Chapter 3

FRAMING AND CLOSING IN

Framing and Closing In

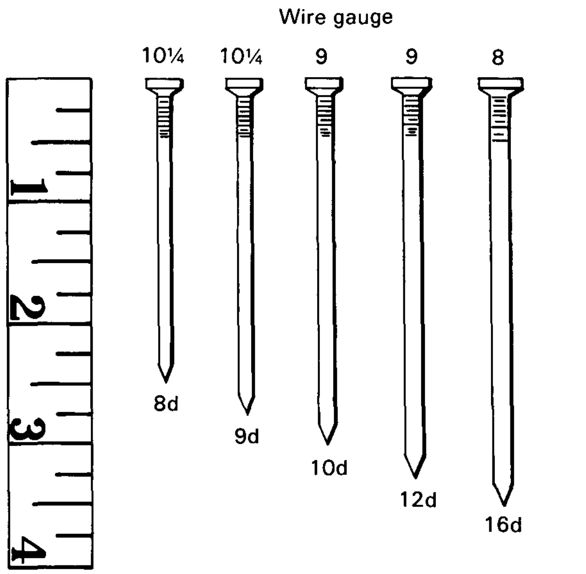
The sections contained in this chapter address the tasks related to erecting the structural framing for the house and creating an enclosure that provides some degree of protection from the elements.

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.

Figure 26 –*Common nails.*



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, 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:*

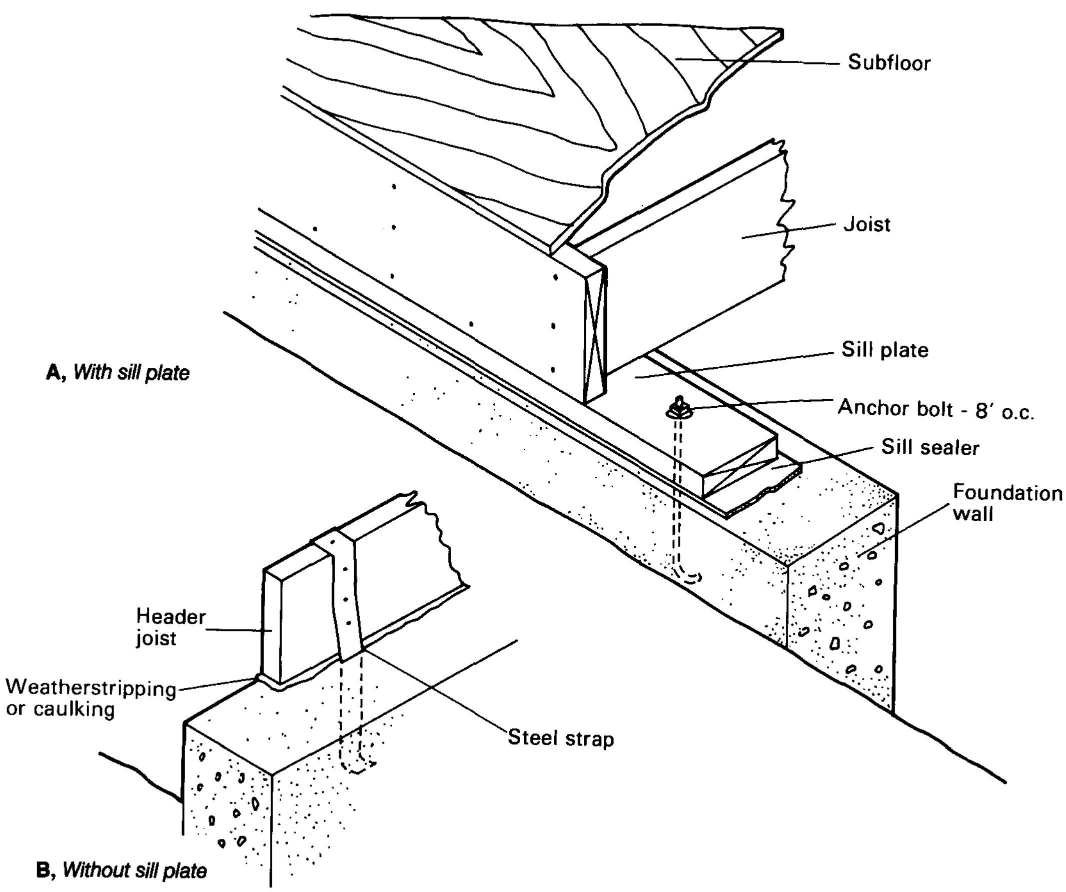
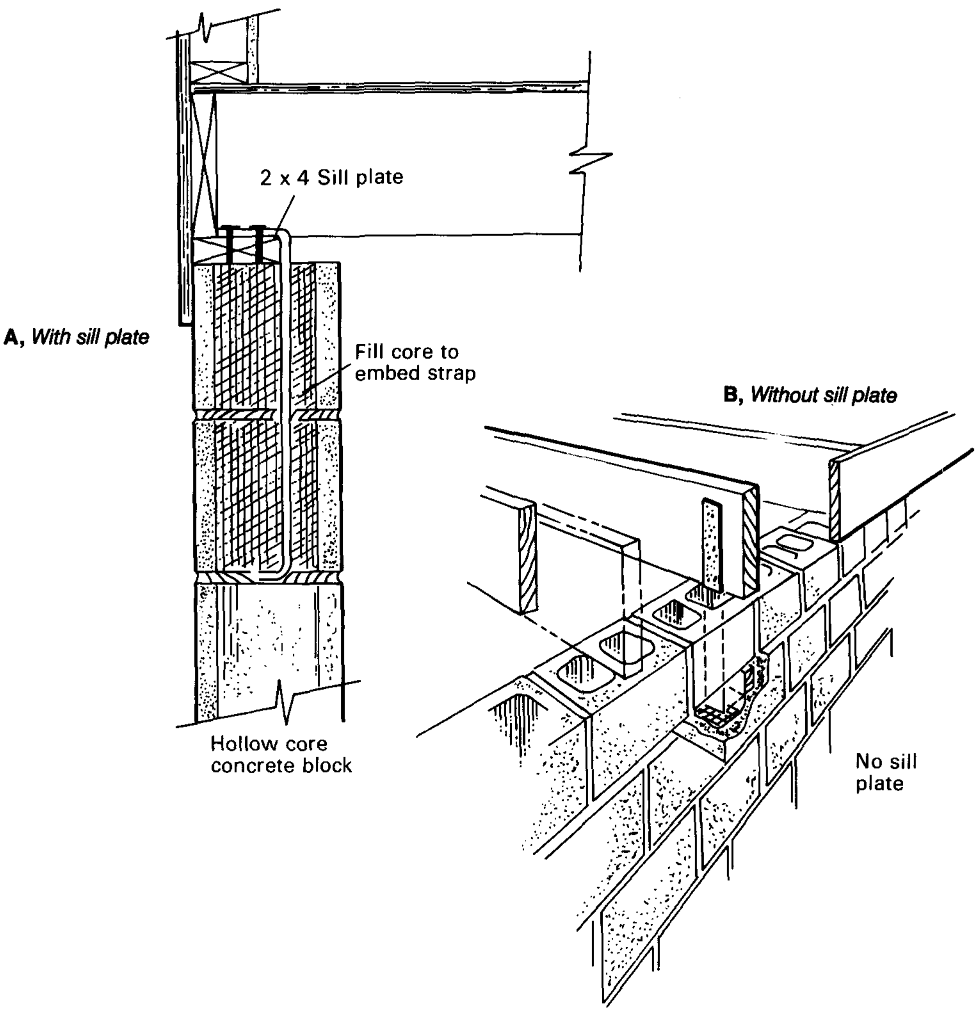


Figure 28 – *Anchoring floor system to concrete block foundation wall:*



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:

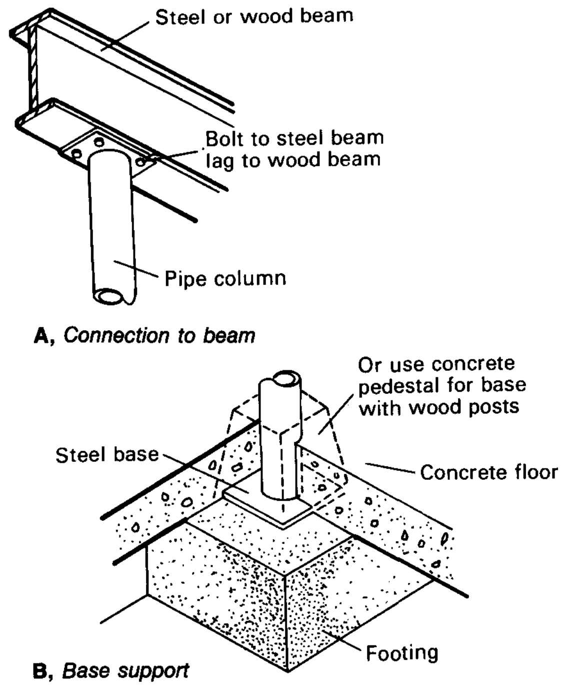
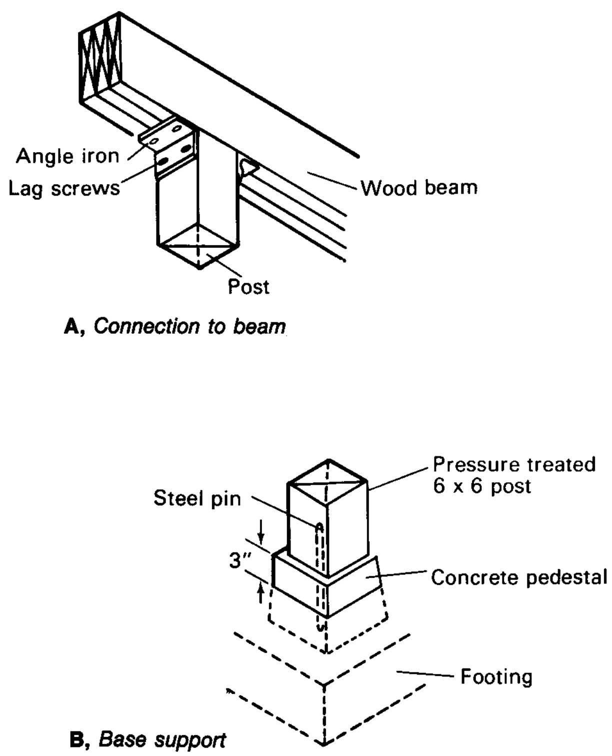


Figure 30 – *wood post support for wood beam:*



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

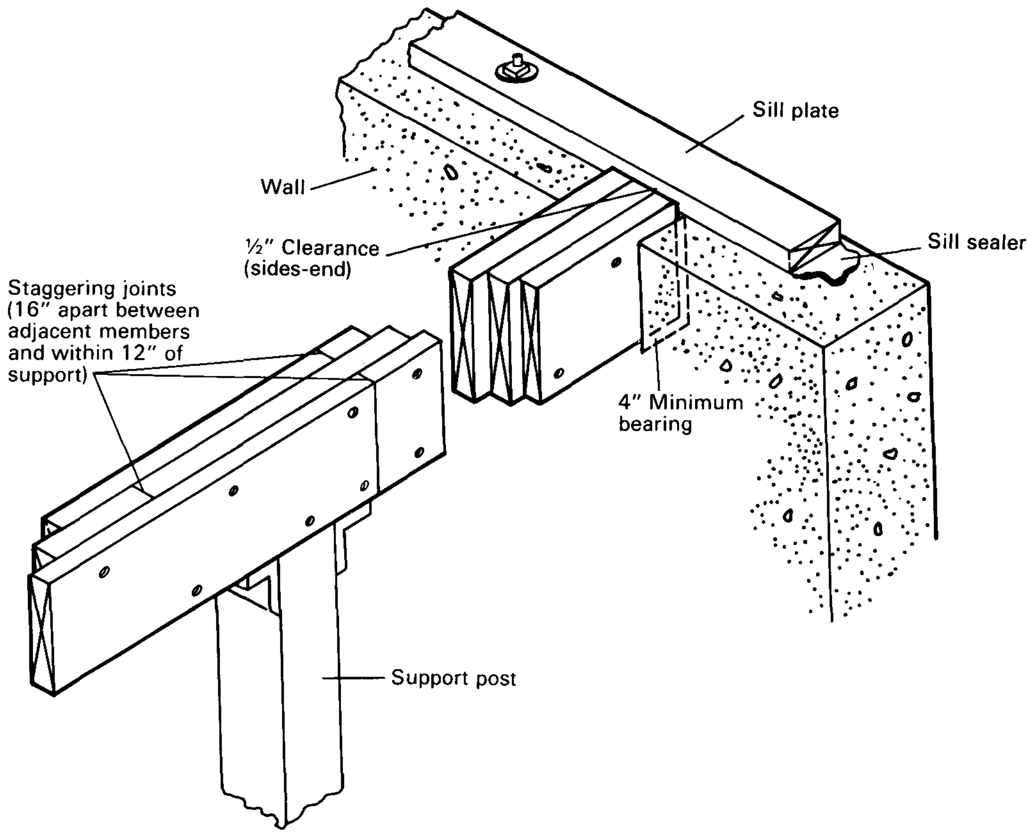
Steel I-beams are often used because they have greater strength and stiffness than wood beams, which enables them to carry a given load over a given span with a beam of lesser depth and thus provides greater headroom or reduces the requirement for additional supporting posts. Allowable spans for steel 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[a]		Minimum required bending stress (9 of 1,500 psi[b]	
		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.

[a]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.

[b]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.

Table 6 – ***Allowable spans between columns or piers supporting steel center beams***[a]

Steel beam designation[b] & 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 Steal Corporation (1980). Steel beam stress & deflection estimator for use in calculating sizes of laterally supported beams for residential and light construction.

[a] 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.

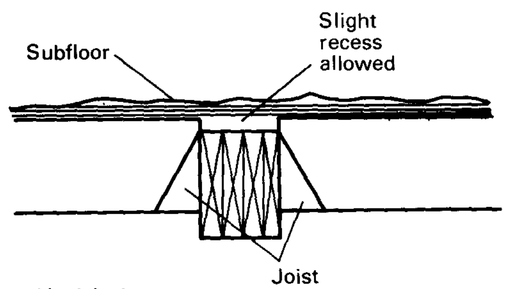
[b]The steel beam designations presented are those most commonly available at building material suppliers. The designation gives the height of the beam in inches, a letter designating the type of I-beam, and the weight of the beam in pounds per linear foot. (An "8B10.0" I-beam is an Pinch-high type B I-beam that weighs 10.0 pounds per linear 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 placed on top, because knots on the upper side of a joist are placed in compression and have less effect on strength.

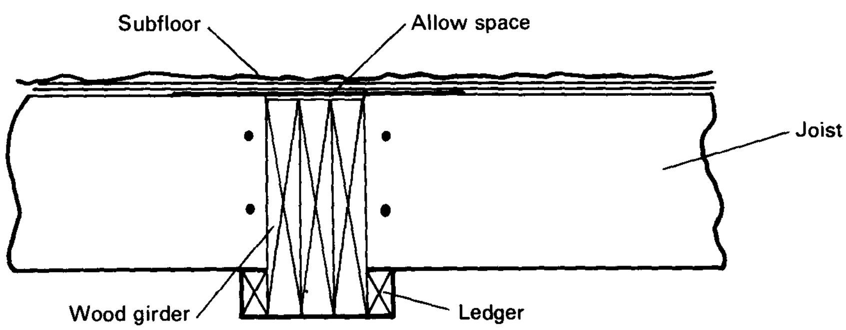
The header joist is fastened by nailing through it into the end of each joist with three 12d or 16d nails. In addition, the header joist and the stringer joists parallel to the exterior wall in platform construction (fig. 34) are toe-nailed to the sill with 10d or 12d nails spaced 16 inches on center.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



A, *Supported by joist hangers;*



B, *Supported by ledger.*

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 x 10^6 pounds per square inch.***

	Length of maximum clear span										
	1.0 x 10^6 psi	**1.1 x 10^6 psi**	**1.2 x 10^6 psi**	**1.3 x 10^6 psi**	**1.4 x 10^6 psi**	**1.5 x 10^6 psi**	**1.6 x 10^6 psi**	**1.7 x 10^6 psi**	**1.8 x 10^6 psi**	**1.9 x 10^6 psi**	**2.0 x 10^6 psi**
Living areas (40 lb/ft² live load)											
Minimum required bending stress (lb/in²)	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"
Sleeping areas (30 lb/ft² live load)											
Minimum required bending stress (lb/in²	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 10^6 pounds per square inch*

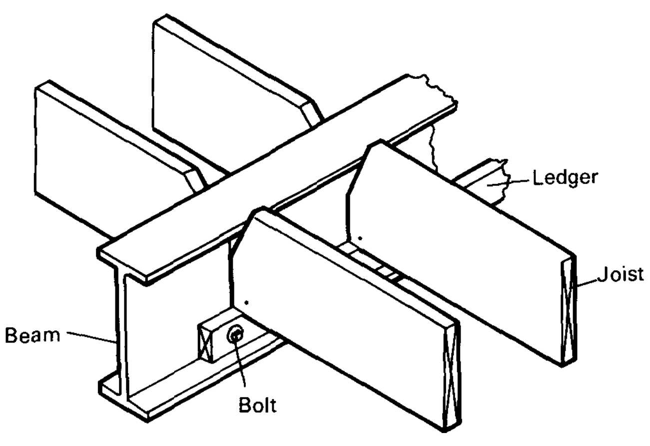
	Length of maximum clear span										
	1.0 x 10^6 psi	1.1 x 10^6 psi	1.2 x 10^6 psi	1.3 x 10^6 psi	1.4 x 10^6 psi	1.5 x 10^6 psi	1.6 x 10^6 psi	1.7 x 10^6 psi	1.8 x 10^6 psi	1.9 x 10^6 psi	2.0 x 10^6 psi
Living areas (40 lb/ft^2 live load)											
Minimum required bending stress (lb/in^2)	920	980	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″
Sleeping areas (30 lb/ft^2 live load)											
Minimum required bending stress (lb/in^2)	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.

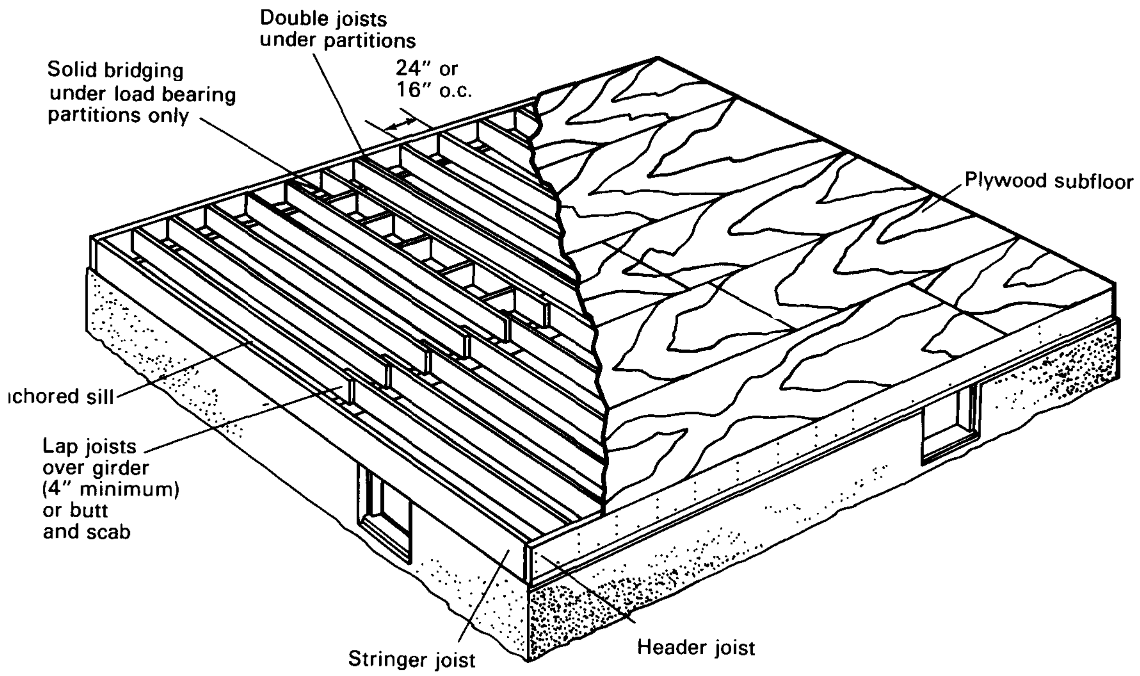


Figure 35 – *Off-center spliced joist system allows use of one short joist in every pair of joists.*

