ inch thick	Facenail			1%-inch roofing nail, 3 inch on center at edges and 6 inch on center intermediate
Roof sheathing, boards, 4-, 6-, 8-inch width	Facenail	2	8d	At each rafter
Roof sheathing, plywood				
$\frac{3}{8}$ inch and less thick	Facenail		6d	6 inch on center at edges and 12 inch on center intermediate
$\frac{1}{2}$ inch and over thick	Facenail		8d	

ing the installation of such items as sheathing, gypsum wallboard, cabinets, carpeting, counter tops, wallpaper, etc. The recommended method of establishing square comers involves the use of a pocket calculator and the Pythagorean theorem. The Pythagorean theorem states that, in a right triangle, the length of the hypotenuse (C) is equal to the square root of the sum of the squares of the lengths of the other two sides (A and B).

$$C = \sqrt{(A^2 + B^2)}$$

Applying this to footing layout begins by squaring the length of each of the two sides of the building, adding these two answers together, and taking the square root of the sum to produce the exact length of the diagonal that will produce a perfectly square comer for the footings.

The simplest approach to solving this arithmetic problem is to use a pocket calculator designed to work in feet and inches. If such a calculator is not available, the

dimensions will have to be converted to feet and decimal parts of a foot. (Alternatively, inches could be used as the unit of measurement.) For example, 12 feet 6 inches would have to be converted to 12.5 feet.

***Converting dimensions in feet and inches to decimal form***

Given a dimension of 25 feet  $3\frac{7}{8}$  inches, start the conversion by dividing the 7 by 8 to get 0.875 inch. Add this to the 3 inches to get 3.875 inches. Then divide the 3.875 inches by 12 to get 0.32292 foot. Add this result to the 25 to get 25.32292 feet, which is the decimal equivalent of 25 feet  $3\frac{7}{8}$  inches.

***Converting dimensions in decimal form to feet and inches***

Given a dimension of 44.71875 feet, start by setting aside the 44 feet and multiplying the decimal part (0.71875) by 12 to get 8.625 inches. Set aside the 8 inches and multiply the decimal part by 8 to get  $\frac{5}{8}$  inch. The result of the conversion is 44 feet  $8\frac{5}{8}$  inches, which is the feet and inches equivalent of 44.71875 feet.

***Example of squaring a foundation layout***

A rectangular house is to have a foundation wall with outside dimensions of 52 by 32 feet. Squaring these two numbers and adding the squared values gives a value of 3,728. The square root of 3,728 is 61.05735 feet. Setting aside the 61 feet and multiplying the decimal part (0.05735) by 12 gives 0.68820 inch. This means that the fractional part of a foot is less than 1 inch. Multiplying the 0.68820 by 8 gives 5.5 eighths of an inch or eleven-sixteenths of an inch. Therefore the exact length of the diagonal between the outside corners of the foundation wall should be 61 feet  $\frac{11}{16}$  inch, which is the feet and inches equivalent of 61.05735 feet. If the foundation walls are placed so that the length of the diagonal between the outside corners of the wall is 61 feet  $\frac{11}{16}$  inch, then the foundation has square corners.



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## GLOSSARY OF HOUSING TERMS



**Air-dried lumber.** Lumber that has been piled in yards or sheds for any length of time. For the United States as a whole, the minimum moisture content of thoroughly air-dried lumber is 12 to 15 percent and the average is somewhat higher.

**Anchor bolt.** A bolt to secure a wooden sill plate to concrete or masonry floor or foundation wall.

**Apron.** The flat member of the inside trim of a window placed against the wall immediately beneath the stool.

**Asphalt.** Most native asphalt is a residue from evaporated petroleum. It is insoluble in water but soluble in gasoline and melts when heated. Used widely as a waterproofing agent in the manufacture of waterproof roof coverings of many types, exterior wall coverings, flooring tile, and the like.

**Attic ventilator.** A screened opening provided to ventilate an attic space. They are located in the soffit area as inlet ventilators and in the gable end or along the ridge as outlet ventilators. Attic ventilation can also be provided by means of power-driven fans. See also Louver.

**Backfill.** The replacement of excavated earth into a trench around and against a basement foundation.

**Backhoe.** A machine that digs narrow, deep trenches for foundations, drais, cable, etc.

**Baluster.** A vertical member in a railing used on the edge of stairs, balconies, and porches.

**Balustrade.** A railing made up of balusters, top rail, and sometimes bottom rail.

**Band joist.** See under Joist, band.

**Base or Baseboard.** A board placed against the wall around a room next to the floor.

**Base molding.** Molding used to trim the upper edge of baseboard.

**Base shoe.** Molding used next to the floor on baseboard. Sometimes called a carpet strip.

**Batten.** A narrow strip of wood used to cover joints or as decorative vertical members over plywood or wide boards.

**Batter board.** One of a pair of horizontal boards nailed to posts set at the corners of an excavation, used to indicate the desired level. They are also used as fastenings for stretched strings to indicate outlines of foundation walls.

