CHAPTER 14

Structural Systems

Section 14.1
Framing Systems & Structural Design

Section 14.2
Nails & Connectors

Chapter Objectives

After completing this chapter, you will be able to:

- **Describe** the differences between platform-frame construction and balloon-frame construction.
- **Name** the stresses that structural wood must resist.
- **List** the advantages of structural insulated panels.
- **Demonstrate** how to read a span table.
- **Explain** the difference between a live load and a dead load.
- **Identify** various nails and connectors.

Discuss the Photo

Well Kept The Paul Revere House in Boston is one of the oldest buildings in North America. It is proof of wood's strength and durability if maintained properly. *Why is wood a common framing material?*

Writing Activity: Create a Survey

Plan to interview a builder in your community about what type of framing he or she uses to build structures. Write at least three grammatically correct questions. Report your findings in a one-paragraph summary.

Chapter 14 Reading Guide

Before You Read Preview

The structural design of a house is based on an understanding of how materials and fastening systems interact. Choose a content vocabulary or academic vocabulary word that is new to you. When you find it in the text, write down the definition.

Content Vocabulary

- balloon-frame construction
- platform-frame construction
- in-line framing
- post-and-beam framing
- structural insulated panel
- spline
- shear wall
- load
- design value
- span table
- on center (OC)
- dead load
- live load
- framing connector

Academic Vocabulary

You will find these words in your reading and on your tests. Use the academic vocabulary glossary to look up their definitions if necessary.

- crucial
- function

Graphic Organizer

As you read, use a chart like the one shown to organize the characteristics and process of each type of framing. Add bullets as needed.

Type of Framing	Characteristics	Process
balloon-frame construction	Studs run from the sill plate to the top plate of the second floor.	The frame is constructed as one piece. The second floor joists are connected to the same studs as the first floor joists.

Go to **glencoe.com** for this book's OLC for a downloadable version of this graphic organizer.

Academic Standards

Science

Earth and Space Science: Energy in the earth system (NSES)

Earth and Space Science: Origin and evolution of the earth system (NSES)

Physical Science: Motions and forces (NSES)

Physical Science: Chemical reactions (NSES)

English Language Arts

Use different writing process elements to communicate effectively (NCTE 7)

Mathematics

Geometry: Use visualization, spatial reasoning, and geometric modeling to solve problems (NCTM)

Industry Standards

Framing Materials

Nails and Connectors

NCTE National Council of Teachers of English

NCTM National Council of Teachers of Mathematics

NSES National Science Education Standards

Section 14.1

Framing Systems & Structural Design

Structural Materials & Framing

What is balloon framing?

Most homes in the United States and Canada have a structural frame made of wood or wood products. Metal-frame houses are structurally similar.

Wood-frame houses have several important features. They often cost less than houses built using other structural systems. They are easily insulated, which reduces heating and air-conditioning costs. They can support a wide variety of exteriors. This flexibility allows architects and builders to produce nearly any architectural style. In addition, a well-built and properly maintained wood-frame home is very durable.

Conventional Framing

Most houses are built using wood framing that consists of many individual pieces. The main pieces are joists, studs, beams, and rafters, as shown in **Figure 14-1**. These pieces are spaced at regular intervals. They are fastened together in a way that enables them to support and strengthen the house. In this way, every piece supports part of the load.

Wood panels, called *sheathing*, are fastened to the wood framing to give it more strength and stiffness (see Chapter 13, "Engineered Wood" for more on sheathing products). Together, the framing and sheathing form the basic structure of a house. The two main types of conventional framing are balloon-frame construction and platform-frame construction, shown in **Figure 14-2** on the next page and **Figure 14-3** on page 372.

Balloon Framing In **balloon-frame construction**, also called *balloon framing*, the studs run from the sill plate to the top plate of the second floor, as shown in Figure 14-2. The first-floor joists also rest on this sill. The second-floor joists bear on 1×4 ribbons (sometimes called *ribands*) cut into the inside edges of the studs. Wood expands and contracts *across* the grain but is relatively stable *with* the grain. Because less cross-grain framing is used, balloon-frame construction is less affected by expansion and contraction.

Balloon framing is not used often to frame modern houses. This is partly because long, straight lengths of lumber are no longer readily available. Remodeling and restoration contractors see this system primarily when they remodel and repair old houses. With the development of finger-jointed lumber, however, portions of new houses may be constructed using this system.