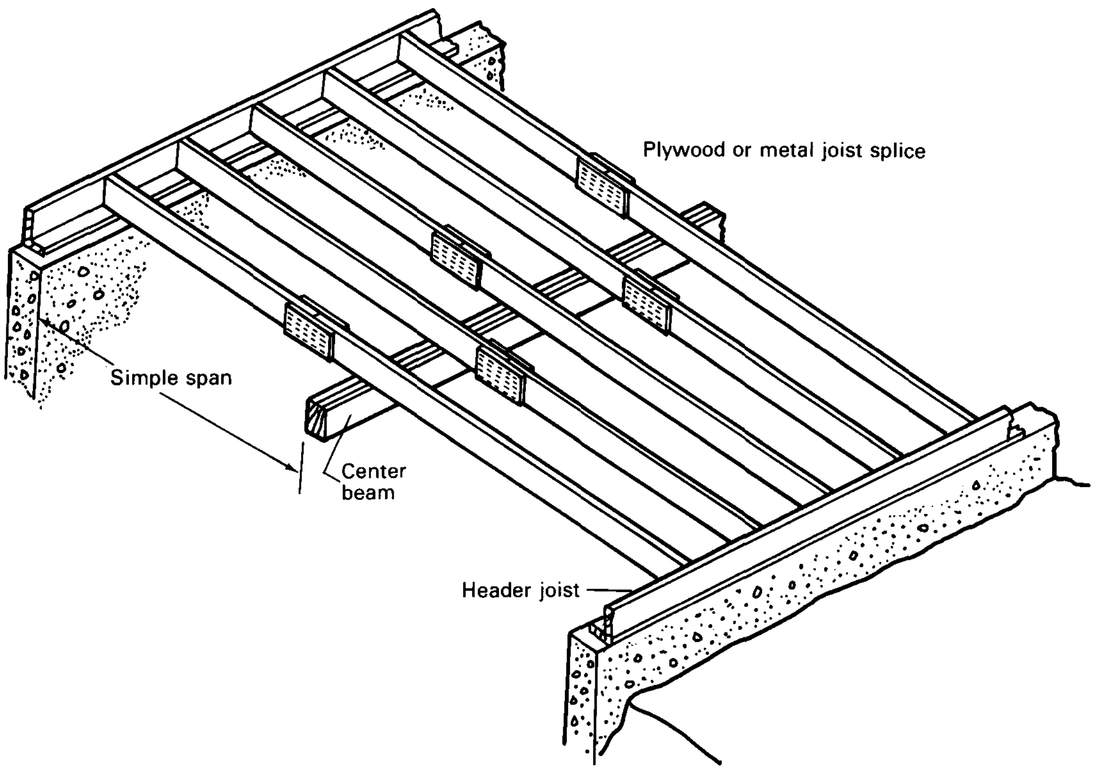
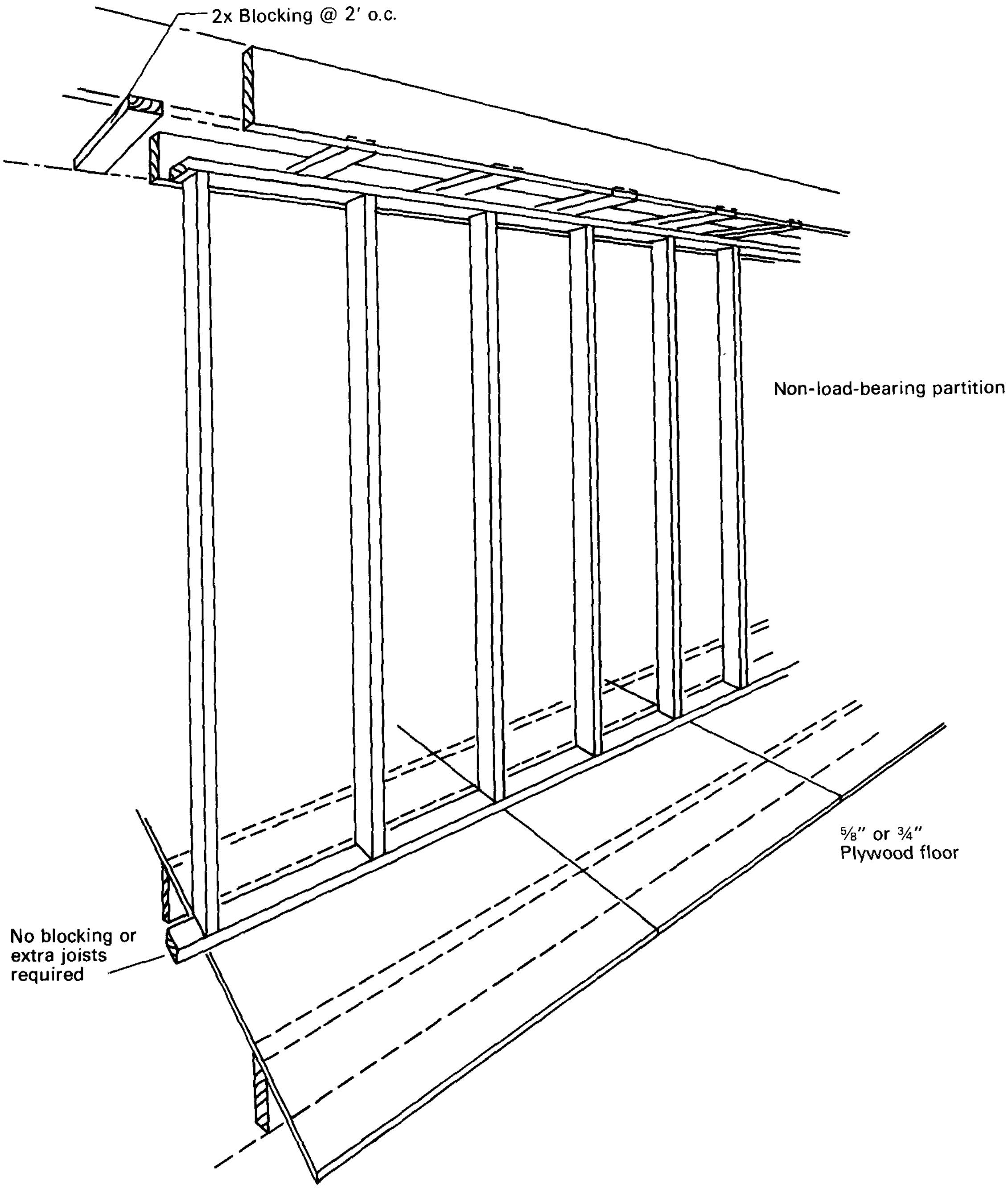


Figure 36 – *Non-load-bearing partitions need no extra floor framing or blocking with ⁵⁄₈-inch or thicker ply-wood floor.*



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 10^6 pounds per square inch*

	Length of maximum clear span							
	0.6 x 10^6 psi	0.8 x 10^6 psi	1.0 x 10^6 psi	1.2 x 10^6 psi	1.4 x 10^6 psi	1.6 x 10^6 psi	1.8 x 10^6 psi	2.0 x 10^6 psi
Living areas (40 lb/ft^2 live load)								
2 x 6 joists								
Minimum required bending stress (lb/in^2)	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^2)	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^2)	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^2)	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^2 live load)								
2 x 6 joists								
Minimum required bending stress (lb/in^2)	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^2)	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^2)	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^2)	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.

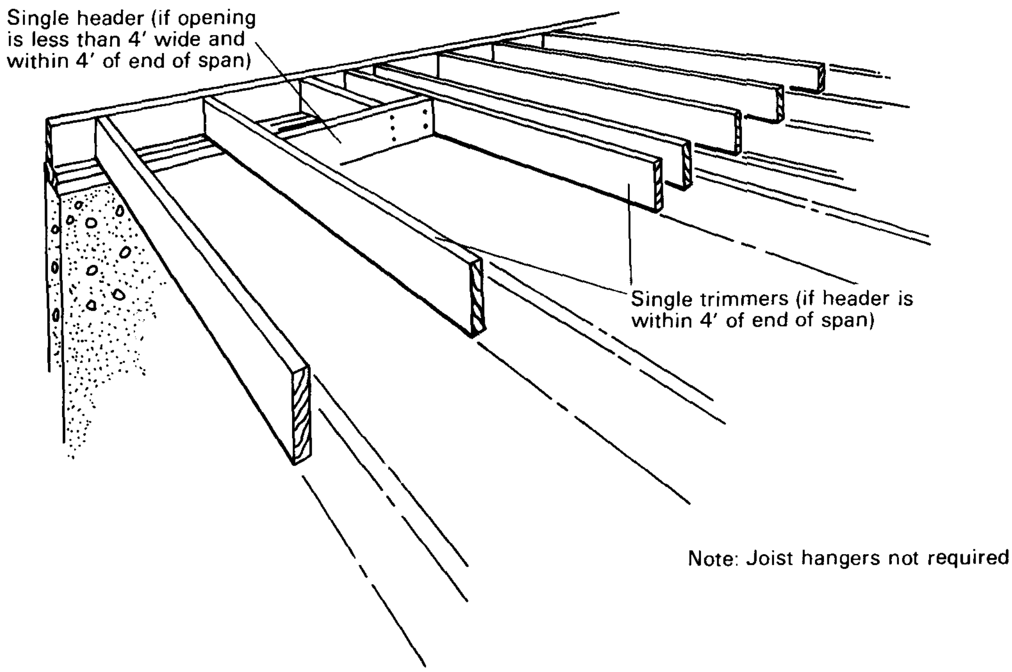
Where wider openings are unavoidable, double headers are generally adequate up to 10 feet (fig. 38). Tail joists may be connected to double headers in the same manner and under the same conditions as specified above for single headers. Tail joists that are end nailed to a double header should be nailed 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

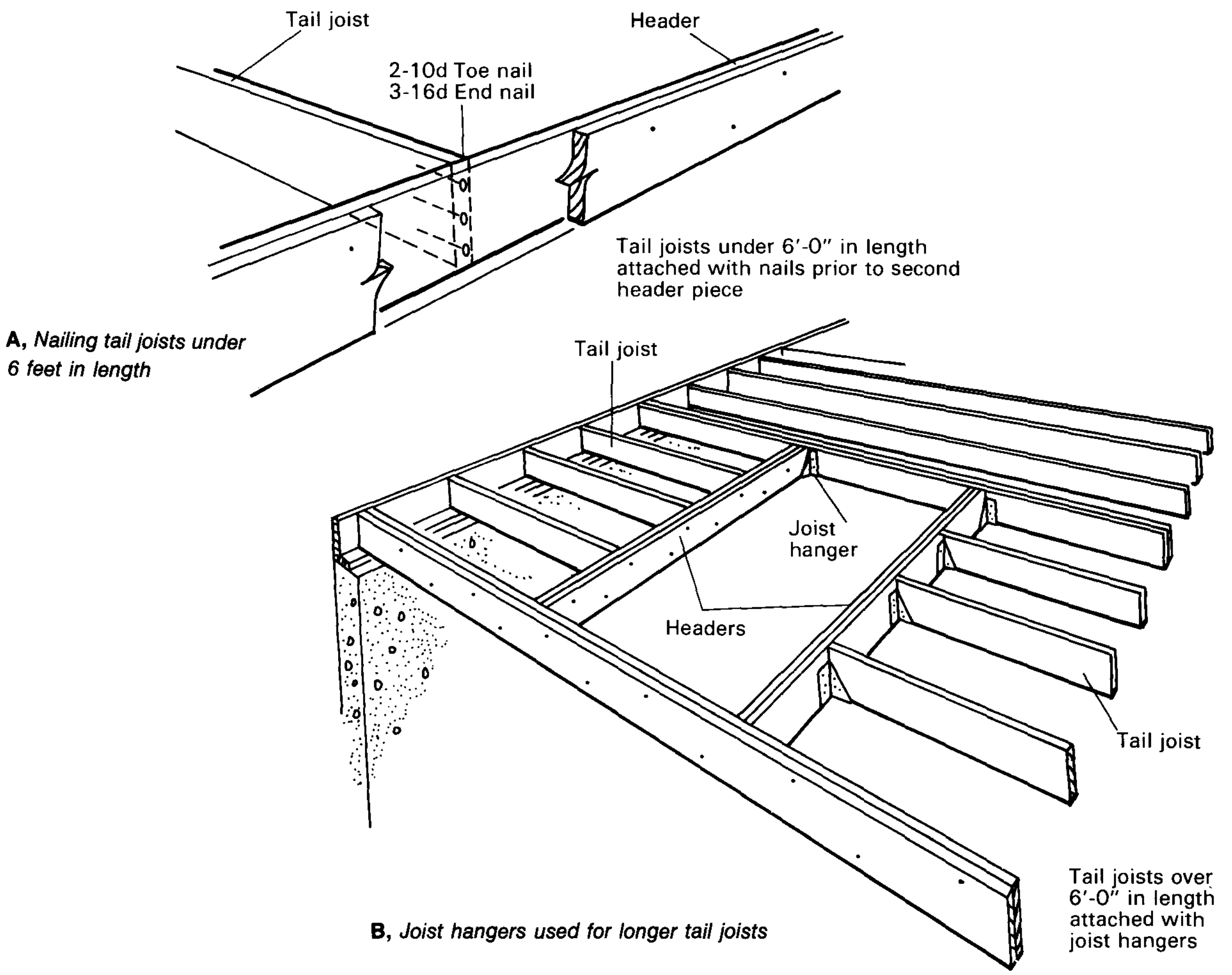
A bathtub full of water is heavy and may cause excessive deflection of floor joists. A doubled floor joist should be provided beneath the tub to support this load (fig. 41). The intermediate joist should be spaced to allow installation of the drain. Metal hangers or wood blocking should be used to support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

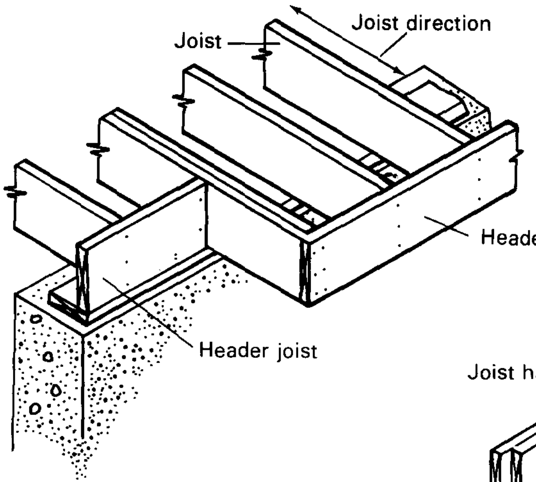
Stairways

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.

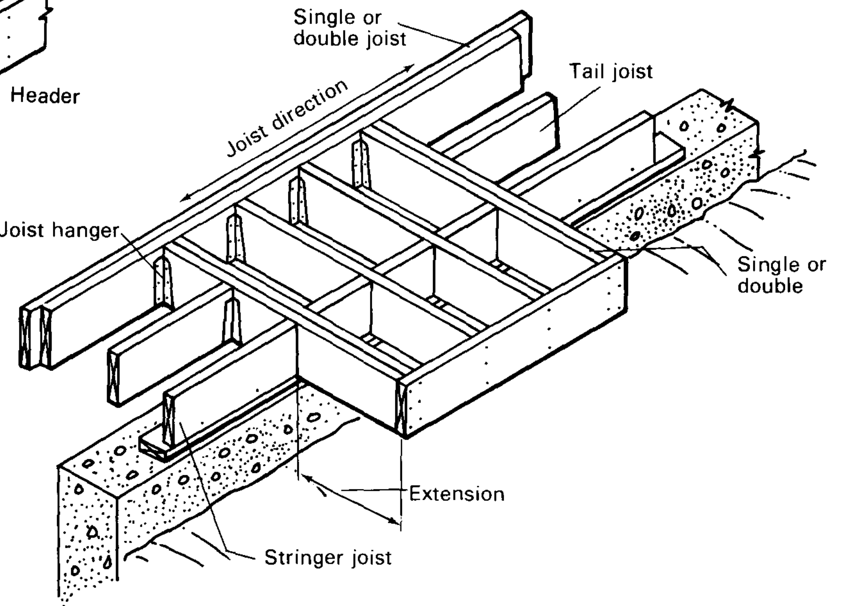
Construction

Both main and service stairs may be ordered prebuilt

Figure 39 – *Floor framing at wall projections:*



A, ***Continuation of floor joists***



B, ***Projection perpendicular to floor joists***

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

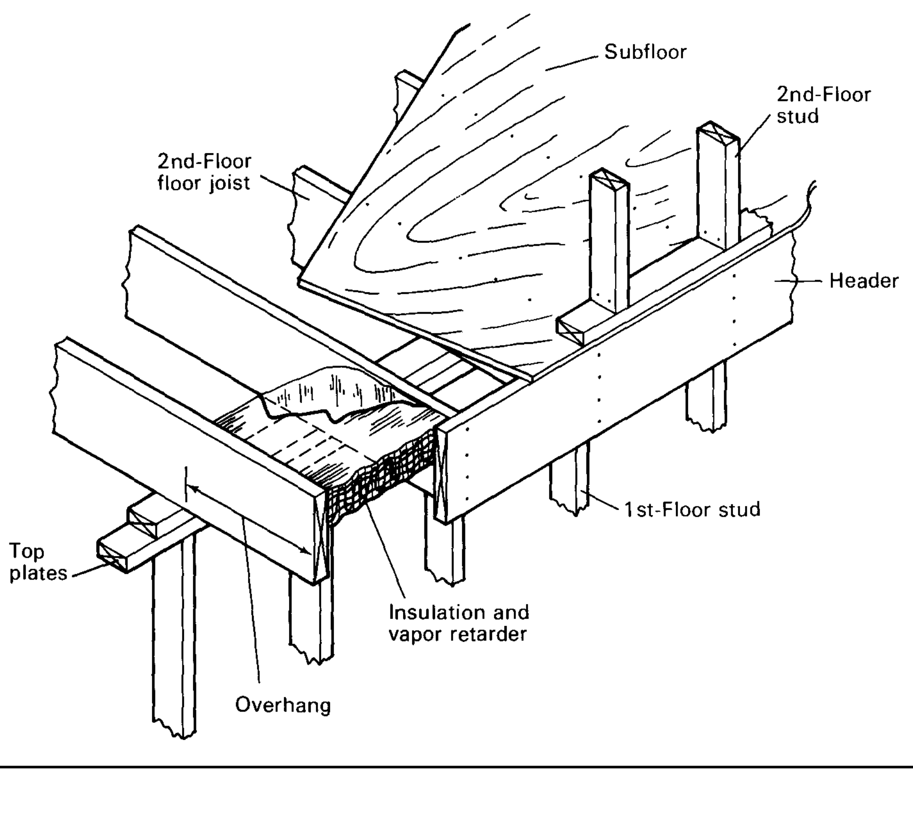


Figure *41—Framing for bathtub.*

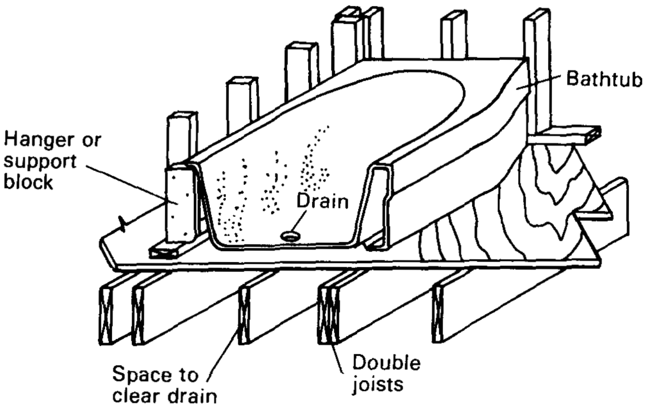


Figure *42—Drilled holes in joists.*

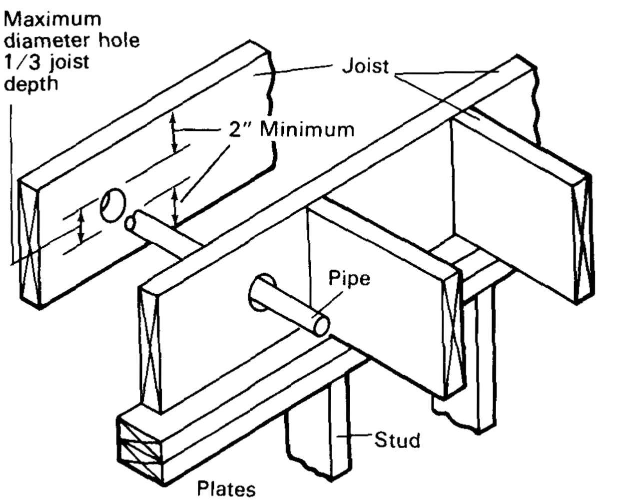
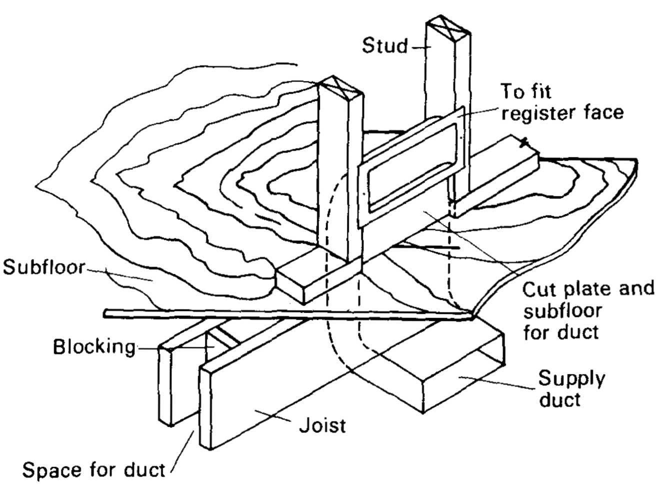


Figure 43 – *Spacing joists to allow installation of ductwork in load-bearing partitions.*



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:

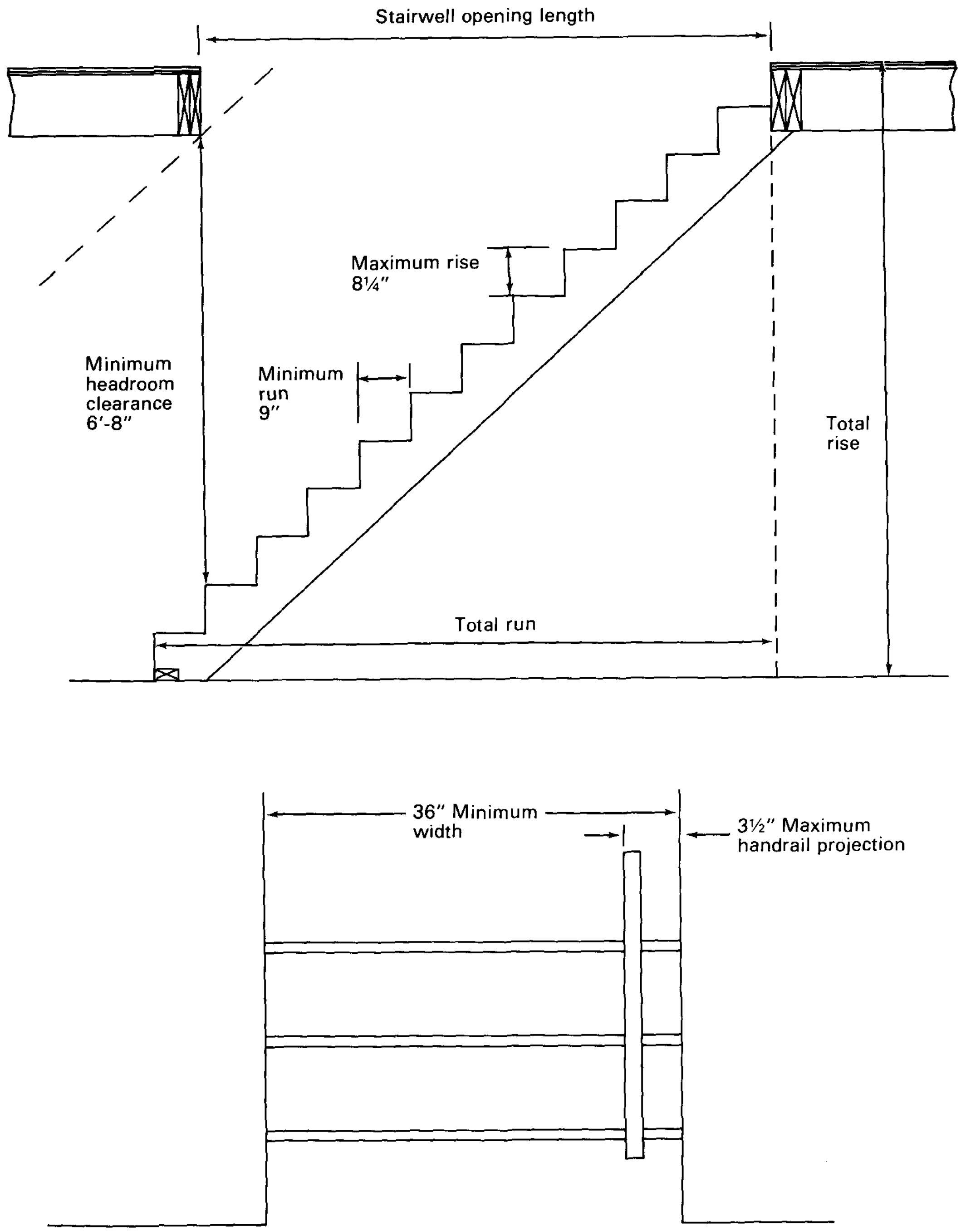
- Minimum headroom clearance — 6 feet 8 inches
- Minimum stairway width — 36 inches
- Minimum stair tread run — 9 inches
- Maximum stair rise — 8% inches