**Bay window.** Any window space projecting outward from the walls of a building, either square or polygonal in plan.

**Beam.** A structural member supporting a load applied transversely to the member.

**Bearing partition.** A partition that supports any vertical load in addition to its own weight.

**Bearing wall.** A wall that supports any vertical load in addition to its own weight.

**Bedding.** A layer of mortar into which brick or stone is set.

**Berm.** A raised area of earth such as earth pushed against a wall.

**Blind-nailing.** Nailing in such a way that the nailheads are not visible on the face of the work. Blind nailing is usually done at the tongue of matched boards.

**Bolster.** A short horizontal wood or steel beam on top of a column to support and decrease the span of beams or girders.

**Boston ridge.** A method of applying shingles at the ridge or hips of a roof as a finish.

**Brace.** An inclined piece of framing lumber applied to wall or floor to stiffen the structure. Often used temporarily on walls until framing has been completed.

**Breather paper.** A paper that lets water vapor pass through, often used on the outer face of walls to stop wind and rain while not trapping water vapor.

**Brick veneer.** A facing of brick laid against and fastened to the sheathing of a frame wall or tile wall construction.

**Bridging.** Small wood or metal members inserted in a diagonal position between the floor joists at midspan to brace the joists.

**Built-up roof.** A roofing composed of three to five layers of asphalt felt laminated with coal tar, pitch, or asphalt. The top layer is covered with crushed slag or gravel. Generally used on flat or low-pitched roofs.

**Butt joint.** The junction where the ends of two timbers or other members meet in a square-cut joint.

**Cantilever.** A horizontal structural component that projects beyond its support, such as a second-story floor that projects out from the wall of the first floor.

**Cant strip.** A triangular-shaped piece of lumber used at the junction of a flat deck and a wall to prevent cracking of the roofing that is applied over it.

**Cap.** The upper member of a column, pilaster, door cornice, or molding.

**Carriage.** See Stringer.

**Casement frame and sash.** A frame of wood or metal enclosing part or all of a sash, which can be opened by means of hinges affixed to the vertical edge.

**Casing.** Molding of various widths, forms, and thicknesses, used to trim door and window openings at the jambs.

**Caulk.** To fill or close a joint with a seal to make it watertight and airtight. The material used to seal a joint.

**Cement mortar.** A mixture of cement with sand and water used as a bonding agent between bricks or stones.

**Chalking string.** A string covered with chalk that, when stretched between two points and snapped, marks a straight line between the points.

**Chamfer.** The beveled edge of a board.

**Checking.** Fissures that can appear with age in exterior paint coatings. Such fissures, at first superficial, may in time penetrate entirely through the coating.

**Check rails.** Also called meeting rails. The upper rail of the lower sash and the lower rail of the upper sash of a double-hung window. Meeting rails are made sufficiently thicker than the rest of the sash frame to close the opening between the two sashes. Check rails are usually beveled to insure a tight fit between the two sashes.

**Clear wood.** Wood that has no knots.

**Cleat.** A length of wood fixed to a surface, as a ramp, to give a firm foothold or to maintain an object in place.

**Collar beam.** A member nominally 1 or 2 inches thick connecting opposite roof rafters at or near the ridge board. Collar beams serve to stiffen the roof structure.

**Column.** In architecture: A vertical supporting member, circular or rectangular in section, usually consisting of a base, shaft, and capital. In engineering: A vertical structural compression member that supports loads acting in the direction of its longitudinal axis.

**Condensation.** Beads or films of water, or frost in cold weather, that accumulate on the inside of the exterior covering of a building when warm, moisture-laden air from the interior reaches a point where the temperature no longer permits the air to sustain as vapor the moisture it holds.

**Construction, frame.** A type of construction in which the structural parts are wood or depend upon a wood frame for support. In codes, if masonry veneer is applied to the exterior walls, the structure is still classified as frame construction.

**Control joint.** A joint that penetrates only partially through a concrete slab or wall so that if cracking occurs it will be a straight line at that joint.

**Coped joint.** See Scribing.

**Corner board.** A board used as trim for the external corner of a house or other frame structure, against which the ends of siding are butted.

**Corner brace.** A diagonal brace placed at the corner of a frame structure to stiffen and strengthen the wall.

**Cornice.** Overhang of a pitched roof at the eave line, usually consisting of a fascia board, a soffit for a closed cornice, and appropriate moldings.

**Cornice return.** The underside of the cornice at the corner of the roof where the walls meet the gable end roofline. The cornice return serves as trim rather than as a structural element, providing a transition from the horizontal eave line to the sloped roofline of the gable.

**Counterflashing.** A flashing usually used on chimneys at the roofline to cover shingle flashing and to prevent moisture entry.

**Course.** A continuous horizontal range of blocks, bricks, siding boards, or shingles.

**Cove molding.** A molding with a concave face used as trim or to finish interior corners.

**Crawl space.** A shallow space below the living quarters of a basementless house, normally enclosed by the foundation wall.