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

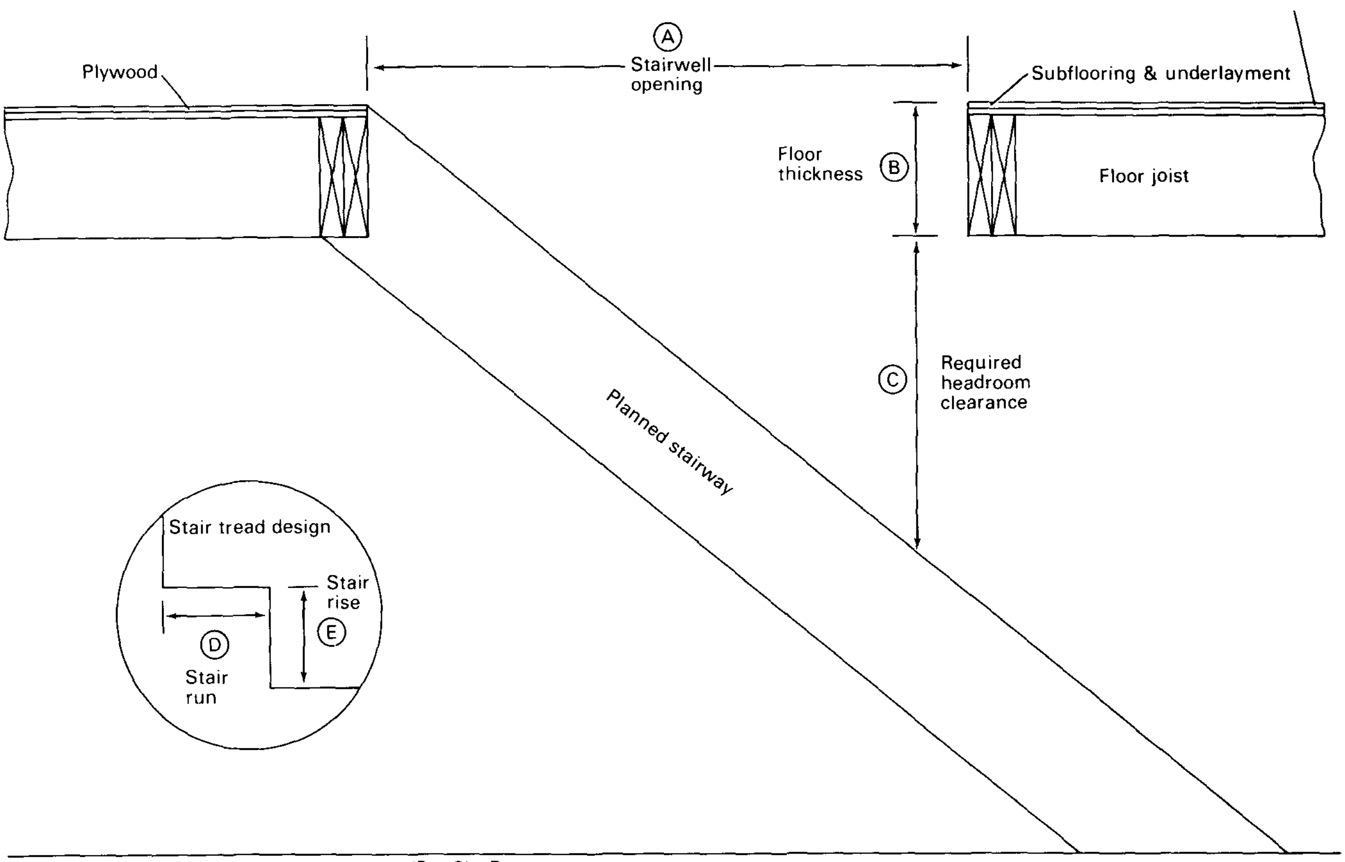
The total run of the stairway is a critical value only in those circumstances where the direction of the stairs causes them to terminate close to a wall. If there is insufficient space to construct a single straight-run stairway, a stairway with landing (fig. 46) must be considered. In certain instances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



$$A = \frac{(B + C) \times D}{E}$$

where A is the length of the stairwell opening in inches.

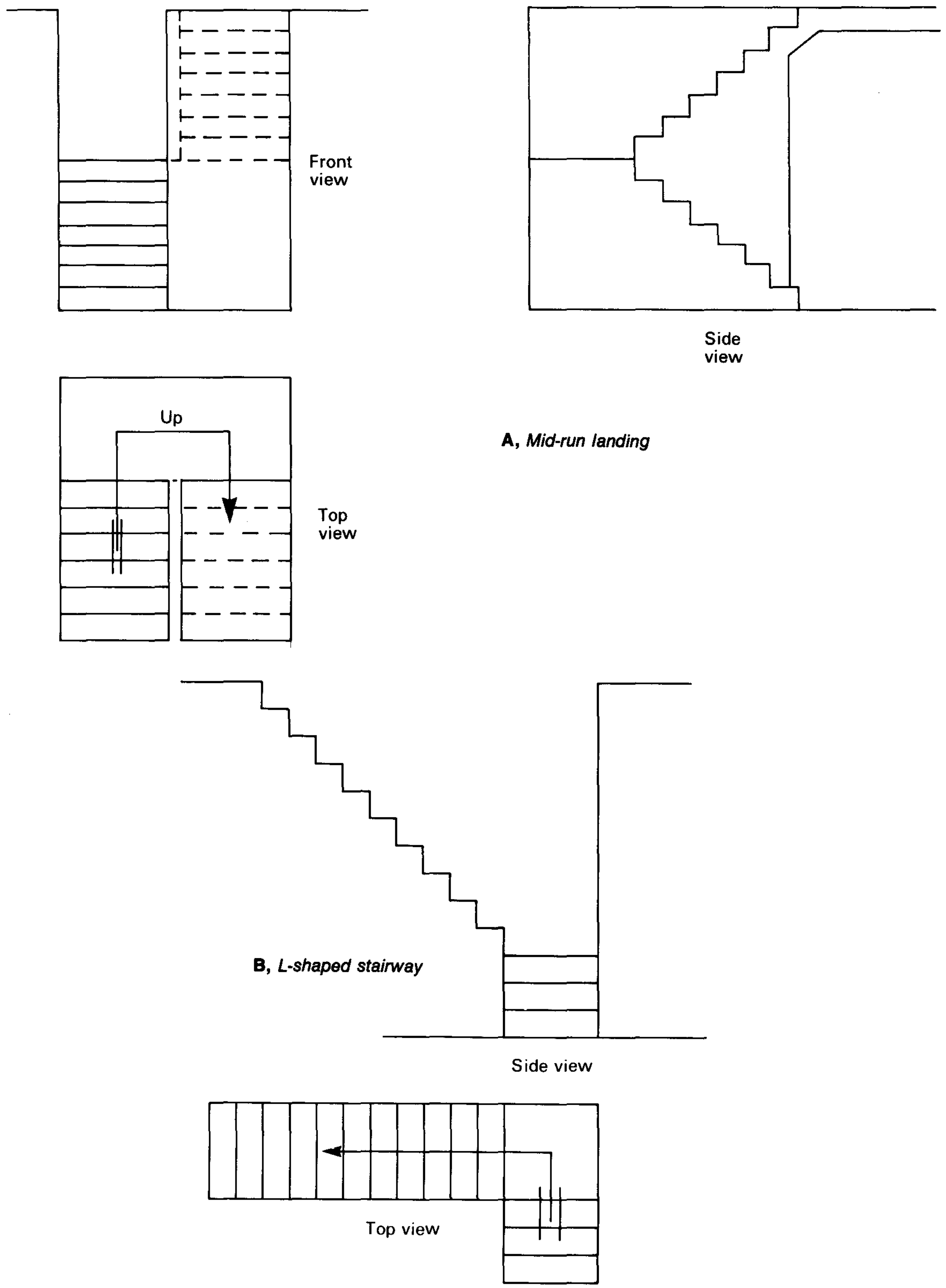
B is the total thickness of the upper floor system including joist, subflooring, and underlayment in inches.

C is the headroom clearance required in inches.

D is the planned stair tread run in inches.

E is the planned stair tread rise in inches.

Figure 46 – *Space-saving stair design:*



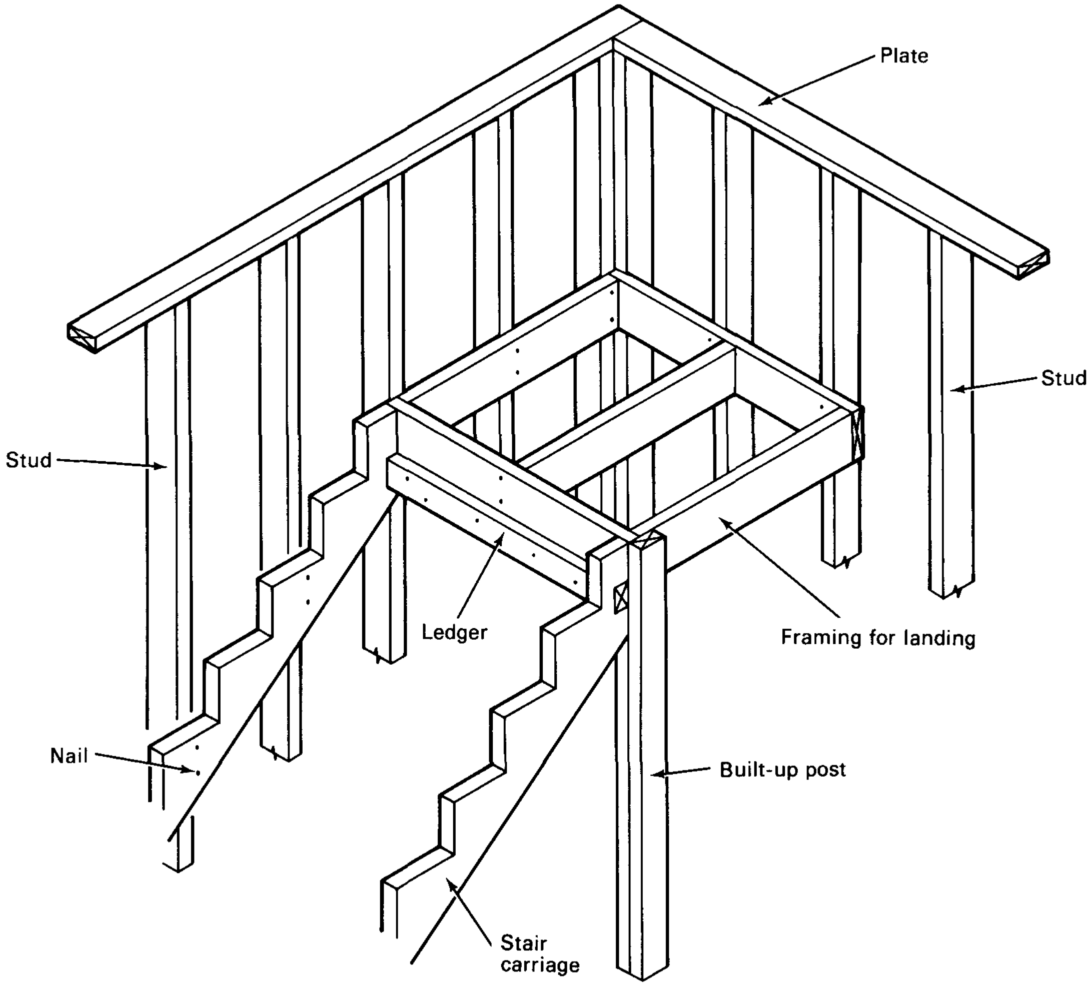
A, *Mid-run landing*

B, *L-shaped stairway*

Service stairs

Service stairs consist of the stair treads and the stringers or stair carriages that carry the treads and support 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.

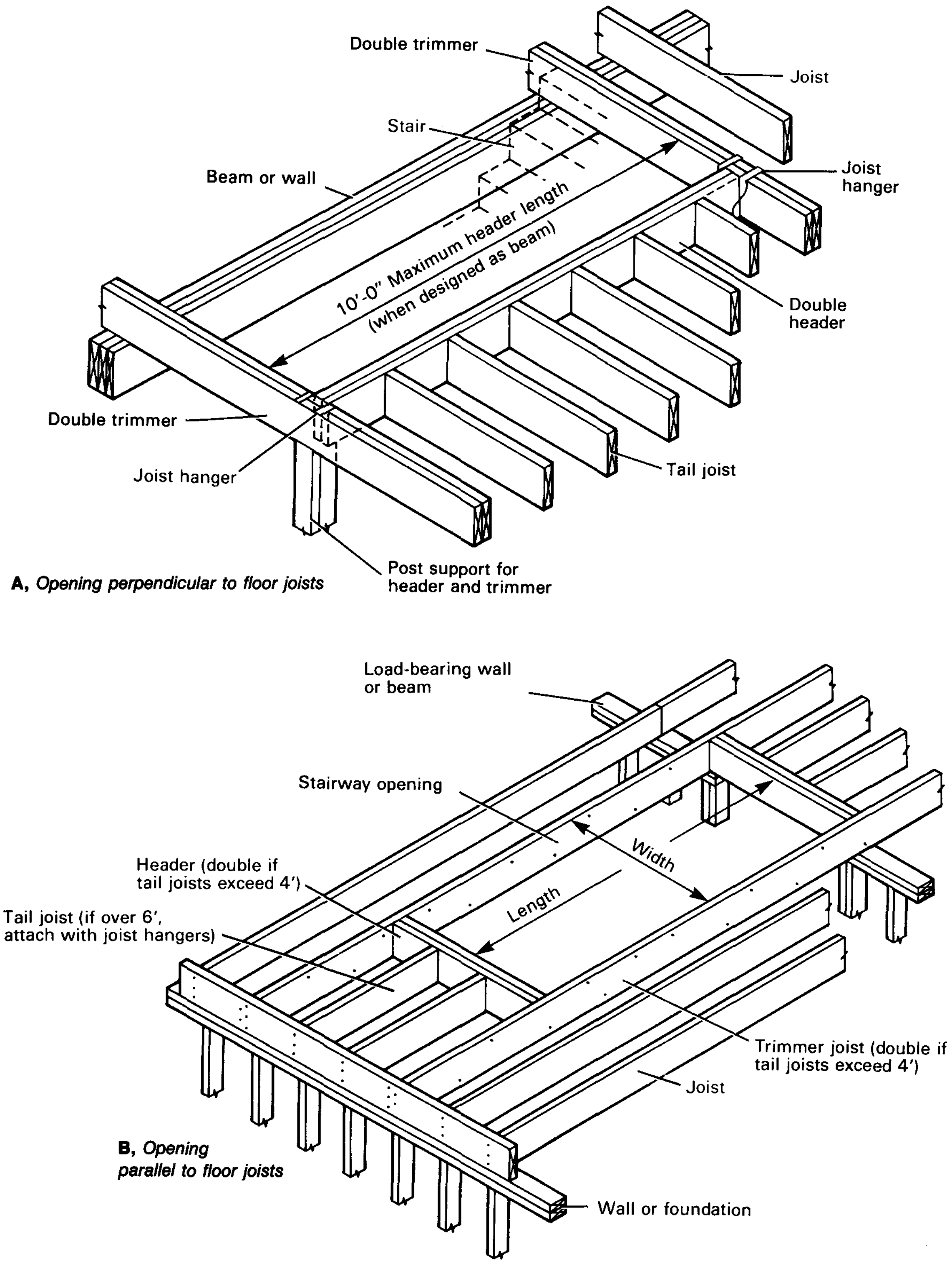
The stringers can be toenailed to the joist header at the top of the stairway (fig. 49B). At the bottom of the stairway the stringers rest on and can be anchored to a concrete footer or a basement floor. Alternatively, the stringers can be anchored to a 2- by 4-inch or 2- by 6-inch kicker plate of pressure-treated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



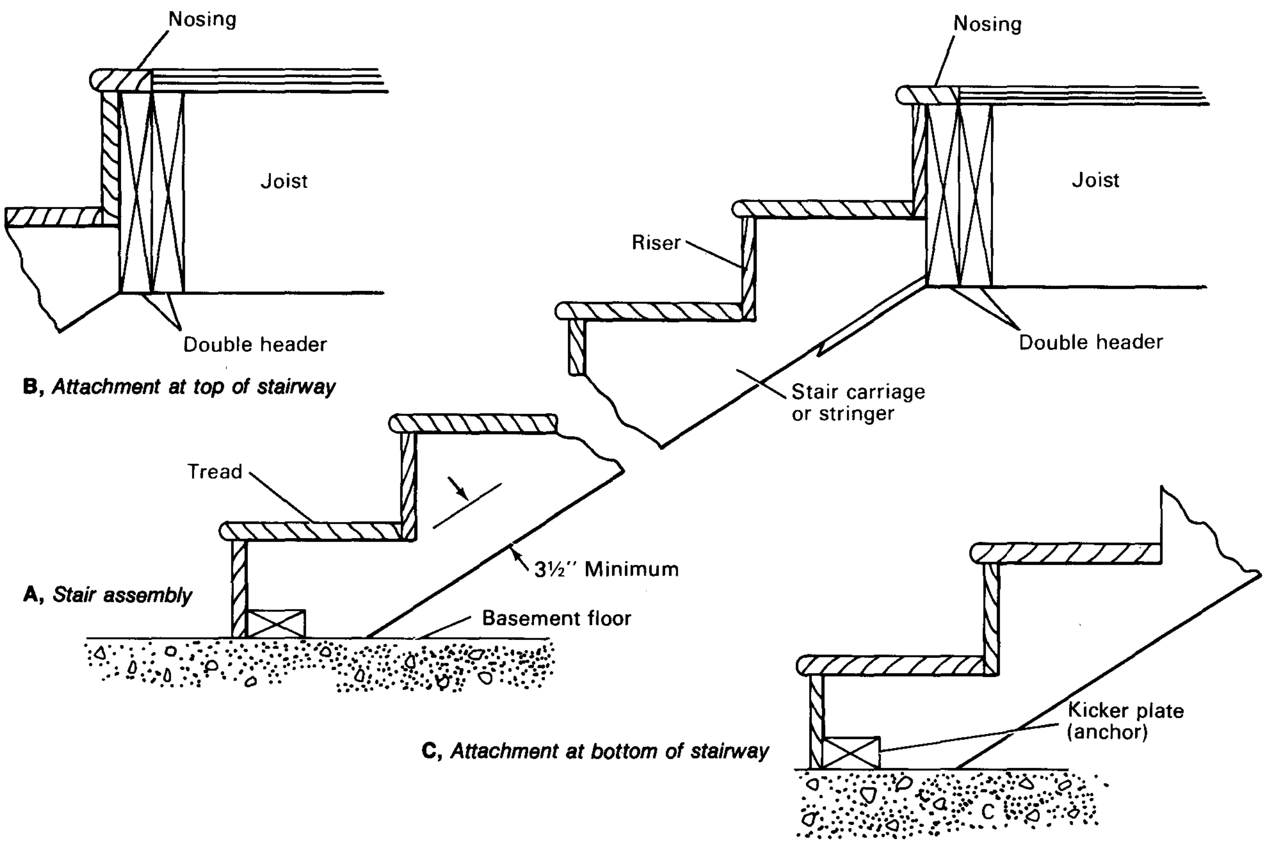
A, *Opening perpendicular to floor joists*

B, *Opening parallel to floor joists*

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.

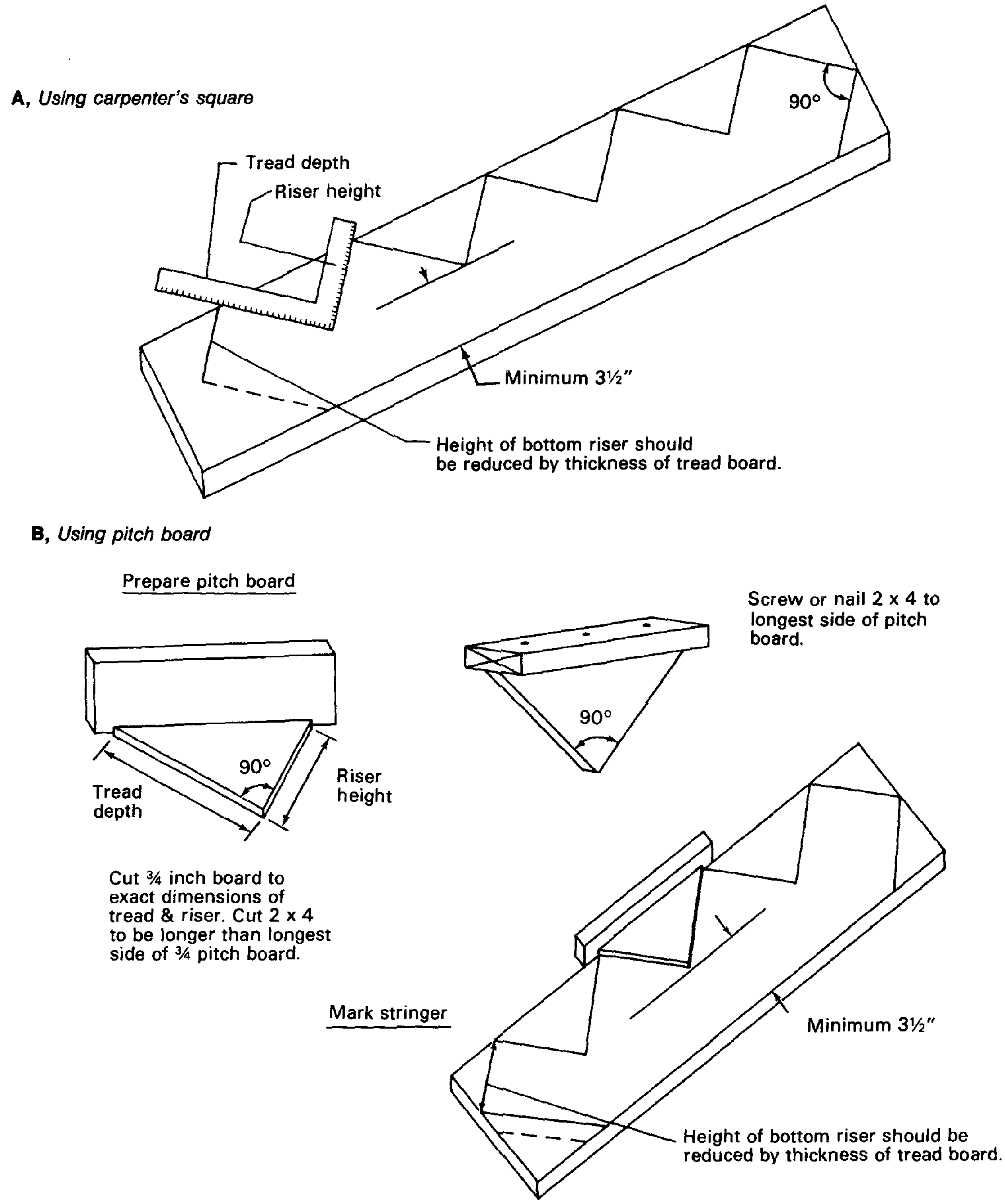
Perhaps the simplest technique for stair construction is to nail 1- by 3-inch or 2- by 2-inch cleats to the stringers below each tread line (fig. 51B). After treads are cut to the proper length they are placed between the stringers on top of the cleats. When the treads are in place, they are nailed at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

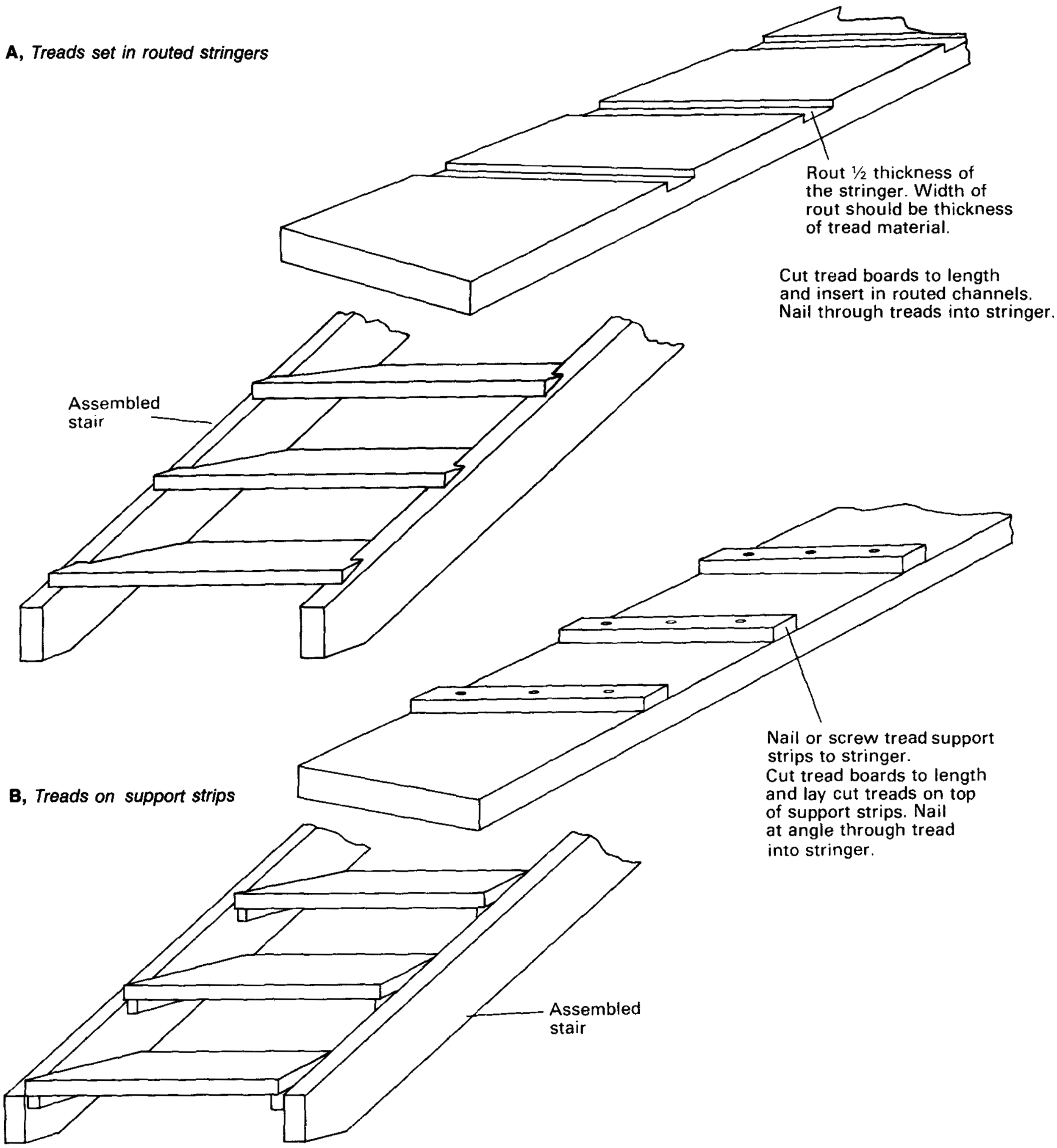


trim boards, cove moldings nailed beneath stair tread nosing and between trim boards and wall, and decorative railing and balusters; and that they are of wood species that are clear and can be given a durable natural finish.

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 ¾-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:*



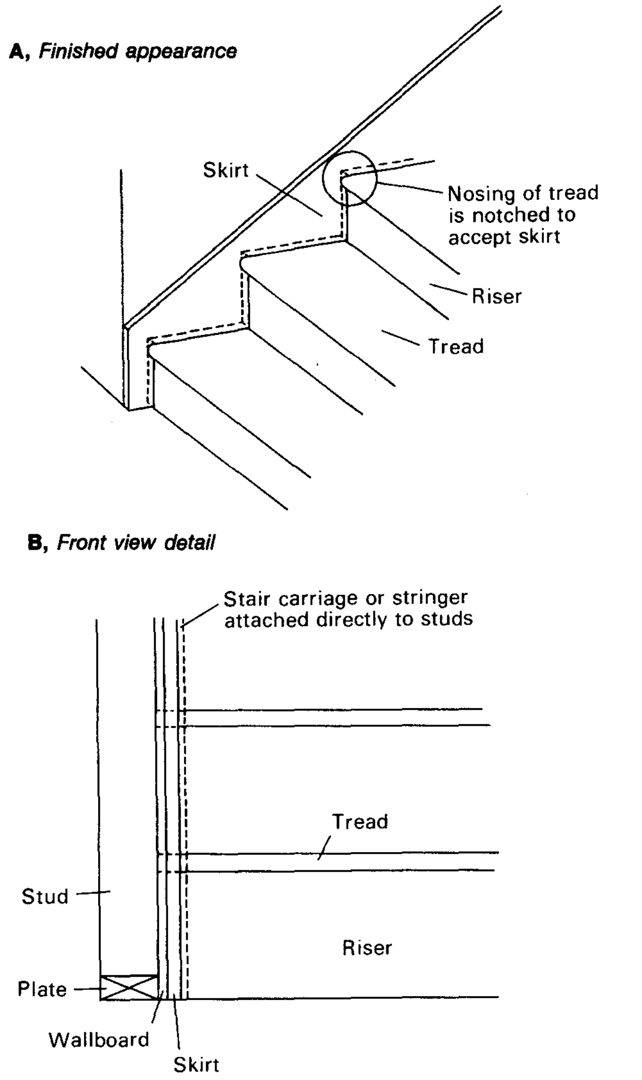
The trim work required to produce an attractive and safe main stairway is often best performed by a local millwork contractor. In addition to possessing the skills and equipment, such a contractor is familiar with the local regulations that control stair design and construction.

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:*



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 ½ inch to 1⅛ 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 ¾ 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 1⅝-inch narrow crown staples for plywood ½ to ¾ 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 ⅛-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 sheating or subfloor. For example, an index mark of 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 ½ inch when joists are spaced 16 inches on center, and ¾ 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 ¾ 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. Comer 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.*

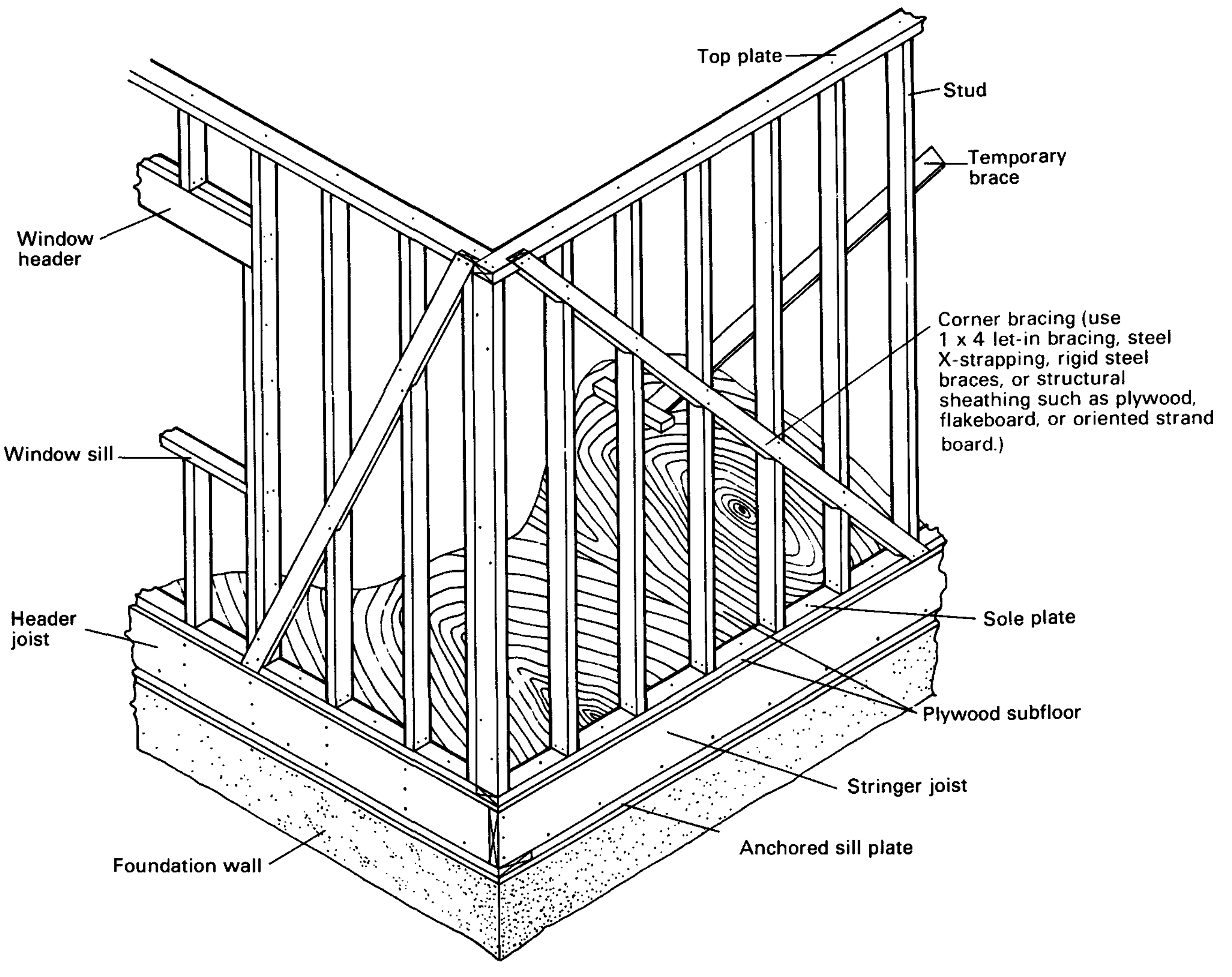
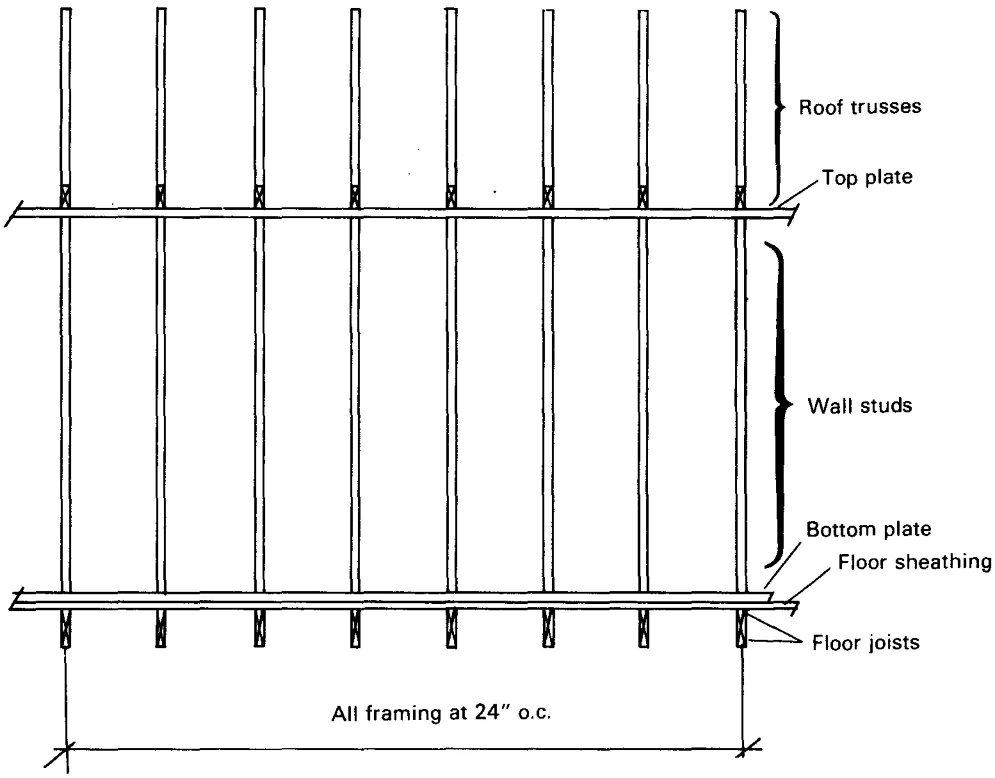


Figure 54 – *Vertical alignment of framing members simplifies framing and transmits loads directly down through structural members.*



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 comers can be used in framing the walls. Blocking between two comer 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

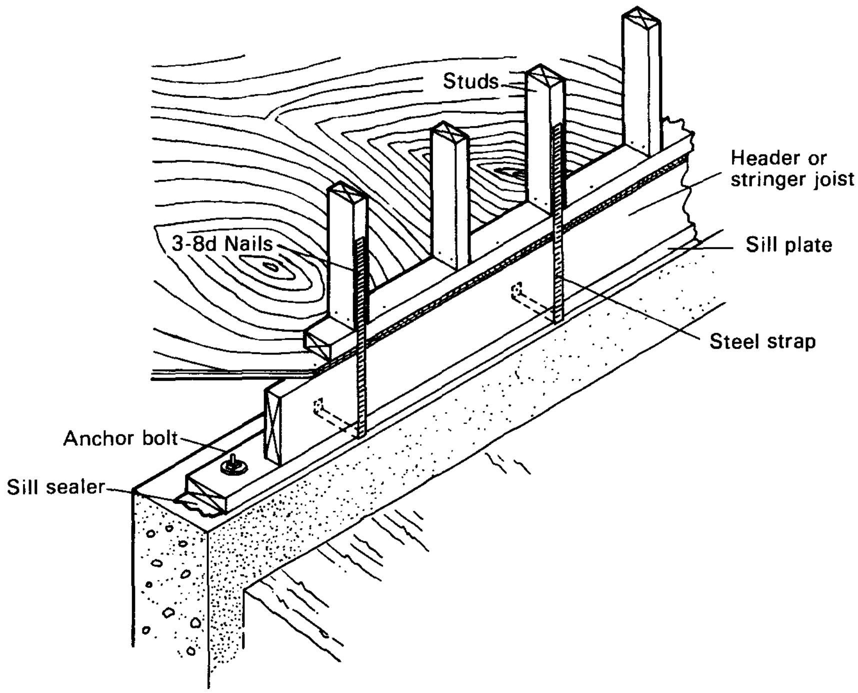
Figure 58 shows a commonly used method of wall and ceiling framing for platform construction in 1½-story or 2-story houses with finished rooms above the first floor. The edge floor joist is toenailed to the top wall plate with 8d nails spaced 24 inches on center. The subfloor and wall framing are then 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 %-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 ½ 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 %-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 jambs 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

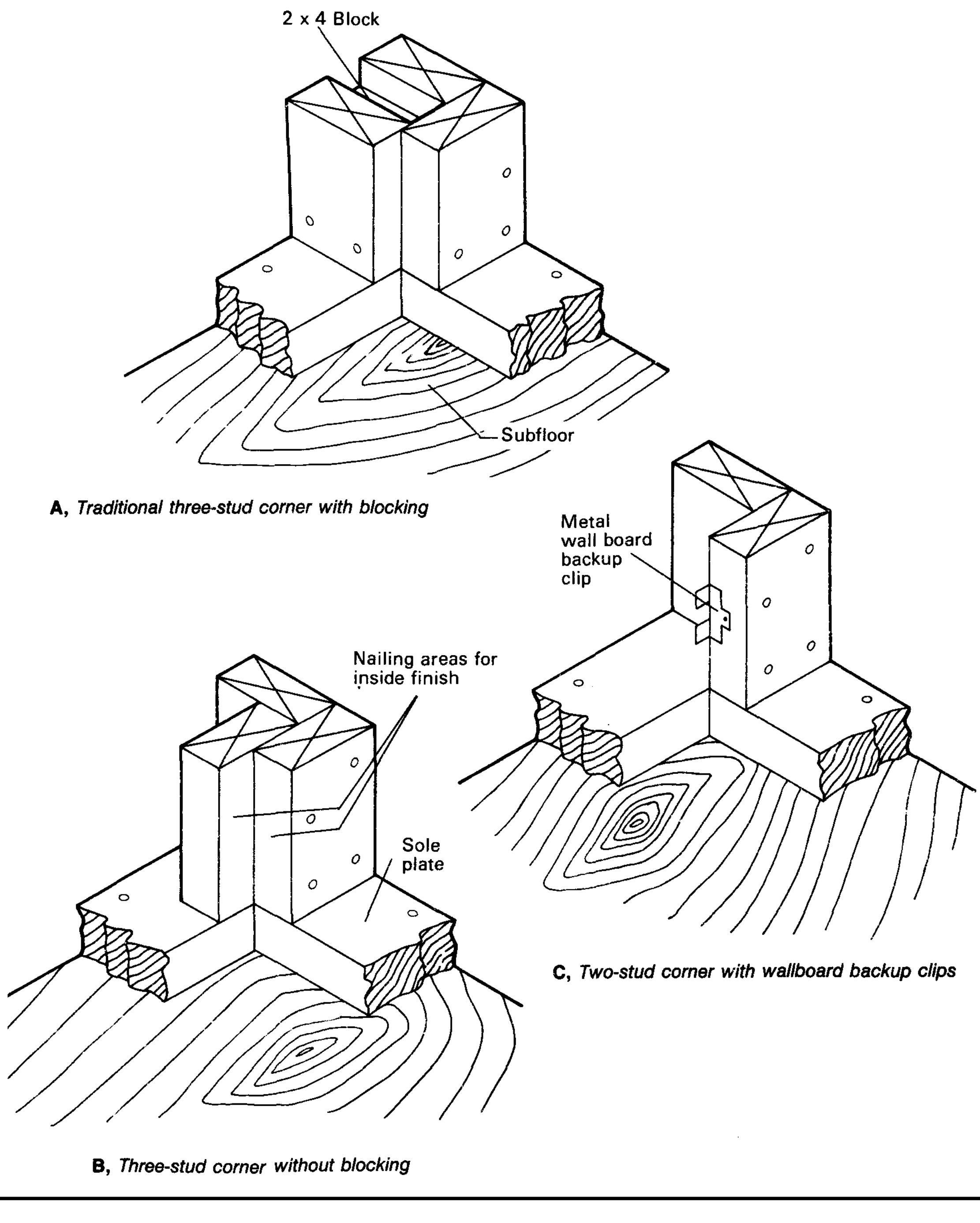
Exterior wall sheathing is the covering applied over the outside wall framework of studs, plates, and window and door headers. It forms a base upon which the exterior finish can be applied. Certain types of sheathing and methods of application can provide great rigidity to the house, eliminating the need for special comer 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 $^5/_{16}$ inch to ¾ inch in various grades and constructions for stud spacings of 16 inches and 24 inches on center. When plywood sheathing is adequately nailed, additional comer 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 comers only, the remainder of the wall being covered with other sheathing materials. In this method, plywood panels replace comer 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:*