**Cricket.** See Saddle.

**Crimp.** A crease formed in sheet metal for fastening purposes or to make the material less flexible.

**Crown molding.** A molding used on cornice or wherever an interior angle is to be covered. If a molding has a concave face, it is called a cove molding.

**Dead load.** The weight, expressed in pounds per square foot, of elements that are part of the structure.

**Deadman timber.** A large buried timber used as an anchor as for anchoring a retaining wall.

**Decay.** Disintegration of wood or other substance through the action of fungi, as opposed to insect damage.

**Deck paint.** An enamel with a high degree of resistance to mechanical wear, designed for use on such surfaces as porch floors.

**Deformed shank nail.** A nail with ridges on the shank to provide better withdrawal resistance. See under Nail.

**Density.** The mass of substance in a unit volume. When expressed in the metric system, it is numerically equal to the specific gravity of the same substance.

**Dewpoint.** Temperature at which a vapor begins to deposit as a liquid. Applies especially to water in the atmosphere.

**Dimension.** See Lumber, dimension.

**Doorjam, interior.** The surrounding case into which and out of which a door closes and opens. It consists of two upright pieces, called side jambs, and a horizontal head jamb.

**Dormer.** A roofed projection from a sloping roof, into which a dormer window is set. See eye dormer and shed dormer.

**Downspout.** A pipe, usually of metal, for carrying rainwater from roof gutters.

**Dressed and Matched.** See Tongue and groove.

**Drip.** (1) A structural member of a cornice or other horizontal exterior-finish course that has a projection beyond the parts for water runoff. (2) A groove in the underside of a sill or drip cap to cause water to run off on the outer edge.

**Drip cap.** A molding placed on the exterior top side of a door or window frame to cause water to run off beyond the outside of the frame.

**Drywall.** Interior covering material which is applied in large sheets or panels. The term has become basically synonymous with gypsum wallboard.

**Ducts.** Round or rectangular metal pipes for circulating warm air in a forced air heating or air-conditioning system.

**Eave.** The lower margin of a roof projecting over the wall.

**Edgenailing.** Nailing into the edge of a board. See Nail.

**Endnailing.** Nailing into the end of a board, which results in very poor withdrawal resistance. See Nail.

**Expansion joint.** A bituminous fiber strip used to separate blocks or units of concrete to prevent cracking caused by expansion as a result of temperature changes. Also used on concrete slabs.

**Eye dormer.** A dormer that has a gable roof.

**Facenailing.** Nailing perpendicular to the initial surface being penetrated. Also termed direct nailing.

**Fascia.** A flat board, band, or face, used by itself or, more often, in combination with moldings, generally located at the outer face of the cornice.

**Fascia backer.** The main structural support member to which the fascia is nailed.

**Filler.** A heavily pigmented preparation used for filling and leveling off the pores in open-pored woods.

**Fire stop.** A solid, tight closure of a concealed space, placed to prevent the spread of fire and smoke. In a frame wall, this usually consists of 2 by 4 cross blocking between studs.

**Flagstone** (flagging or flags). Flat stones, from 1 to 4 inches thick, used for rustic walks, steps, and floors.

**Flashing.** Sheet metal or other material used in roof and wall construction to prevent water entry into adjoining parts of the structure.

**Flat paint.** An interior paint that contains a high proportion of pigment, and dries to a flat or lusterless finish.

**Flue.** The space or passage in a chimney through which smoke, gas, or fumes ascend. Each such passage is called a flue, which together with any others and the surrounding masonry make up the chimney.

**Flue lining.** Fire clay or terra cotta pipe, round or square, usually made in all ordinary flue sizes and in 2-foot lengths, used for the inner lining of chimneys with the brick or masonry work around the outside. Flue lining in chimneys runs from about a foot below the flue connection to the top of the chimney.

**Fly rafters.** End rafters of the roof overhang supported by sheathing and lookouts.

**Footing.** A concrete section in a rectangular form, wider than the bottom of the foundation wall or pier it supports. With a pressure-treated wood foundation, a gravel footing may be used in place of concrete.

**Formwork.** A temporary mold for giving a desired shape to poured concrete.

**Foundation.** The supporting portion of a structure below the first-floor construction, or below grade.

**Framing, balloon.** A system of framing in which all exterior studs extend in one piece from the sill plate to the roof plate.

**Framing, ladder.** Framing for the roof overhang at a gable. Cross pieces are used similar to a ladder to support the overhang.

**Framing, platform.** A system of framing in which floor joists of each story rest on the top plates of the story below or on the foundation sill for the first story, and the bearing walls and partitions rest on the subfloor of each story.

**Frieze.** A horizontal member connecting the top of the siding with the soffit of the cornice.

**Frost line.** The depth of frost penetration in soil. This depth varies in different parts of the country.

**Fungi, wood.** Microscopic plants that live in damp wood and cause mold, stain, and decay.

**Fungicide.** A chemical that is poisonous to fungi.

**Furring.** Strips of wood or metal applied to a wall or other surface to even it and to serve as a fastening base for finish material.