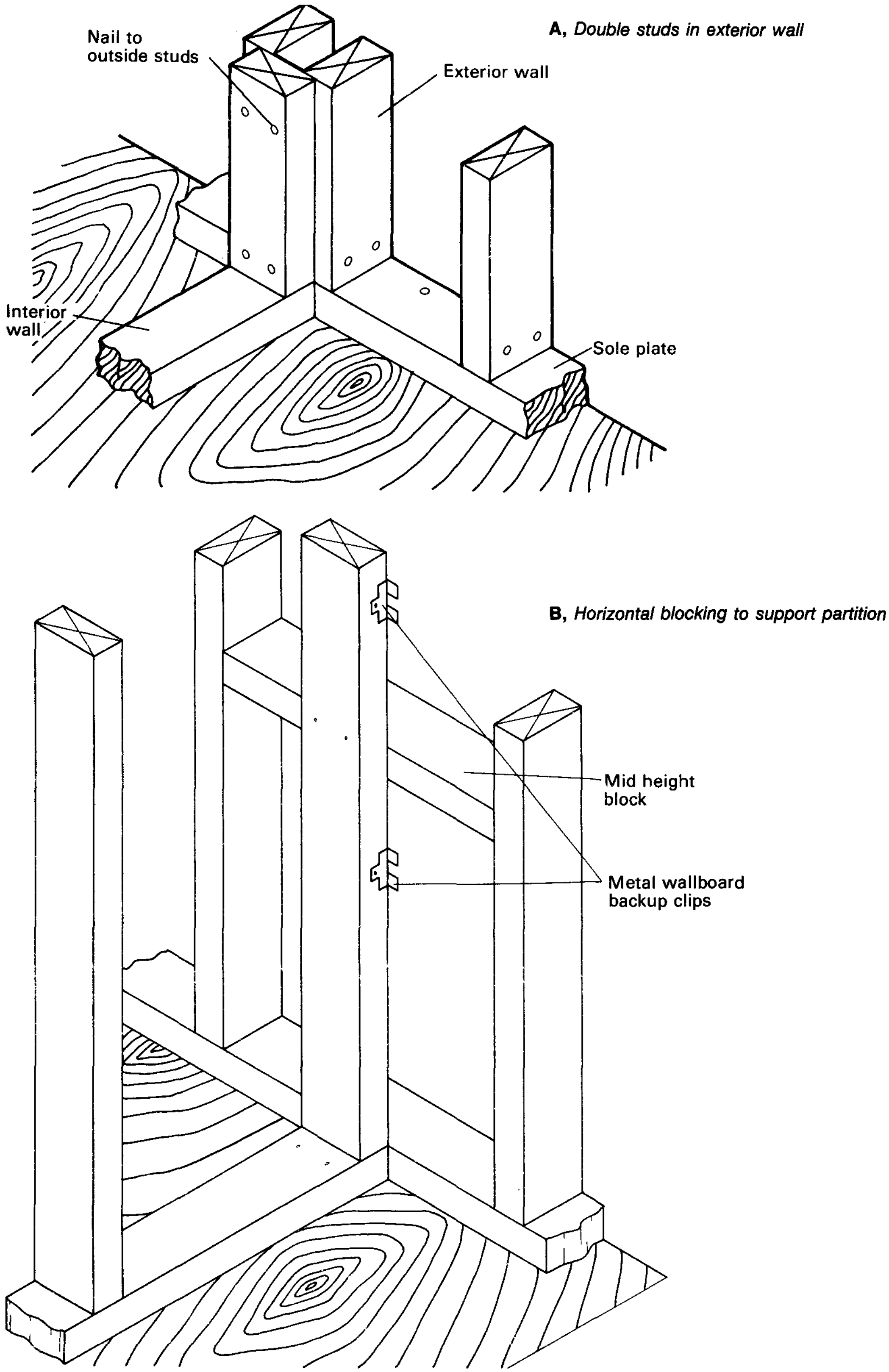
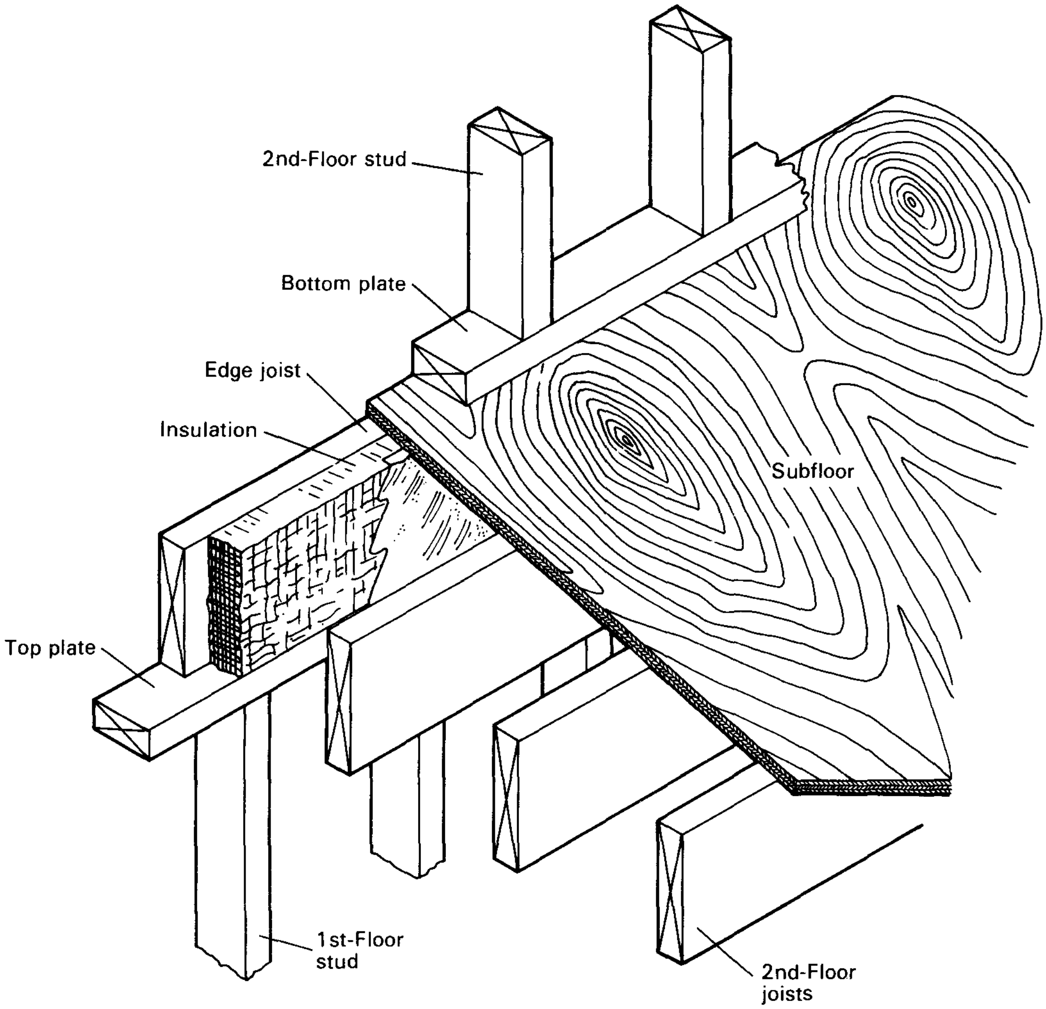


Figure 58 – *Second-story framing for platform construction.*



Waferboard, described in a later section on roof sheathing, is commonly available in thicknesses ranging from $^{7}/_{16}$ inch to ¾ 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 $^{1}/_{8}$ inch thicker than plywood for the same applications.

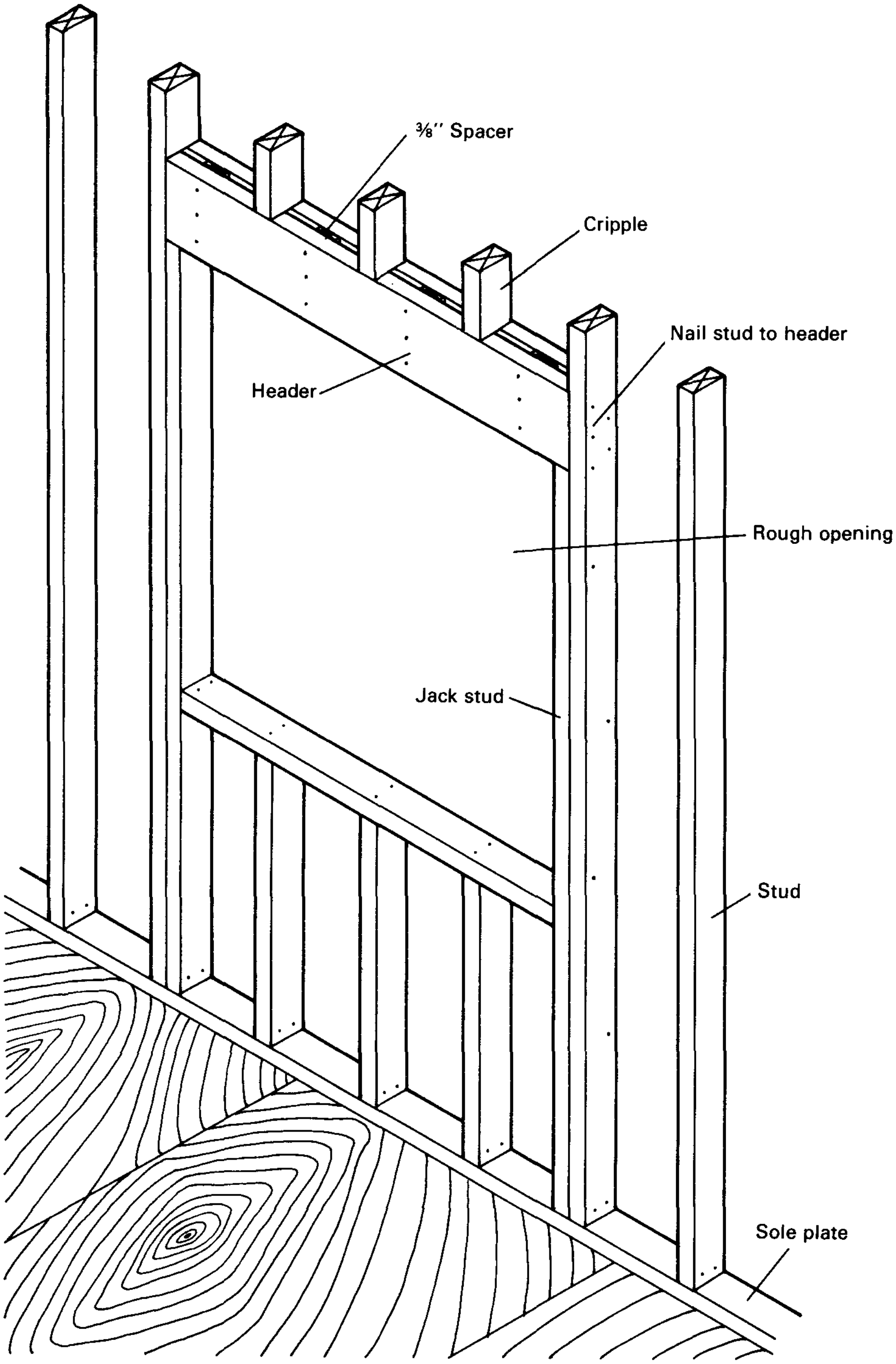
Oriented strandboard, often called OSB, is a composite panel of compressed strand-like wood particles arranged in layers, usually three to five, oriented at right angles to each other in the same fashion as plywood. Bonding is accomplished with a phenolic resin as with waferboard. Production thicknesses 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 $^{5}/_{8}$-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 composition (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	1,000	75	1	3′8″	3′5″	3′3″	3′1″	2′11″
only			2	6′8″	6′6″	6′3″	6′1″	5′10″
Roof	1,000	75	1	4′0″	3′9″	3′6″	3′3″	3′1″
only			2	7′0″	6′9″	6′6″	6′4″	6′2″
Roof &	1,000	75	1	2′1″	2′0″	—	—	—
floor			2	4′3″	4′0″	3′9′	3′6″	3′4
Floor	1,500	90	1	4′5″	4′2″	3′11″	3′8″	3′6″
only			2	8′2″	7′11″	7′8″	7′5″	7′0″
Roof	1,500	90	1	4′10″	4′6″	4′2″	3′11″	3′8″
only			2	8′6″	8′3″	8′0″	7′9″	7′6″
Roof &	1,500	90	1	2′6″	2′4″	2′3″	3′1″	2′0″
floor			2	5′0″	4′9″	4′5″	4′2″	4′0″
Live and dead loads: floor = 50 lb/ft²; roof = 40 lb/ft²								
Roof	1,000	75	1	3′0″	2′10″	2′7″	2′5″	2′4″
only			2	6′0″	5′7″	5′3″	4′11″	4′7″
Roof &	1,000	75	1	—	—	—	—	—
floor			2	3′7″	3′4″	3′2″	3′0″	2′10″
Roof	1,500	90	1	3′7″	3′4″	3′2″	2′11″	2′9″
only			2	7′3″	6′9″	6′3″	5′11″	5′7″
Roof &	1,500	90	1	2′2″	2′0″	—	—	—
floor			2	4′4″	4′0″	3′9″	3′7″	3′4″
Live and dead loads: floor = 50 lb/ft²; roof = 50 lb/ft2								
Roof	1,000	75	1	2′5″	2′3″	2′1″	2′0″	—
only			2	4′9″	4′6″	4′2″	3′11″	3′8″
Roof &	1,000	75	1	—	—	—	—	—
floor			2	3′2″	2′11″	2′9″	2′7″	2′5″
Roof	1,500	90	1	2′10″	2′8″	2′6″	2′4″	2′3″
only			2	5′9″	5′4″	5′0″	4′8″	4′5″
Roof &	1,500	90	1	—	—	—	—	—
floor			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 comer 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.

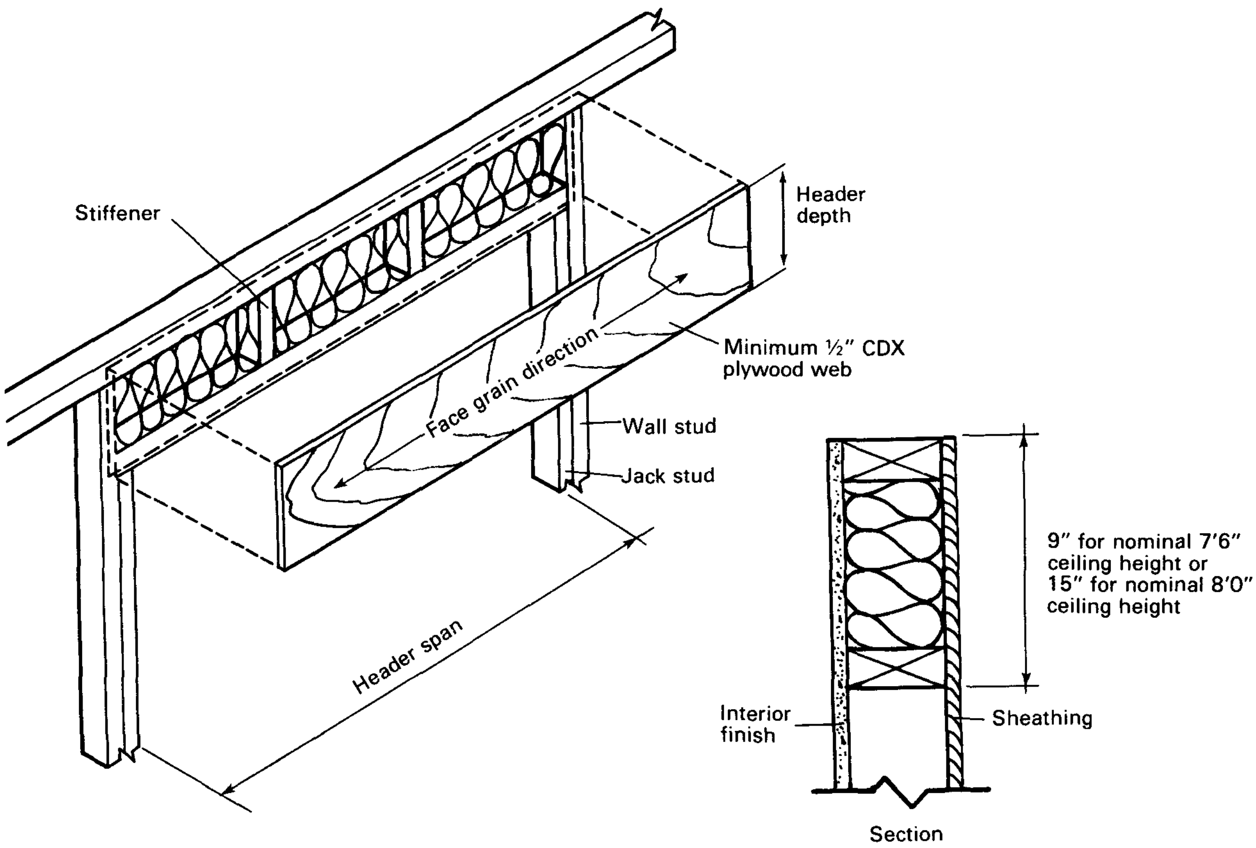
Insulating fiberboards are manufactured in ½-inch thickness and in 4- by 8-foot and 4- by 9-foot sizes for vertical applications of ½-inch regular-density sheathing. Insulating board sheathing should be fastened to the wall framing with 1½-inch roofing nails or with crown staples 1⅝-inches wide.

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 ⅛ 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 % 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 comer bracing is required. Panels for wall sheathing are usually produced in thicknesses from $^{3}/_{8}$ 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 ½-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 $1^{5}/_{8}$ inches long are used for plywood ranging from 5/16 inch through ½ 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 $^{1}/_{8}$ inch and end spacing of $^{1}/_{16}$ inch should be maintained between panel sheets.

If this type of sheathing is installed only at comers to eliminate let-in wood bracing, ½-inch thickness should be used. The panels should be nailed with 1½-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 ¾ 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 comer bracing for wall framework. Diagonal wood sheathing should be applied at a 45° angle. This method of sheathing adds greatly to the rigidity of the wall and eliminates the need for comer 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 ½-inch medium density or nail-base structural insulating board sheathing is used. Galvanized roofing nails 1½ inches long or wide crown staples 1⅝ inches long should be used to attach the boards to the framing. Manufacturers usually recommend ⅛-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 1¼ 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 ½ 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 1½-inch galvanized roofing nails spaced about 3½ inches apart to produce seven nails in the 2-foot height. This eliminates the need for corner bracing. If comer 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, 1½-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—anothetriangular 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 roof trusses

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 $^3/_8$ inch or ½ 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.*

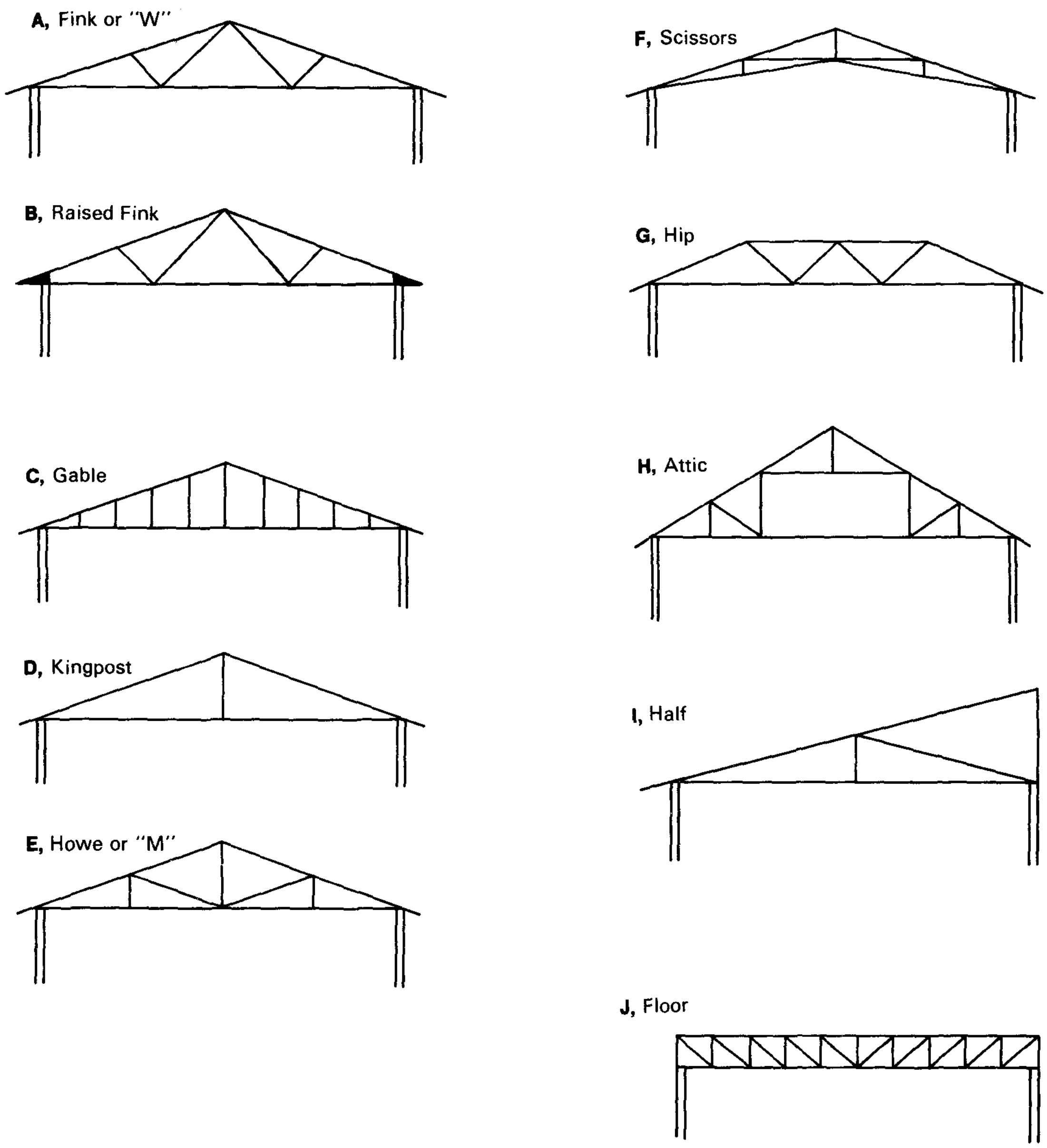
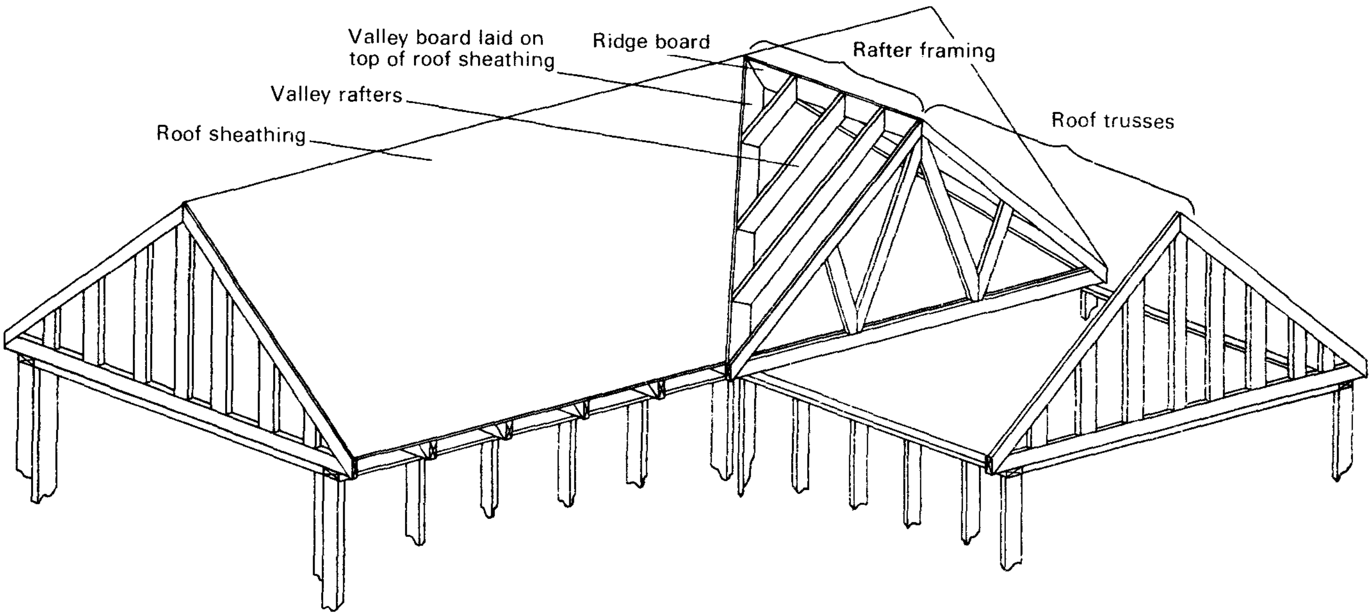


Figure 62 – *Rafter framing joining perpendicular truss roof segments.*



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. 611) 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. 615) 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 %-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).

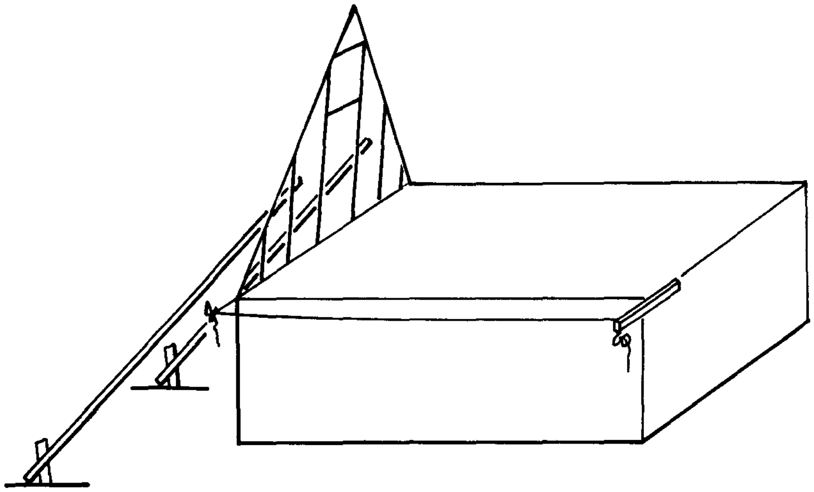
After six or seven trusses are erected, a temporary diagonal brace should be installed on top of the trusses running from the bottom of the gable truss to the top of the last truss on both sides of the house. This brace is then nailed into every truss with duplex nails. Temporary braces can prevent sudden 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.

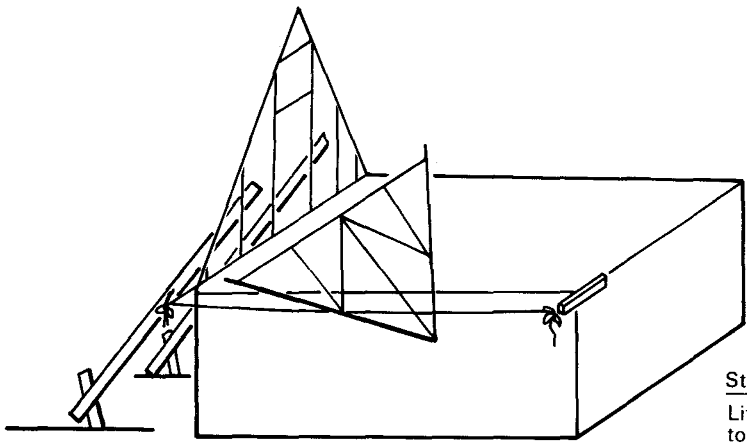
L-shaped houses have a wing attached perpendicular to the main house. Roof trusses are erected and sheathing installed on the main portion of the house. The roof trusses are then erected and the sheathing installed on the wing portion of the house. The two perpendicular rooflines are connected with rafter 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.*



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.

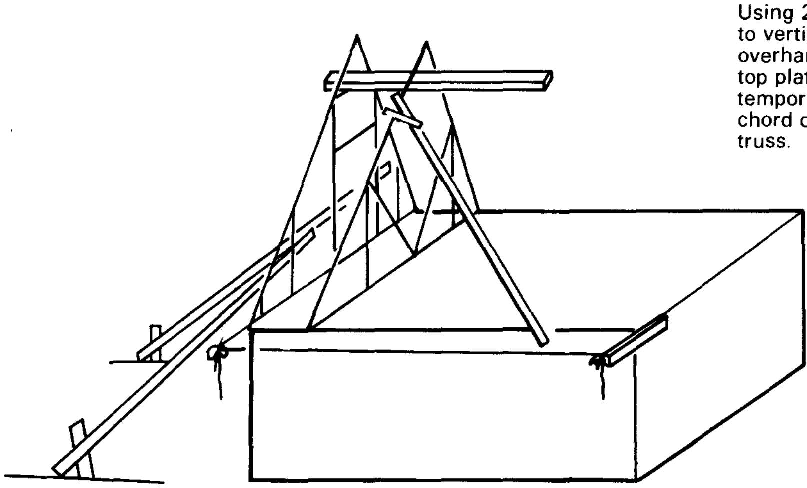


Step 2

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.

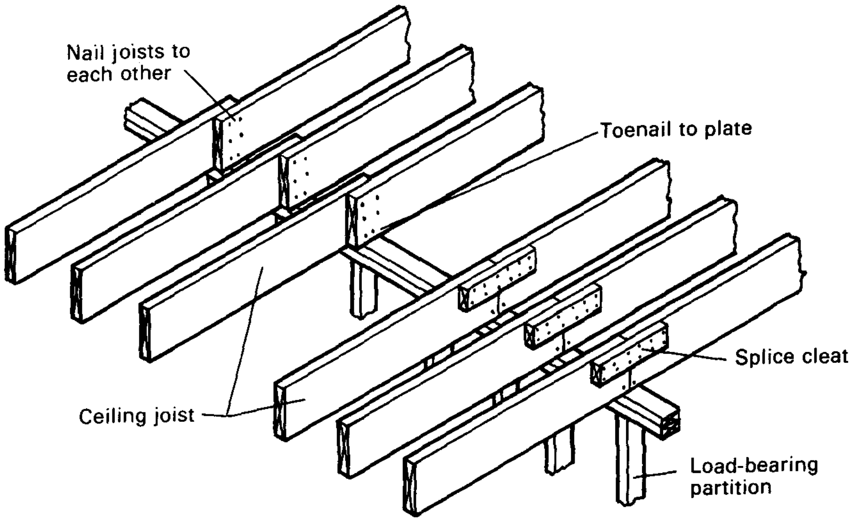
Rafters. In pitched roof construction, the ceiling joists are nailed in place after the interior and the exterior wall framing are complete. Rafters should not be erected until ceiling joists are fastened in place, because the outward thrust of the rafters may push out the exterior walls.

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).

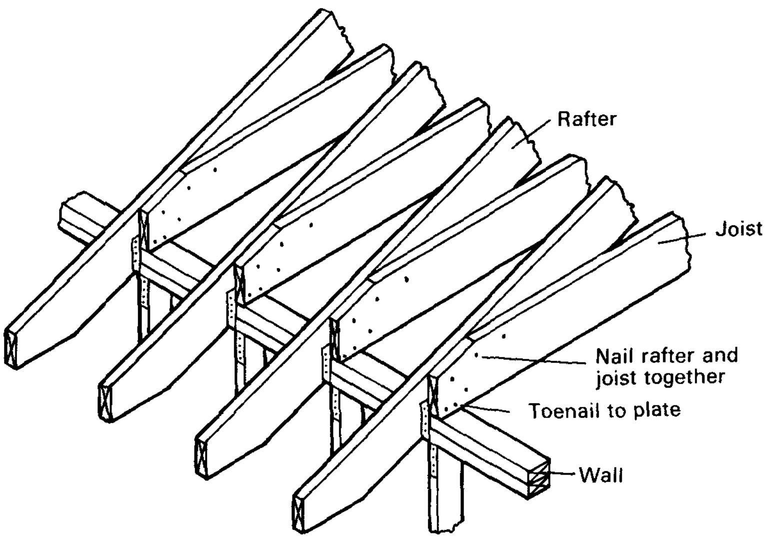
When roof spans are long and slopes are flat, it is common practice to use collar beams between opposing rafters. Steeper slopes and shorter spans may also require collar beams, but only between every third pair of rafters. Collar beams can be 1- by 6-inch material. In 1½-story houses, 2- by 4-inch or 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:*



A, *At center bearing partition with joists lapped or butted*



B, *At exterior wall*

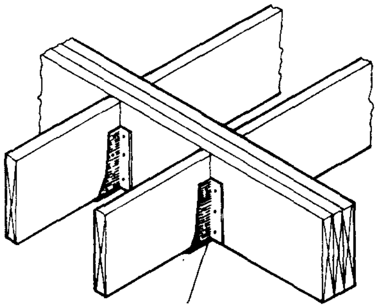
Valley rafters. A valley is the internal angle formed by the juncture of the two sloping planes of perpendicular roof sections. The key member in valley construction is termed the valley rafter. In the intersection of two equal-size roof sections, the valley rafter is doubled (fig. 68) to carry the roof 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 comer of the wall to the ridge board at a 45° angle. Jack rafters extend from the top plates to the hip rafters (fig. 69).

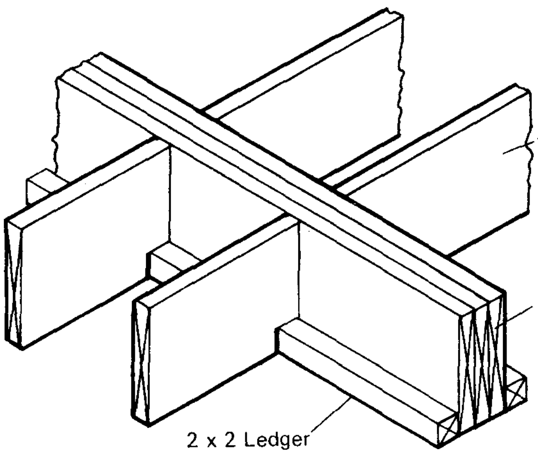
Cape Cod and saltbox. A variation of the gable roof, used for Cape Cod or saltbox house styles, includes the use of shed and gable dormers (see fig. 66B). The ridgeline on the Cape Cod is in the center of the roof; on the saltbox the ridgeline is off center. Both are 1½-story houses with about half as 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***



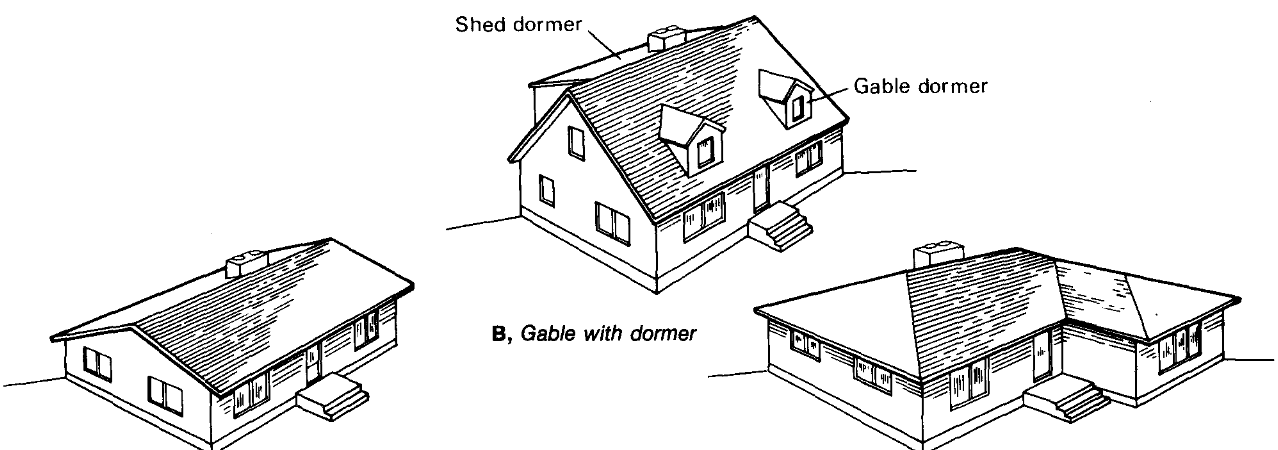
Gable dormers. In construction of small gable (eye) dormers, the rafters at each side of the dormer opening are doubled. The side studs and the short valley rafter rest on these members (fig. 70). Side studs can be carried past the rafters to bear on a bottom plate nailed to the floor framing and subfloor. 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:*



A, *Gable*

B, *Gable with dormer*

C, *Hip*

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

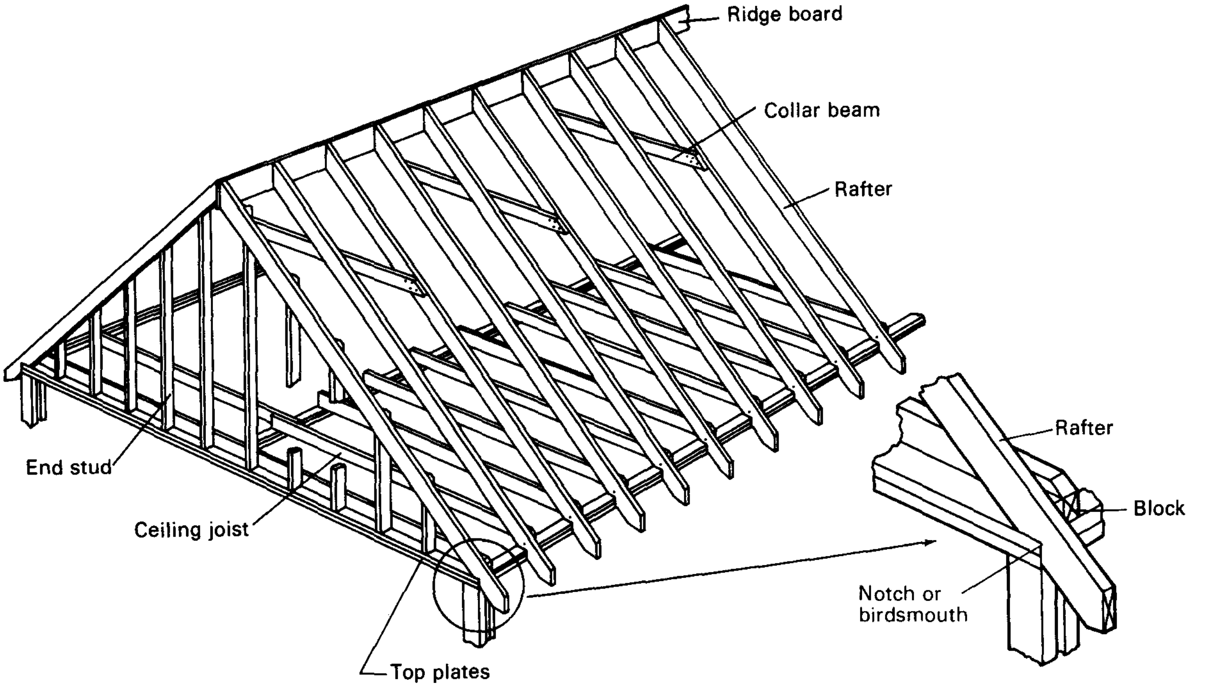
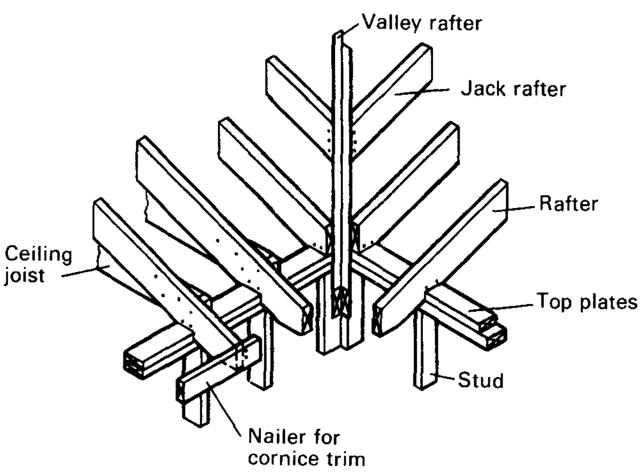


Figure 68 – *Framing at valley in rafter roof.*



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.

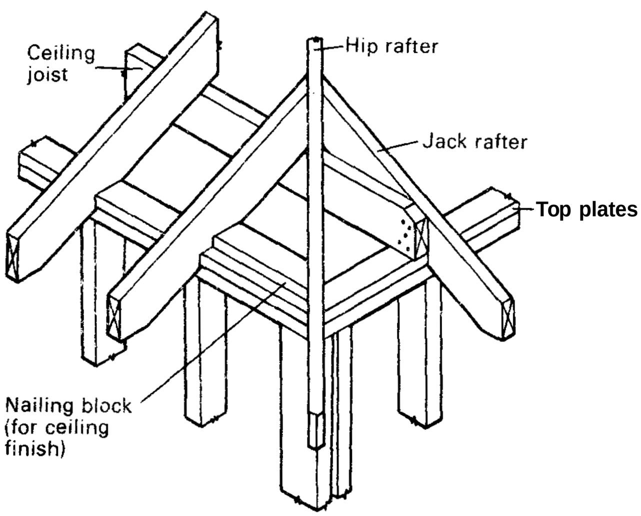
Exposed 4- by 6-inch or 4- by 8-inch rafters may be installed on a 32-inch or 48-inch spacing. Decking of 2- by 6-inch tongue-and-groove material is frequently used to span from joist to joist, wall to beam, or beam to beam. This decking serves both as structural sheathing and as interior ceiling finish 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 airway 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.*

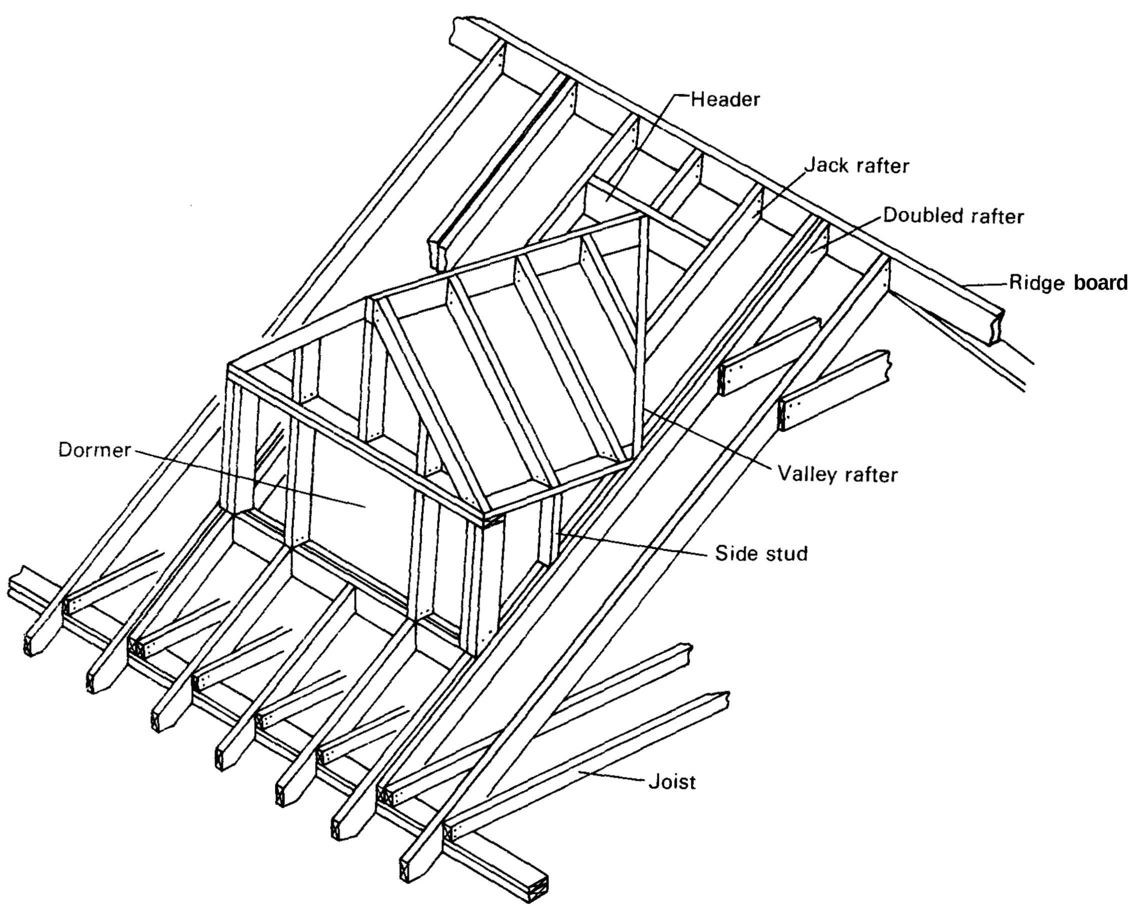
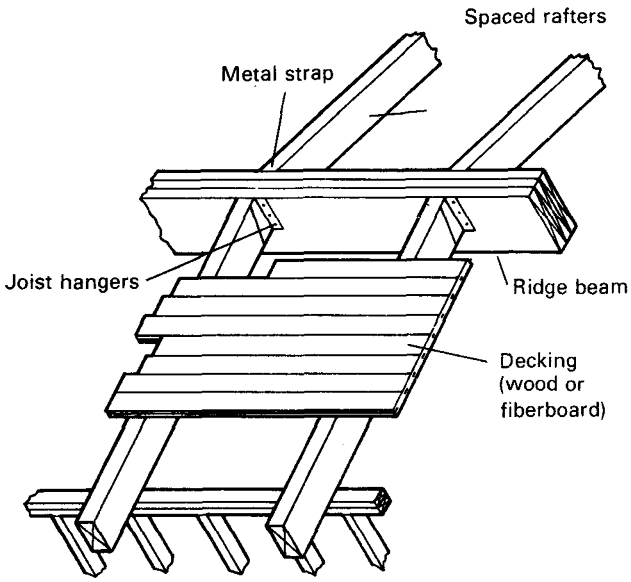


Figure 71 – *Wood decking over exposed beams.*



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, $^3/_8$-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, $^5/_{16}$-inch plywood sheathing is the minimum. To provide better

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

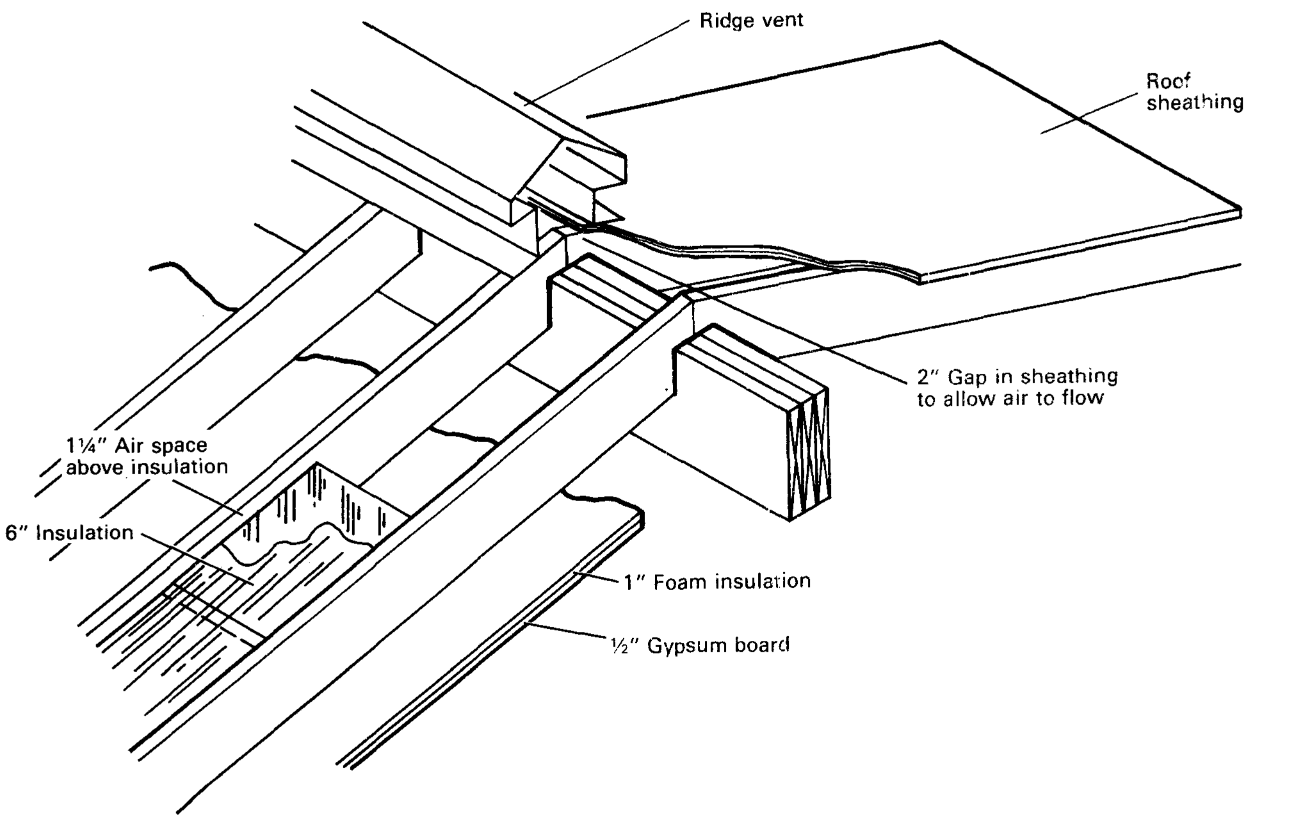
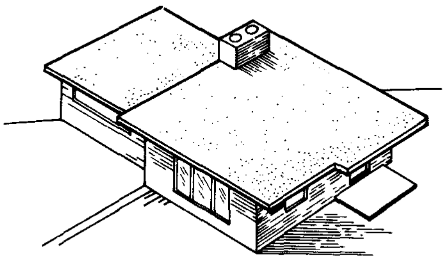
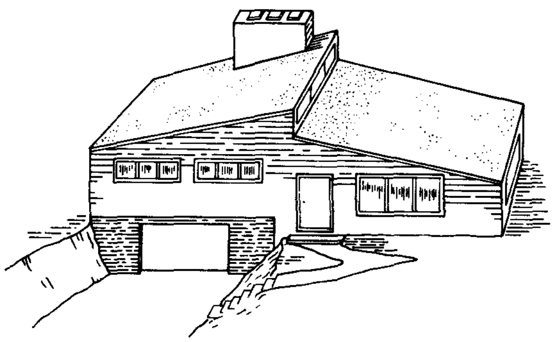