**Gable.** The portion of the roof above the eave line of a double-sloped roof.

**Gable end.** An end wall having a gable.

**Gambrel.** A roof that slopes steeply at the edge of the building, but changes to a shallower slope across the center of the building. This allows the attic to be used as a second story.

**Gloss paint, Gloss enamel.** A paint or enamel that contains a relatively low proportion of pigment and dries to a sheen or luster.

**Glueline, exterior.** Waterproof glue at the interface of two veneers of plywood.

**Girder.** A large or principal beam of wood or steel used to support loads at points along its length.

**Grade.** The ground level around a building. The natural grade is the original level. Finished grade is the level after the building is complete and final grading is done.

**Grain.** The direction, size, arrangement, appearance, or quality of the fibers in wood.

**Grain, edge or vertical.** Edge-grain lumber has been sawed parallel to the pith of the log and approximately at right angles to the growth rings; i.e., the rings form an angle of 45° or more with the wide surface of the piece.

**Grain, flat.** Flat-grain lumber has been sawed parallel to the pith of the log and approximately tangential to the growth rings, i.e., the rings form an angle of less than 45° with the surface of the piece.

**Grout.** Mortar that will flow into the joints and cavities of masonry work and fill them solidly.

**Gusset.** A flat wood, plywood, or similar type member used to provide a connection at intersections of wood members. Most commonly used in joints of wood trusses.

**Gutter or eave trough.** A shallow channel or conduit of metal or vinyl set below and along the eaves of a house to catch and carry off rainwater from the roof.

**H-clip.** A metal clip into which edges of adjacent plywood sheets are inserted to hold edges in alignment.

**Header.** (1) A beam placed perpendicular to joists, to which joists are nailed in framing for chimneys, stairways, or other openings. (2) A wood lintel.

**Hearth.** The inner or outer floor of a fireplace, usually made of brick, tile, or stone.

**Heartwood.** The wood extending from the pith to the sapwood, the cells of which no longer participate in the life process of the tree.

**Heel wedges.** Triangular shaped pieces of wood that can be driven into gaps between rough framing and finished items, such as window frames, to provide a solid backing for these items.

**Hip.** The external angle formed by the meeting of two sloping sides of a roof.

**Hip roof.** A roof that rises by inclined planes from all four sides of a building.

**Hopper window.** A window that is hinged at the bottom to swing inward.

**Humidifier.** A device designed to increase the humidity within a room or a house by means of the discharge of water vapor. Humidifiers may consist of individual room-size units or larger units attached to the heating plant to condition the entire house.

**I-beam.** A steel beam with a cross section resembling the letter I. I-beams are used for long spans as basement beams or over wide wall openings, such as a double garage door, when wall and roof loads are imposed on the opening.

**Insulation board, rigid.** A structural building board made of coarse wood or cane fiber impregnated with asphalt or given other treatment to provide water-resistance. It can be obtained in various size sheets, in various thicknesses, and in various densities.

**Insulation, thermal.** Any material high in resistance to heat transmission that, when placed in the walls, ceiling, or floors of a structure, reduces the rate of heat flow.

**Isolation joint.** A joint in which two incompatible materials are isolated from each other to prevent chemical action between the two.

**Jack rafter.** A rafter that spans the distance from the wall plate to a hip, or from a valley to a ridge.

**Jackstud.** A short stud that does not extend from floor to ceiling, for example, a stud that extends from the floor to a window.

**Jamb.** The side and head lining of a doorway, window, or other opening.

**Joint.** The space between the adjacent surfaces of two members or components that are held together by nails, glue, cement, mortar, or other means. *See* Control joint, Coped joint, Expansion joint, and Isolation joint.

**Joint cement.** A powder that is usually mixed with water and used for joint treatment in gypsum wallboard finish. Joint cement, often called "spackle," can be purchased in a ready-mixed form.

**Joist.** One of a series of parallel beams, usually 2 inches in thickness, used to support floor and ceiling loads, and supported in turn by larger beams, girders, or bearing walls. *See* Band joist, Header, Tail beam, and Trimmer.

**Kerf.** A cut or incision made by a saw in a piece of wood.

**Keyways.** A tongue-and-groove type connection where perpendicular planes of concrete meet to prevent relative movement between the two components.

**Kiln-dried lumber.** Lumber that has been dried by means of controlled heat and humidity, in ovens or kilns, to specified ranges of moisture content. *See also* Air-dried lumber and Lumber, moisture content.

**Knee wall.** A short wall extending from the floor to the roof in the second story of a 1½-story house.

**Landing.** A platform between flights of stairs or at the termination of a flight of stairs.

**Lath.** The base to which plaster is applied. Expanded metal is commonly used.

**Lay up.** To place materials together in the relative positions they will have in the finished building.

**Ledger strip.** A strip of lumber nailed along the bottom of the side of a girder, on which joists rest.

**Let-in brace.** A board nominally 1 inch thick applied diagonally into notched studs.

**Light.** Space in a window sash for a single pane of glass. Also, a pane of glass.

**Lintel.** A horizontal structural member that supports the load over an opening such as a door or window. Also called a header.