Figure 73 – *Roof types with single-member construction:*



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, $^5/_8$-inch plywood is considered minimal for rafters spaced 24 inches on center and ½-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 glueline. 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 $1^3/_8$-inch narrow crown staple should be used for $^5/_{16}$-inch and $^3/_8$-inch plywood. An 8d common nail, 7d threaded nail, or $1^5/_8$-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 glueline, 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 $^1/_8$-inch edge space and a $^1/_{16}$-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 $^1/_8$-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

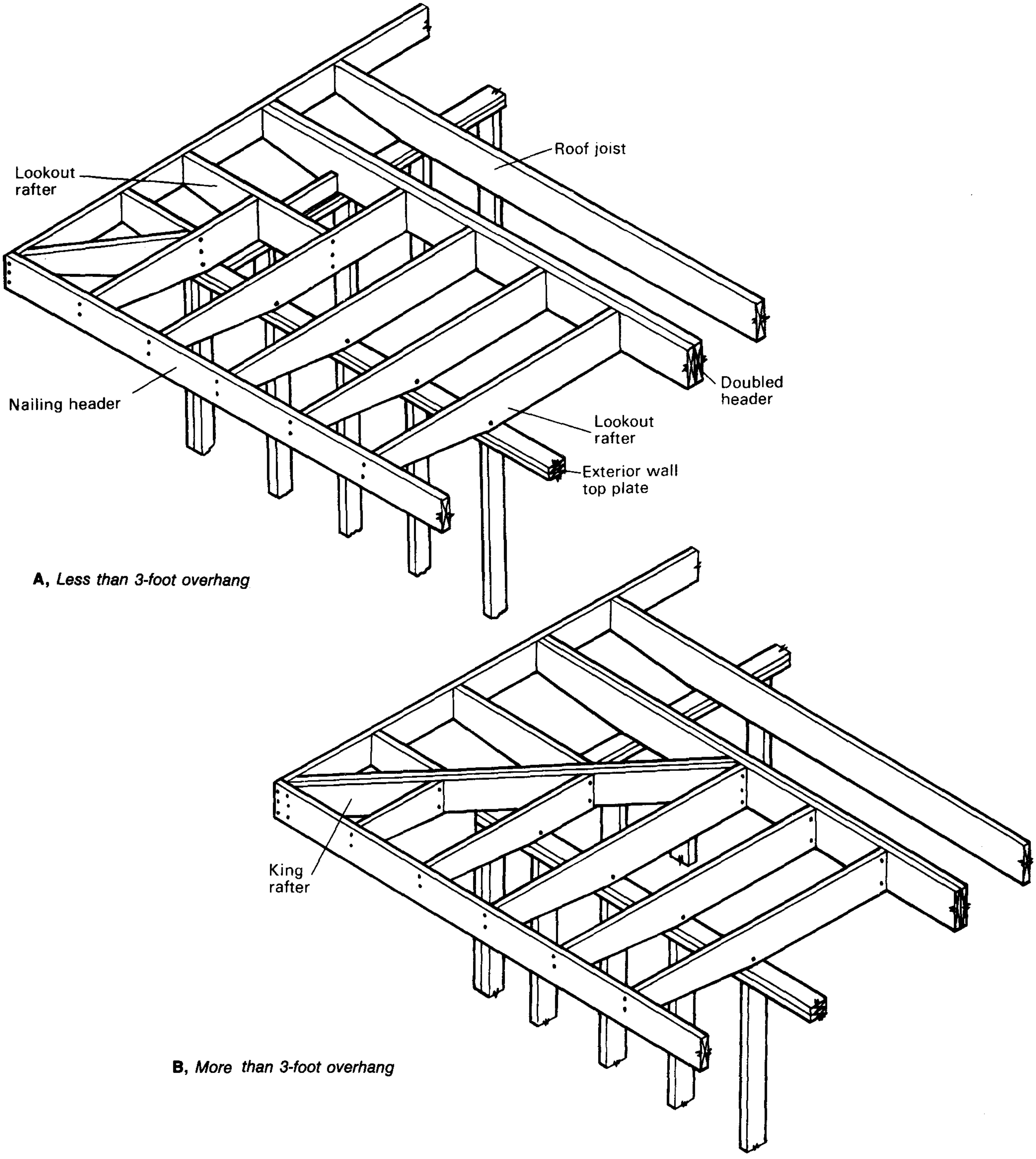
Structural flakeboards (including waferboard and OSB) are applied like plywood: rafter or truss spacing, nailing, and edge treatments are the same, and the same thicknesses are used. Some structural flakeboard panels have flakes or strands aligned to increase the directional strength parallel to the 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.

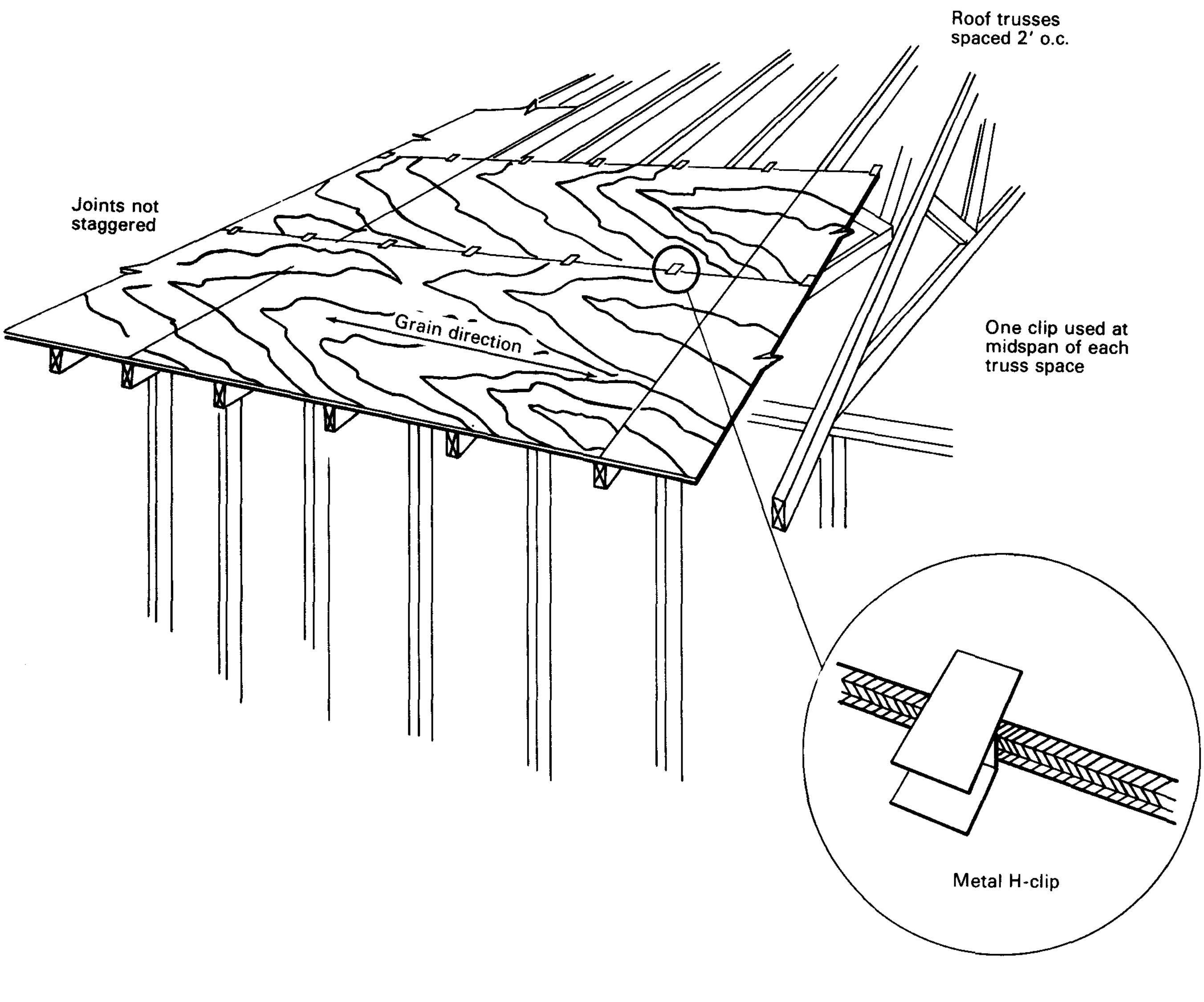
Boards may be tongue-and-groove, shiplapped, or square-edged. End joints should be made over the center line of rafters. It is preferable to use boards no wider than 6 to 8 inches to minimize problems caused by shrinkage. Boards should have a minimum thickness of ¾ inch for rafters spaced 16 inches to 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 $1^3/_8$ to 1½ 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 $^{3}/_{8}$ 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.*

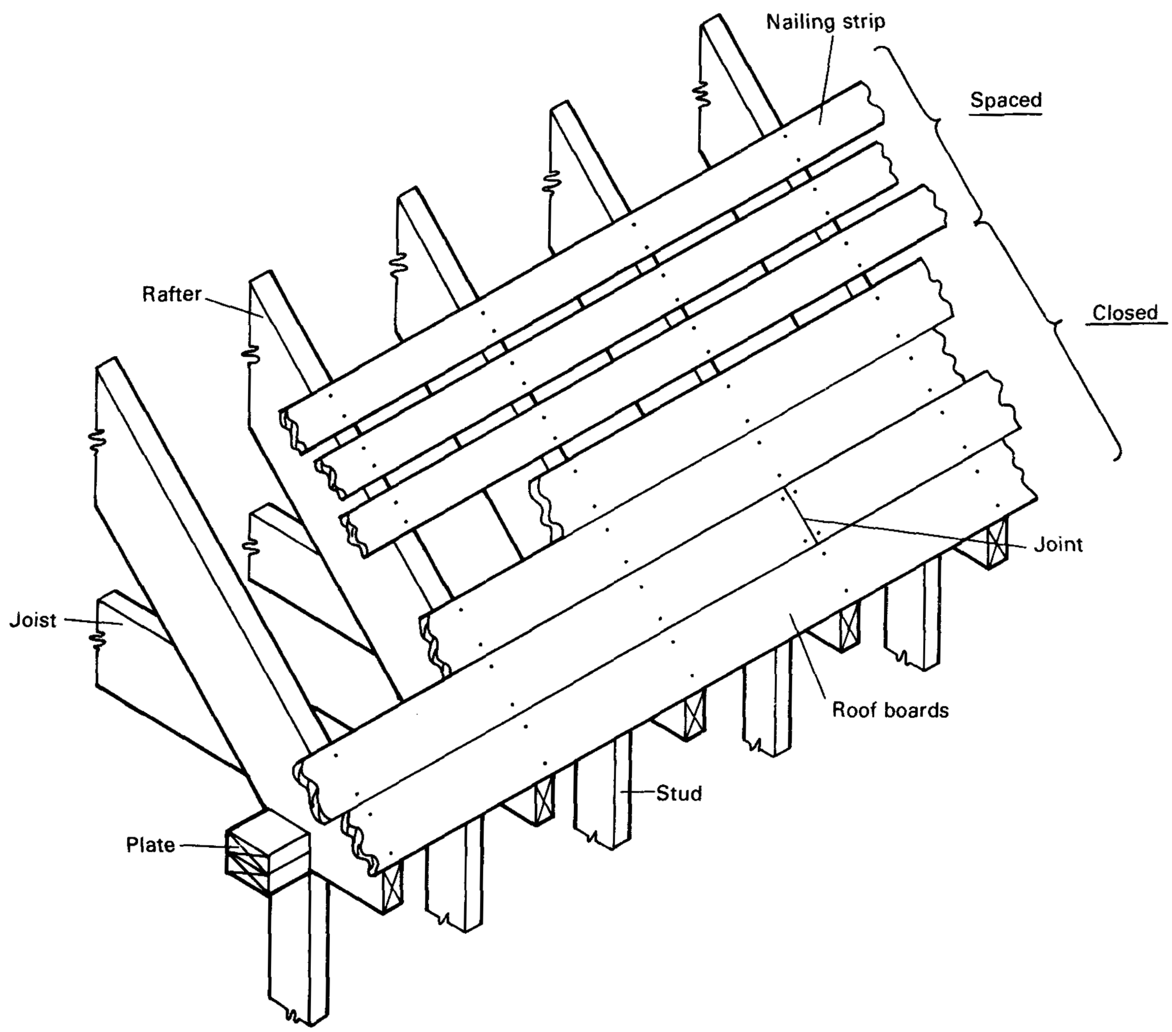
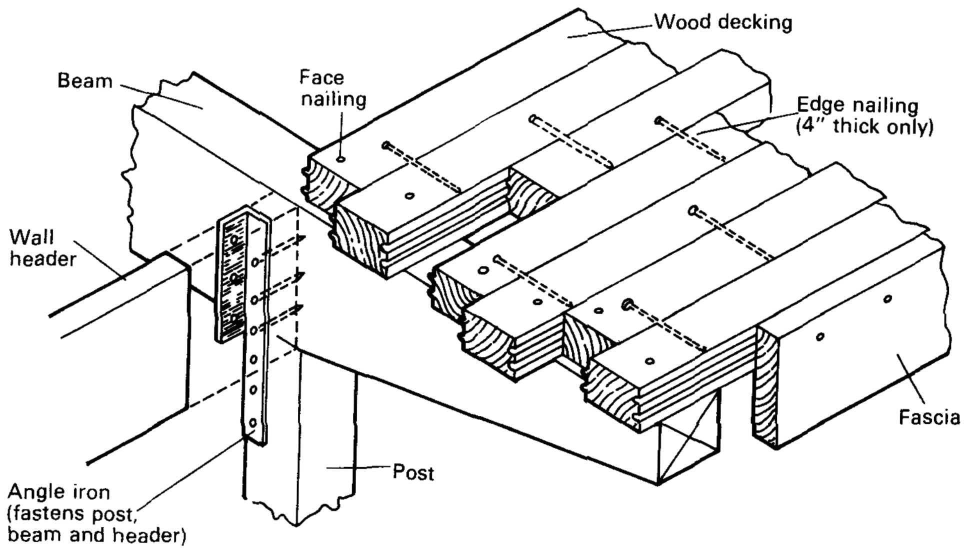


Figure 77 – *Plank roof decking common in post and beam construction.*



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^2.

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.*

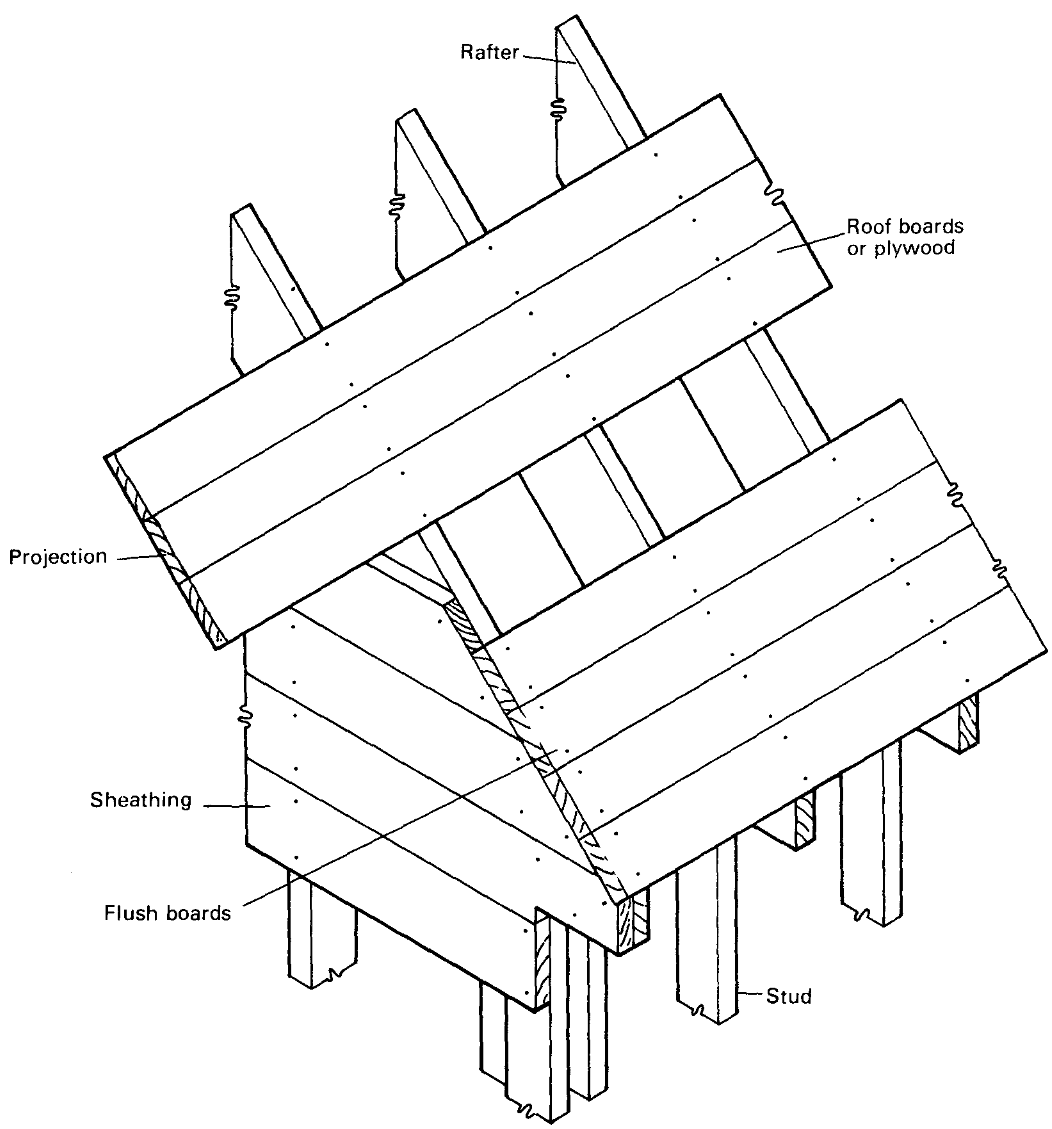
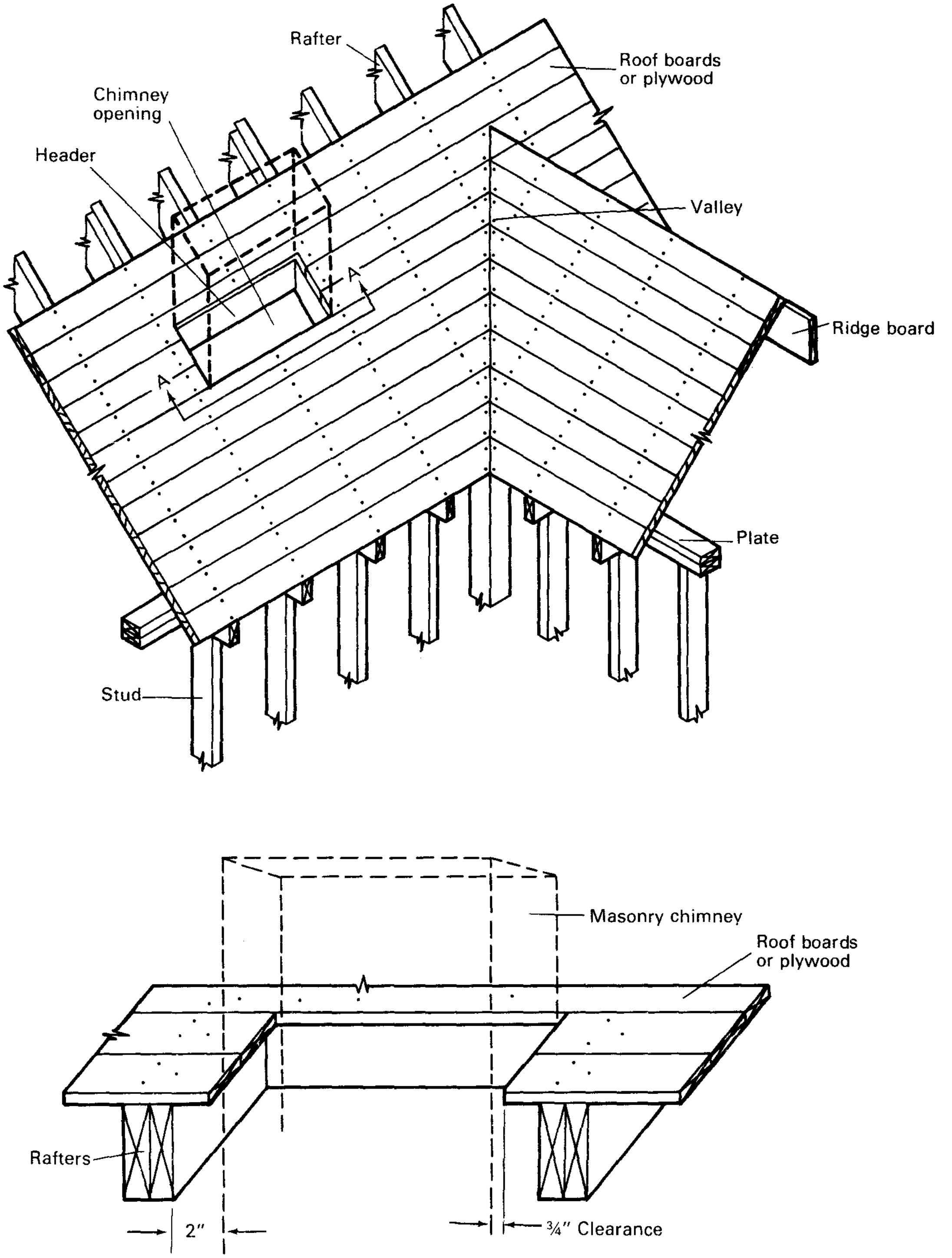