**Live load.** The load, expressed in pounds per square foot, of people, furniture, snow, etc., that are in addition to the weight of the structure itself.

**Lookout.** A short wood bracket or cantilever to support an overhang portion of a roof, usually concealed from view by a soffit.

**Louver.** An opening with a series of horizontal slats arranged to permit ventilation but to exclude rain, sunlight, or vision. *See also* Attic ventilators.

**Lumber, boards.** Lumber less than 2 inches thick and 2 or more inches wide.

**Lumber, dimension.** Lumber from 2 inches to, but not including, 5 inches thick and 2 or more inches wide. Includes joists, rafters, studs, plank, and small timbers.

**Lumber, dressed size.** The dimension of lumber after shrinking from green dimension and after machining to size or pattern.

**Lumber, matched.** *See* Tongue and groove.

**Lumber, moisture content.** The weight of water contained in wood, expressed as a percentage of the total weight of the wood. *See also* Air-dried lumber and Kiln-dried lumber.

**Lumber, pressure-treated.** Lumber that has had a preservative chemical forced into the wood under pressure to resist decay and insect attack.

**Lumber, shiplap.** Lumber that has been milled along the edge to make a close rabbeted or lapped joint.

**Lumber, timbers.** Lumber 5 or more inches in least dimension. Includes beams, stringers, posts, caps, sills, girders, and purlins.

**Mansard.** A type of roof that slopes very steeply around the perimeter of the building to full wall height, providing space for a complete story. The center portion of the roof is either flat or very low sloped.

**Mantel.** The shelf above a fireplace. Also used in referring to the trim around both top and sides of a fireplace opening.

**Masonry.** Stone, brick, concrete, hollow-tile, concrete-block, gypsum-block, or other similar building units or materials or a combination of the same, bonded together with mortar to form a wall, pier, buttress, or similar element.

**Mastic.** A pasty material used as a cement in such applications as setting tile or as a protective coating for thermal insulation or waterproofing.

**Mildewcide.** A chemical that is poisonous specifically to mildew fungi. A specific type of fungicide.

**Millwork.** Building materials made of finished wood and manufactured in millwork plants and planing mills. It includes such items as inside and outside window and door frames, blinds, porchwork, mantels, panelwork, stairways, molding, and interior trim. The term does not include flooring or siding.

**Miter joint.** The joint of two pieces at an angle that is half the joining angle. For example, the miter joint at the side and head casing at a door opening is made at a 45° angle.

**Moisture content of wood.** *See* Lumber, moisture content.

**Molding.** A wood strip having a curved or projecting surface used for decorative purposes.

**Mortar.** *See* Cement mortar.

**Mortise.** A slot cut into a board, plank, or timber, usually edgewise, to receive a tenon of another board, plank, or timber to form a joint.

**Mullion.** The vertical member of a window between openings in a multiple-opening frame.

**Muntin.** A short bar, horizontal or vertical, separating panes of glass in a window sash.

**Natural finish.** A transparent finish that does not seriously alter the original color or obscure the grain of the natural wood. Natural finishes are usually provided by sealers, oils, varnishes, water-repellent preservatives, and other similar materials.

**Newel.** A post to which the end of a stair railing or balustrade is fastened. Also, any post to which a railing or balustrade is fastened.

**Nominal.** Of wood dimension, the approximate size of a sawn wood section before it is planed.

**Nonbearing wall.** A wall supporting no load other than its own weight.

**Nosing.** The projecting edge of a molding or drip. Usually applied to the projecting molding on the edge of a stair tread.

**Notch.** A crosswise rabbet at the end of a board.

**On center (O.C.).** The measurement of spacing for elements such as studs, rafters, and joists, from the center of one member to the center of the next.

**Oriented strand board (OSB).** A type of structural flakeboard composed of layers, with each layer consisting of compressed strand-like wood particles in one direction, and with layers oriented at right angles to each other. The layers are bonded together with a phenolic resin.

**Panel.** (1) A thin flat piece of wood, plywood, or similar material, framed by stiles and rails as in a door or fitted in grooves of thicker material with molded edges for decorative wall treatment. (2) A sheet of plywood, fiberboard, structural flakeboard, or similar material.

**Paper, building.** A general term for papers, felts, and similar sheet materials used in construction.

**Parquet.** A floor with inlaid design. For wood flooring it is often laid in blocks with boards at angles to each other to form patterns.

**Particleboard.** Panels composed of small wood particles usually arranged in layers without a particular orientation and bonded together with a phenolic resin. Some particleboards are structurally rated. *See also* Structural flakeboard.

**Partition.** A wall that subdivides spaces within any story of a building.

**Penny.** As applied to nails, it originally indicated the price per hundred. The term now serves as a measure of nail length and is signified by the letter d.

**Perm.** A measure of water vapor movement through a material, for permeation, measured as grains per square foot per hour per inch of mercury difference in vapor pressure.

**Pier.** A column of masonry, usually rectangular in horizontal cross section, used to support other structural members.

**Pigment.** A powdered solid in suitable degree of subdivision for use in adding color to paint or enamel.

**Pilaster.** A projection from a wall forming a column to support the end of a beam framing into the wall.

**Pitch.** The measure of the steepness of the slope of a roof, expressed as the ratio of the rise of the slope over a corresponding horizontal distance. Roof slope is expressed in the inches of rise per foot of run, such as 4 in 12.

**Pitch board.** A template used for marking the rise and run on a stair carriage.

**Pith.** The small, soft core at the original center of a tree around which wood formation takes place.

**Plate.** Sil! plate: a horizontal member anchored to a masonry wall. Sole plate: bottom horizontal member of a frame wall. Top plate: top horizontal member of a frame wall supporting ceiling joists, rafters, or other members.

**Plenum.** A space in which air is contained under slightly greater than atmospheric pressure. In a house, it is used to distribute heated or cooled air.

**Plumb.** Exactly vertical.

**Plumb bob.** A weight on the end of a line used to show vertical direction.

**Ply.** A term denoting one thickness of any material used for building up of several layers, such as roofing felt, veneer in plywood, or layers in built-up materials.

**Plywood.** A piece of wood made of three or more layers of veneer joined with glue, usually laid with the grain of adjoining plies at right angles

**Post and beam roof.** A roof consisting of thick planks spanning between beams that are supported on posts. This construction has no attic or air space between the ceiling and roof.

**Primer.** The first coat of paint in a paint job that consists two or more coats; also the paint used for such a first coat.

**Purlin.** A horizontal timber supporting the common rafters in roofs.

**Quarter round.** A small molding that has the cross section of a quarter circle.

**Quartersawn.** Another term for edge grain, which see.

**Rabbet.** A rectangular longitudinal groove cut in the corner edge of a board or plank.

**Rafter.** One of a series of structural members of a roof designed to support roof loads. The rafters of a flat roof are sometimes called roof joists. See also Fly rafter and Jack rafter.

**Rafter, hip.** A rafter that forms the intersection of an external roof angle.

**Rafter, valley** A rafter that forms the intersection of an internal roof angle. A valley rafter is normally made of double 2-inch-thick members.

**Rail.** (1) A cross member of a panel door or sash. (2) The upper or lower member of a balustrade or staircase extending from one vertical support, such as a post, to another.

**Rake.** Trim members that run parallel to the roof slope and form the finish between the wall and a gable roof extension.

**Reflective insulation.** Sheet material with one or both surfaces of comparatively low heat emissivity, such as aluminum foil. When it is used in building construction, the surfaces face air spaces, reducing the radiation across these spaces.

**Register.** A device for controlling the flow of warmed or cooled air through an opening.

**Reinforcing.** Steel rods or metal fabric placed in concrete slabs, beams, or columns to increase their strength.

**Relative humidity.** The amount of water vapor in the atmosphere, expressed as a percentage of the maximum quantity that the atmosphere could hold at a given temperature. The amount of water vapor that can be held in the atmosphere increases with the temperature.

**Resorcinol.** An adhesive that is high in both wet and dry strength and resistant to high temperatures. It is used for gluing lumber or assembly joints that must withstand severe conditions.

**Reverse board and batten.** Siding in which narrow battens are nailed vertically to wall framing and wider boards are nailed over these so that the edges of boards lap battens. A slight space is left between adjacent boards. This pattern is simulated with plywood by cutting wide vertical grooves in the face ply at uniform spacing.

**Ridge.** The horizontal line at the junction of the top edges of two sloping roof surfaces.

**Ridge board.** The board placed on edge at the ridge of the roof, into which the upper ends of the rafters are fastened.

**Ring shank nail.** A nail with ridges forming rings around the shank to provide better withdrawal resistance.

**Rise.** In stairs, the vertical height of a step or flight of stairs.

**Riser.** Each of the vertical boards closing the spaces between the treads of stairways.

**Rolled roofing.** Roofing material composed of fiber and saturated with asphalt, that is supplied in 36-inch-wide rolls with 108 square feet of material. Weights are generally 45 to 90 pounds per roll.

**Roof, built-up.** See Built-up roof.

**Roof, sheathing.** The boards or sheet material fastened to the rafters, on which shingles or other roof covering is laid.