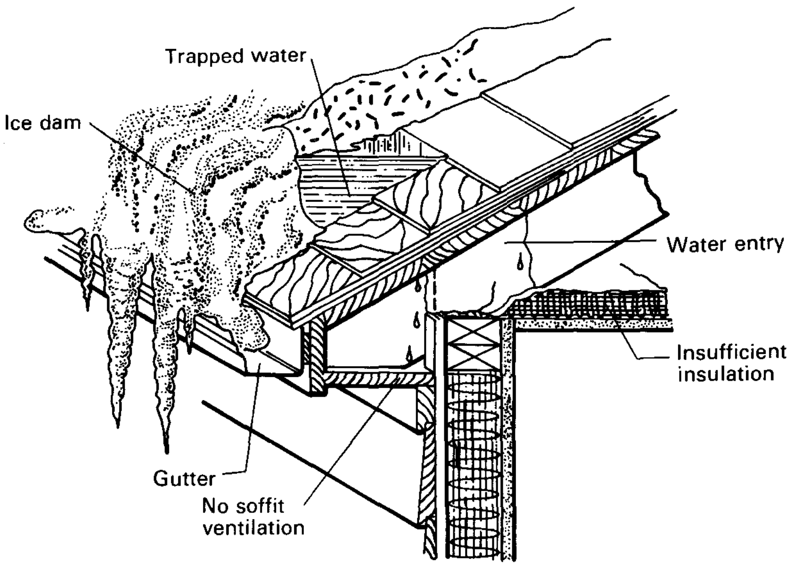
Figure 79 – *Board roof sheathing at valley and chimney opening. Section AA shows clearance at chimney.*



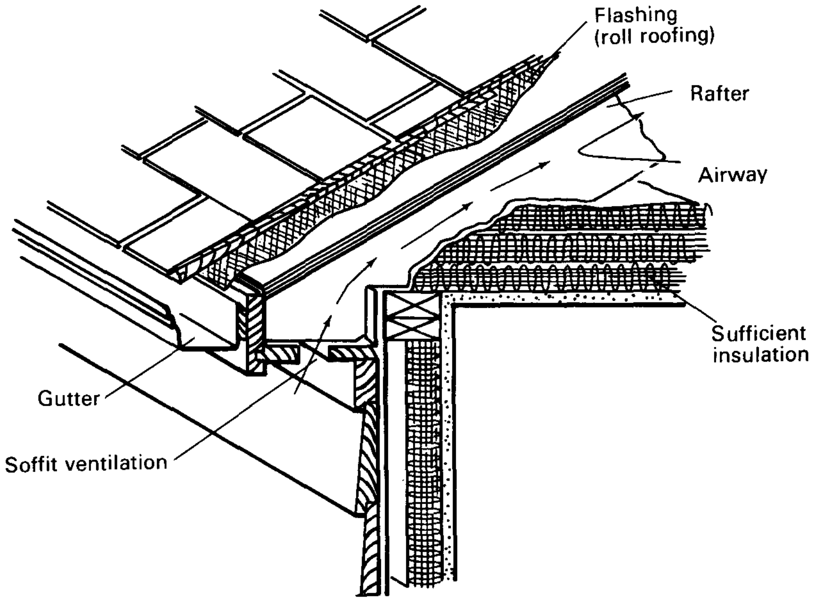
2. Two rust-resistant nails should be used in each shingle, spaced about ¾ inch from the edge and 1½ inches above the butt line of the next course. Nails of 3d size should be used for 16-inch and 18-inch shingles, and 4d nails for 24-inch shingles in new construction. A ring-shank (threaded) nail is often recommended for plywood roof sheathing less than ½ inch thick.

3. The first course of shingles should be doubled. In all courses, $^1/_8$-inch to ¼-inch space between adjacent shingles should be allowed for expansion when wet. The joints between shingles should be offset at least 1 ½ 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.*

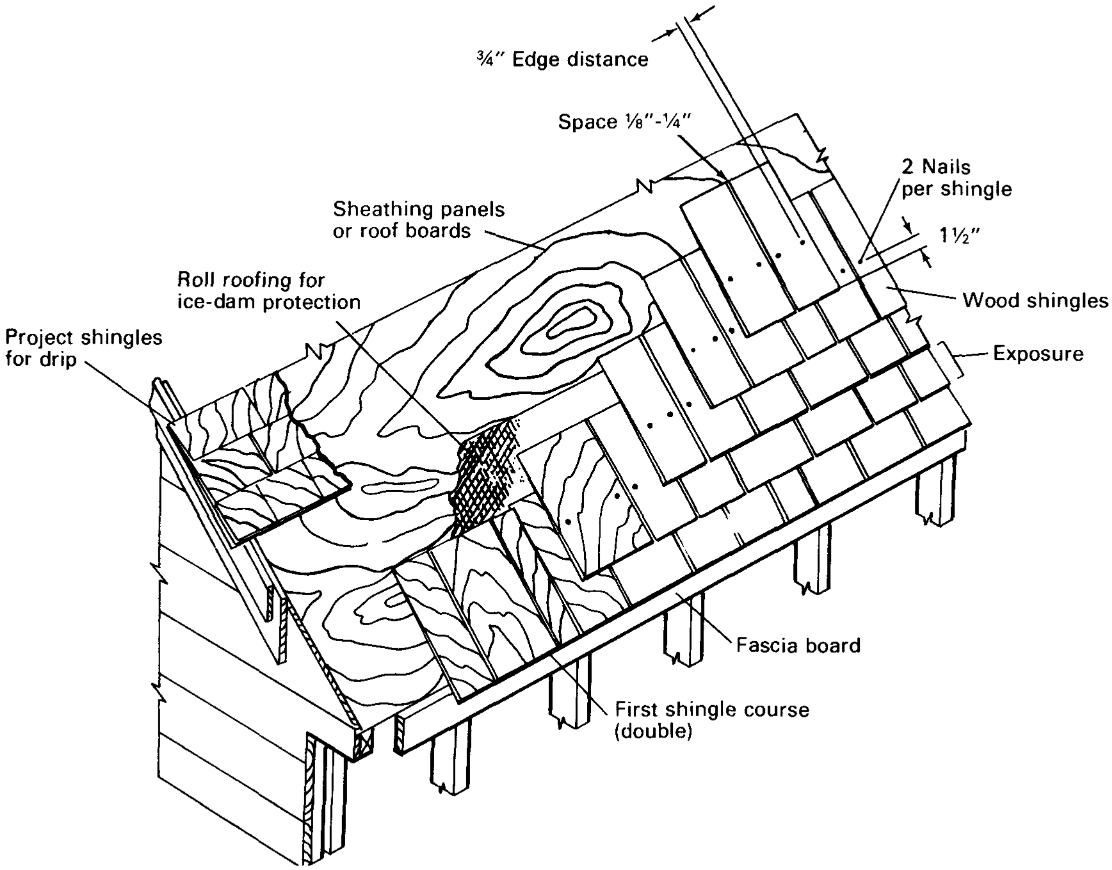


Table 11 – *Recommended exposure for wood shingles*

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.

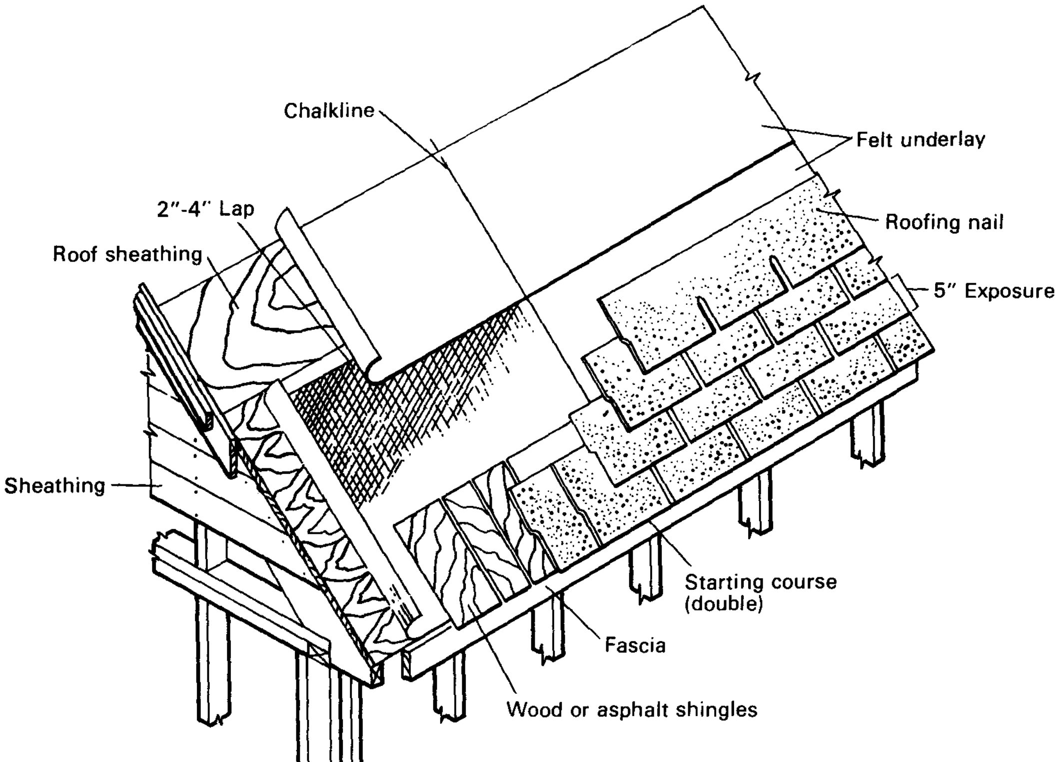
Asphalt and fiberglass shingles. The method of laying an asphalt or fiberglass shingle roof is shown in figure 82A. Manufacturers' requirements for the underlayment beneath the shingles should be followed to insure protection under warranty. The underlayment normally recommended is 15-pound asphalt-saturated 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 ft^2 of roof.)

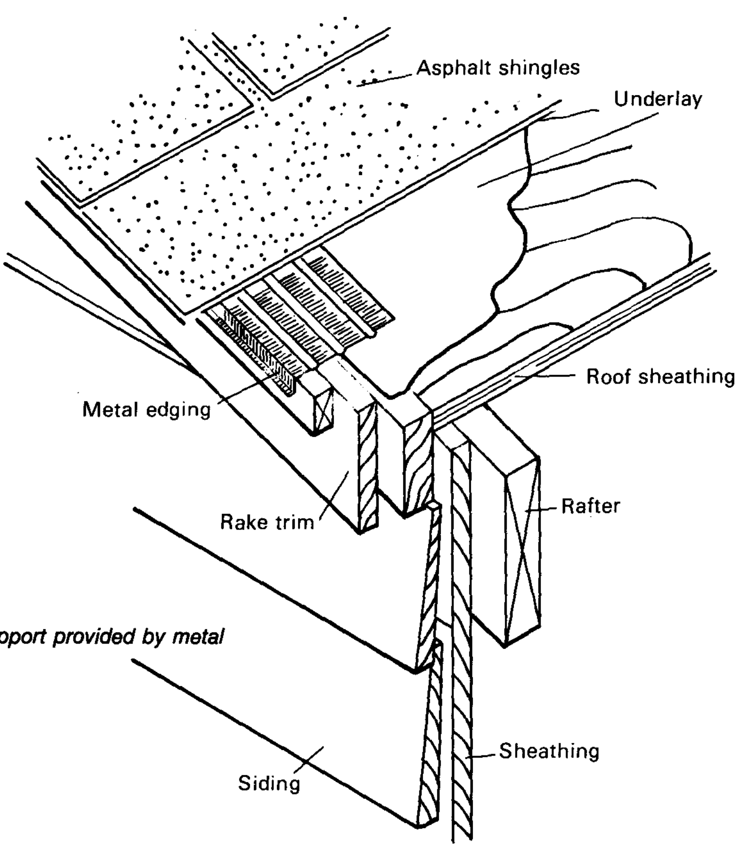
Fiberglass shingles are made of an inorganic fiberglass base coated with asphalt. The usual minimum weight recommended is 220 pounds per square. Fiberglass shingles are generally considered more durable and fire resistant than felt-based shingles. Application methods are the same for both types.

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:*



A, ***Edge support provided by wood shingle course***



B, ***Edge support provided by metal***

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 1¼-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 1⅝ 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.

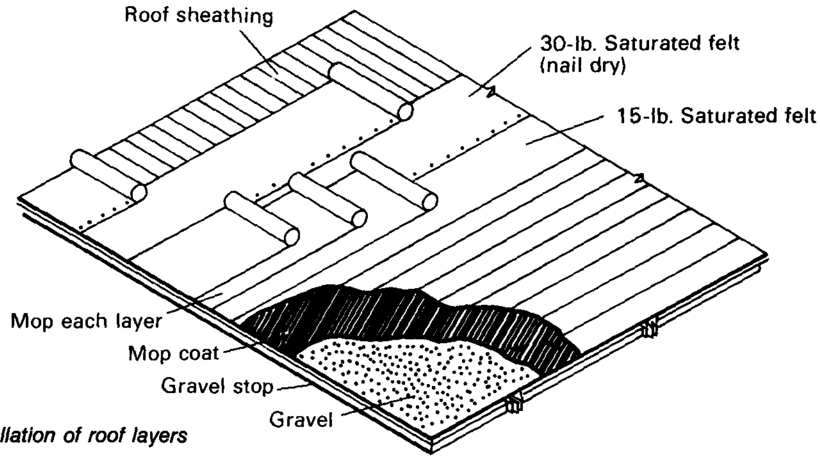
A wood-shingle roof (fig. 84B) can be finished in a Boston ridge with continuous flashing or roll roofing beneath the cap shingles. Flashing or roll roofing is first placed along the length of the ridge, as shown in the figure. Shingles 6 inches wide are alternately lapped, fitted, and blind-nailed. 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.

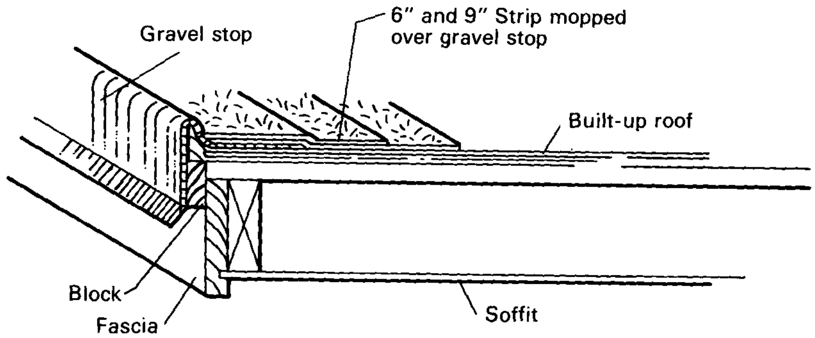
Skylights

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.

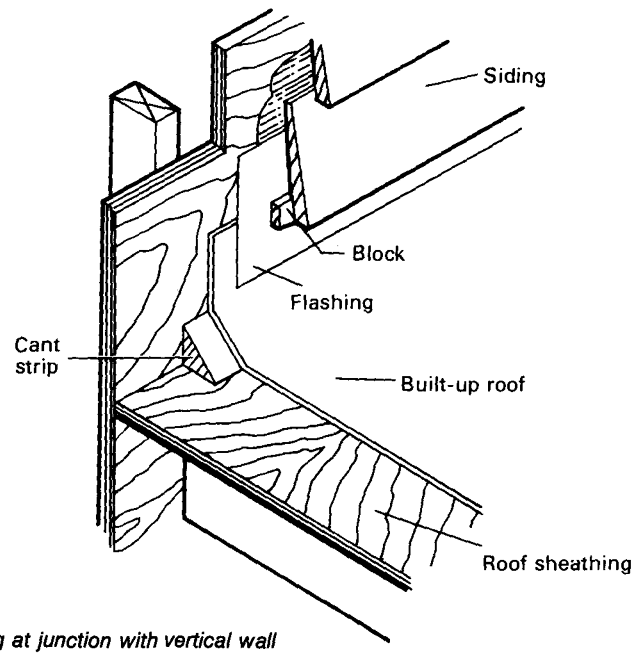
Figure 83 – *Built-up roof:*



A, ***Installation of roof layers***

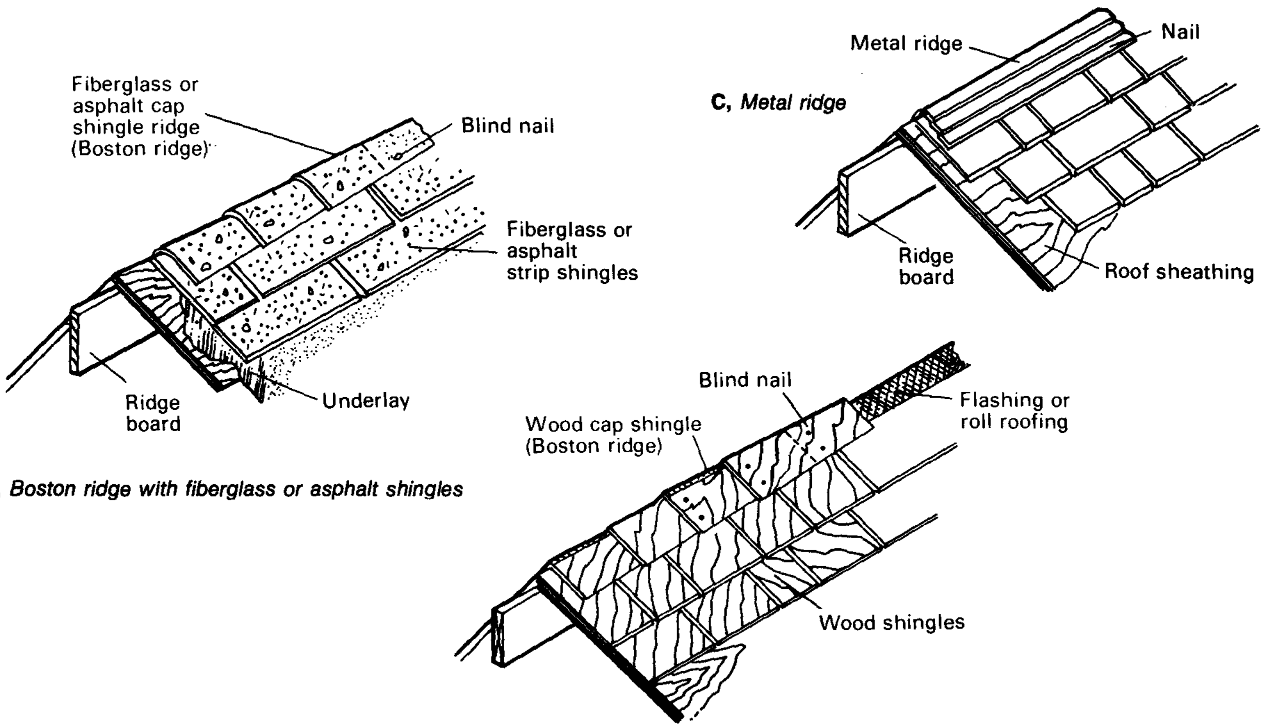


B, ***Gravel stop***



C, ***Finishing at junction with vertical wall***

Figure 84 – *Finishing shingled roof ridge:*



A, ***Boston ridge with fiberglass or asphalt shingles***

C, ***Metal ridge***

B, ***Boston ridge with wood shingles***

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, epecially 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.*

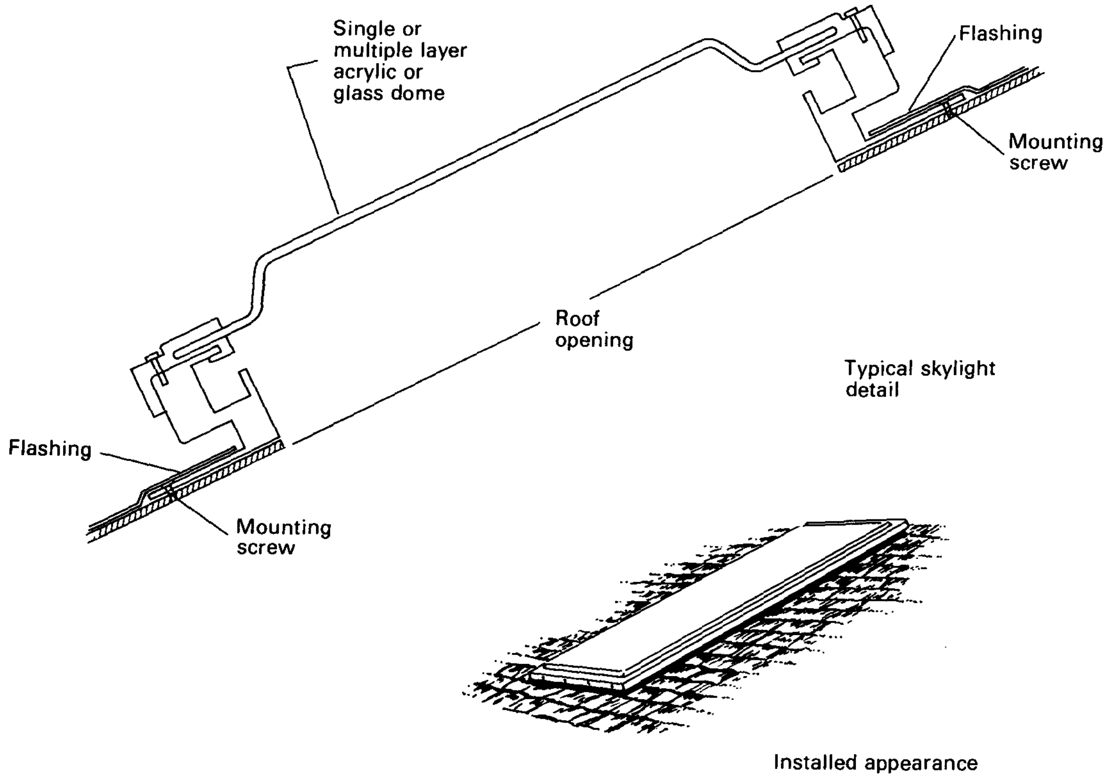


Figure ***86—Curb-mounted skylight.***