**Roof, valley.** See Valley.

- Rottenstone.** A slightly abrasive stone used to rub a transparent interior finish to achieve a smooth surface.
- Run.** In stairs, the net front-to-back width of a step or the horizontal distance covered by a flight of stairs.
- Saddle.** Two sloping surfaces meeting in a horizontal ridge, used between the back side of a chimney, or other vertical surface, and a sloping roof. Saddles are also called crickets.
- Sapwood.** The outer zone of wood in a tree, next to the bark. In the living tree it contains some living cells (the heartwood contains none), as well as dead and dying cells. In most species, it is lighter colored than the heartwood. In all species, it lacks resistance to decay.
- Sash.** A frame containing one or more lights of glass.
- Saturated felt.** Felt impregnated with tar or asphalt.
- Sawkerf.** *See* Kerf.
- Scab.** A short length of board nailed over the joint of two boards butted end to end to transfer tensile stresses between the two boards.
- Scaling.** Loss of smooth surface of concrete as a result of flaking or scaling.
- Scribing.** Fitting woodwork to an irregular surface. With moldings, scribing means cutting the end of one piece to fit the molded face of the other at an interior angle, in place of a miter joint.
- Scuttle Hole.** An opening in the ceiling to provide access to the attic. It is covered by a closure panel when not in use.
- Sealant.** *See* Caulk.
- Sealer.** A finishing material, either clear or pigmented, that is usually applied directly over uncoated wood to seal the surface.
- Seam, standing.** A joint between two adjacent sheets of metal roofing in which the edges are bent up to prevent leakage and the joint between the raised edges is covered.
- Seasoning.** Removing moisture from green wood to improve its serviceability.
- Semigloss paint or enamel.** A paint or enamel made with a slight insufficiency of nonvolatile vehicle so that its coating, when dry, has some luster but is not very glossy.
- Shake.** A thick handsplit shingle, resawed to form two shakes; usually edge-grained.
- Sheathing.** The covering used over joists, studs, or rafters of a structure.
- Sheathing paper.** A building material, generally paper or felt, used in wall and roof construction as a protection against the passage of air and water.
- Shed dormer.** A dormer that has a roof sloping only one direction at a much shallower slope than the main roof of the house.
- Sheet metal work.** All components of a house employing sheet metal, such as ducts, flashing, gutters, and downspouts.
- Sheetrock.** A term commonly applied to gypsum board.
- Shellac.** A transparent coating made by dissolving lac, a resinous secretion of the lac insect (a scale insect that thrives in tropical countries, especially India), in alcohol.
- Shim.** A thin wedge of wood for driving into crevices to bring parts into alignment.
- Shingles.** Roof covering of asphalt, fiberglass, asbestos, wood, tile, slate, or other material or combinations of materials such as asphalt and felt, cut to stock lengths, widths, and thicknesses.
- Shingles, siding.** Various types of shingles used over sheathing for exterior sidewall covering.
- Shiplap.** *See* Lumber, shiplap.
- Shutter.** A lightweight louvered, flush wood or non-wood frame in the form of a door, located at each side of a window. Some are made to close over the window for protection; others are fastened to the wall for decorative purposes.
- Siding, bevel.** In lap siding, wedge-shaped boards used as horizontal siding in a lapped pattern. Bevel siding varies in butt thickness from  $\frac{1}{2}$  to  $\frac{3}{4}$  inch and is available in widths up to 12 inches. Normally used over some type of sheathing.
- Siding, drop.** Siding that is usually  $\frac{3}{4}$  inch thick and 6 or 8 inches wide, with tongue-and-groove or shiplap edges. Often used as siding without sheathing in secondary buildings.
- Sill.** (1) The lowest member of the frame of a structure, resting on the foundation and supporting the floor joists or the uprights of the wall. (2) The member forming the lower side of an opening such as a door sill or window sill.
- Slab.** A concrete floor poured on the ground.
- Sleeper.** A wood member embedded in or resting directly on concrete, as in a floor, that serves to support and to fasten subfloor or flooring.
- Slip tongue.** A spline used to connect two adjacent boards that have grooves facing each other.
- Smokepipe thimble.** *See* Thimble.
- Soffit.** The underside of an overhanging cornice.
- Soil cover or ground cover.** A light covering of plastic film, roll roofing, or similar material, used over the soil in crawl spaces of buildings to minimize movement of moisture from the soil into the crawl space.
- Soil stack.** A general term for the vertical main of a system of soil, waste, or vent piping.
- Sole or sole plate.** *See* Plate.
- Spackle.** *See* Joint cement.
- Spalling.** Chips or splinters breaking loose from the surface of concrete because of moisture moving through from the reverse side.
- Span.** The distance between structural supports such as walls, columns, piers, beams, girders, and trusses.
- Splash Block.** A small masonry block laid with the top close to the ground surface, to receive roof drainage from downspouts and carry it away from the building.

**Spline.** A long, narrow, thin strip of wood or metal often inserted into the edges of adjacent boards to form a tight joint.

**Square.** A unit of measure usually applied to roofing material, denoting a sufficient quantity to cover 100 square feet of surface.

**Stair carriage.** Supporting member for stair treads. Usually a 2-inch plank notched to receive the treads; sometimes called a “rough horse” or “stringer.”

**Stair landing.** See Landing.

**Stair rise.** See Rise.

**STC (Sound Transmission Class).** A numerical measure of the ability of a material or assembly to resist the passage of sound. Materials with higher STC numbers have greater resistance to sound transmission.

**Stile.** An upright framing member in a panel door.

**Stool.** A flat molding fitted over the window sill between jambs and contacting the bottom rail of the lower sash.

**Stop, trim.** The trim member on the jambs of an opening that a door or window closes against.

**Stop, gravel.** A raised ridge of metal at the edge of a tar and gravel roof that keeps the gravel from falling off the roof.

**Strip flooring.** Wood flooring consisting of narrow, matched strips.

**String or stringer.** A timber or other support for cross members in floors or ceilings. In stairs, the stringer (or stair carriage) supports the stair treads.

**Structural flakeboard.** A panel material made of specially produced flakes that are compressed and bonded together with phenolic resin. Popular types include waferboard and OSB (oriented strand board). Structural flakeboards are used for many of the same applications as plywood.

**Stucco.** A plaster for exterior use, made with Portland cement as its base.

**Stud.** One of a series of slender wood or metal vertical structural members placed as supporting elements in walls and partitions. (Plural = studs or studding.)

**Studwall.** A wall consisting of spaced vertical structural members with thin facing material applied to each side.

**Subfloor.** Boards or plywood laid on joists, over which a finish floor is to be laid.

**Tail beam.** A relatively short beam or joist supported by a wall at one end and by a header at the other.

**Tenon.** A projection at the end of a board, plank, or timber for insertion into a mortise.

**Termite shield.** A shield, usually of noncorrodible metal, placed in or on a foundation wall or other mass of masonry or around pipes, to prevent passage of termites.

**Thimble.** The section of a vitreous clay flue that passes through a wall.

**Threshold.** A strip of wood or metal with beveled edges, used over the finish floor and the sill of exterior doors.

**Tieback member.** A timber, oriented perpendicular to a retaining wall, that ties the wall to a deadman buried behind the wall.

**Toenailing.** Driving a nail at a slant with the initial surface to permit it to penetrate into a second member.

**Tongue and groove.** Boards or planks machined in such a manner that there is a groove on one edge and a corresponding projection (tongue) on the other edge, so that a number of such boards or planks can be fitted together. “Dressed and matched” is an alternative term with the same meaning.

**Tread.** The horizontal board in a stairway on which the foot is placed.

**Trim.** The finish materials in a building, such as molding applied around openings (window trim, door trim) or at the floor and ceiling of rooms (baseboard, cornice, and other moldings).

**Trimmer.** A beam or joist to which a header is nailed in framing a chimney, stairway, or other opening.

**Truss.** A framed or jointed structure, composed of triangular elements, designed to act as a beam of long span, while each member is usually subjected to longitudinal stress only, either tension or compression.

**Truss plate.** A heavy-gauge, pronged metal plate that is pressed into the sides of a wood truss at the point where two more members are to be joined together.

**Undercoat.** A coating applied prior to the finishing or top coats of a paint job. When it is the first of two or more coats, it is synonymous with priming coat.

**Underlayment.** A material placed under flexible flooring materials such as carpet, vinyl tile, or linoleum to provide a smooth base over which to lay such materials.

**Valley.** The internal angle formed by the junction of two sloping sides of a roof.

**Vapor retarder.** Material used to retard the movement of water vapor into walls. Vapor retarders are applied over the warm side of exposed walls or as a part of batt or blanket insulation. They usually have perm value of less than 1.0.

**Varnish.** A thickened preparation of drying oil or drying oil and resin suitable for spreading on surfaces to form continuous, transparent coatings, or for mixing with pigments to make enamels.

**Vehicle.** The liquid portion of a finishing material; it consists of the binder (nonvolatile) and volatile thinners.

**Veneer.** Thin sheets of wood made by rotary cutting or slicing.

**Vent.** A pipe or duct, or a screened or louvered opening, which provides an inlet or outlet for the flow of air. Common types of roof vents include ridge vents, soffit vents, and gable end vents.

**Volatile thinner.** A liquid that evaporates readily, used to thin or reduce the consistency of finishes without altering the relative volumes of pigments and nonvolatile vehicles.

**Waferboard.** A type of structural flakeboard made of compressed, wafer-like wood particles or flakes bonded together with a phenolic resin. The flakes may vary in size and thickness may be either randomly or directionally oriented.

**Wallplate.** The cover over an electrical outlet or switch on the wall.

**Wane.** Bark, or lack of wood from any cause, on the edge or corner, of a piece of wood. Hence, waney.

**Water-repellent preservative.** A liquid designed to penetrate into wood, to impart water resistance and moderate preservative protection. It is used for millwork such as sash and frames, and is usually applied by dipping.

**Weatherstripping.** Strips of thin metal or other material, that prevent infiltration of air and moisture around windows and doors. Compression weatherstripping on single- and double-hung windows performs the additional function of holding such windows in place in any position.

**Web.** The thin center portion of a beam that connects the wider top and bottom flanges.

**Whaler.** A large structural member placed horizontally against foundation forms to which braces are temporarily attached to prevent forms from moving horizontally under the pressure of concrete.

**Withe.** A vertical layer of bricks, one brick thick.





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