Platform Framing In **platform-frame construction**, also called *platform framing*, each level of the house is constructed separately. The floor is a platform built independently of the walls, as shown in

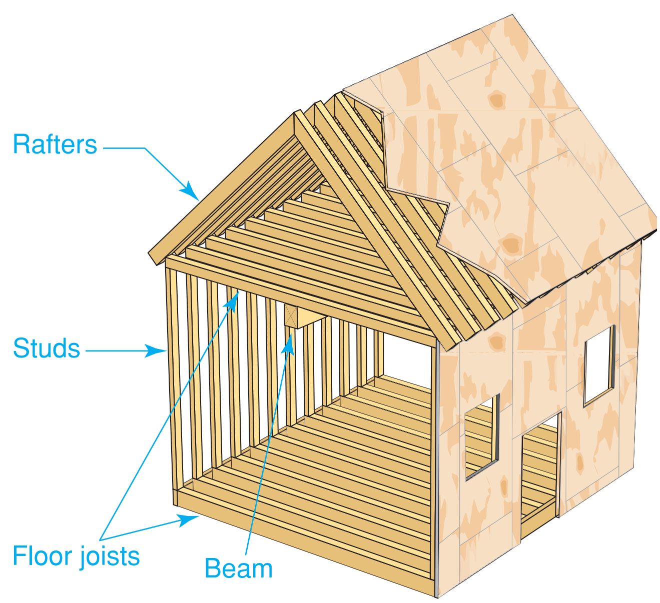


Figure 14-1 Conventional Framing
Four Major Parts Joists, studs, beams, and rafters.

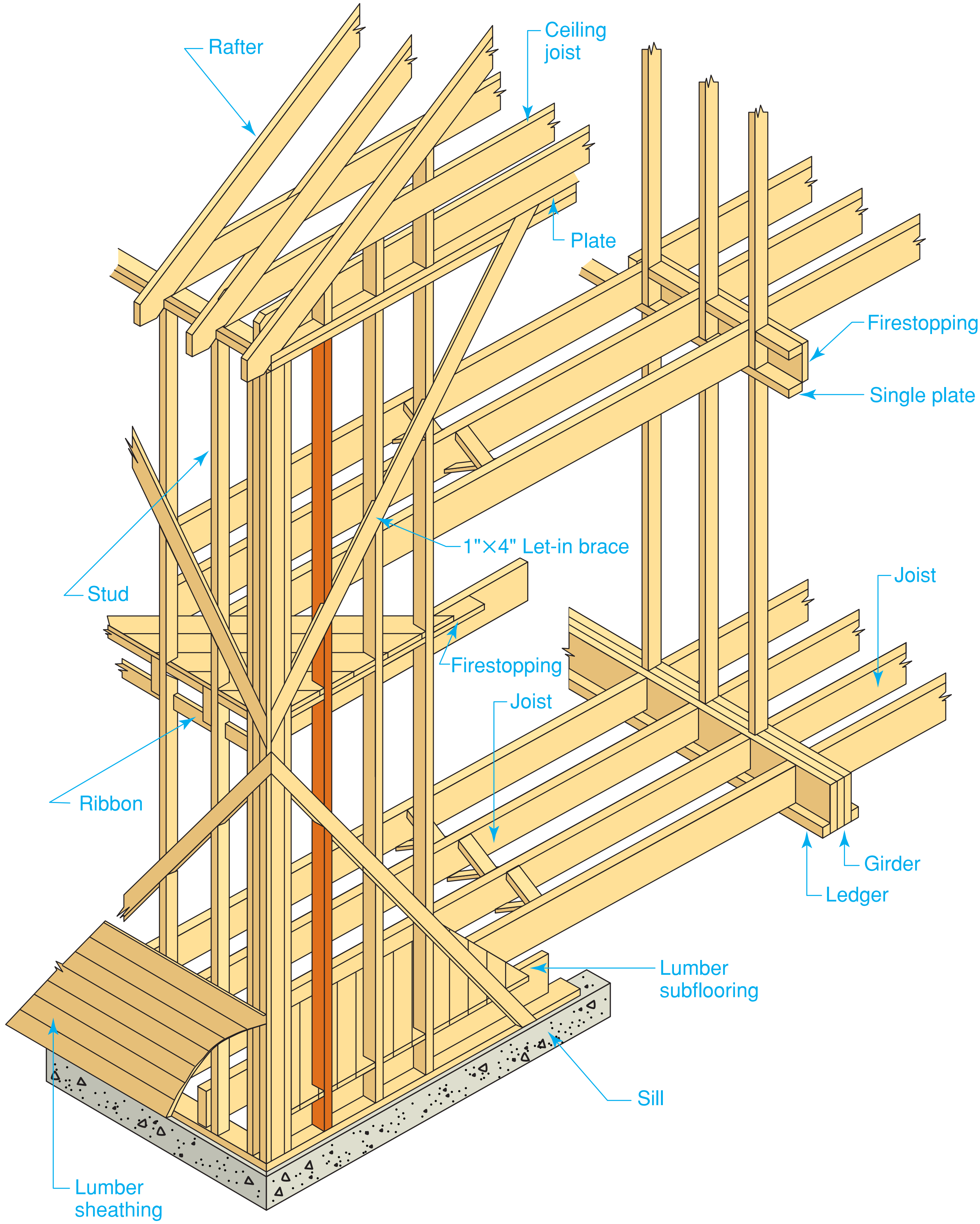


Figure 14-2 Balloon-Frame Construction

Long Lengths Wall studs extend in continuous lengths from one story to another. All joints are nailed.

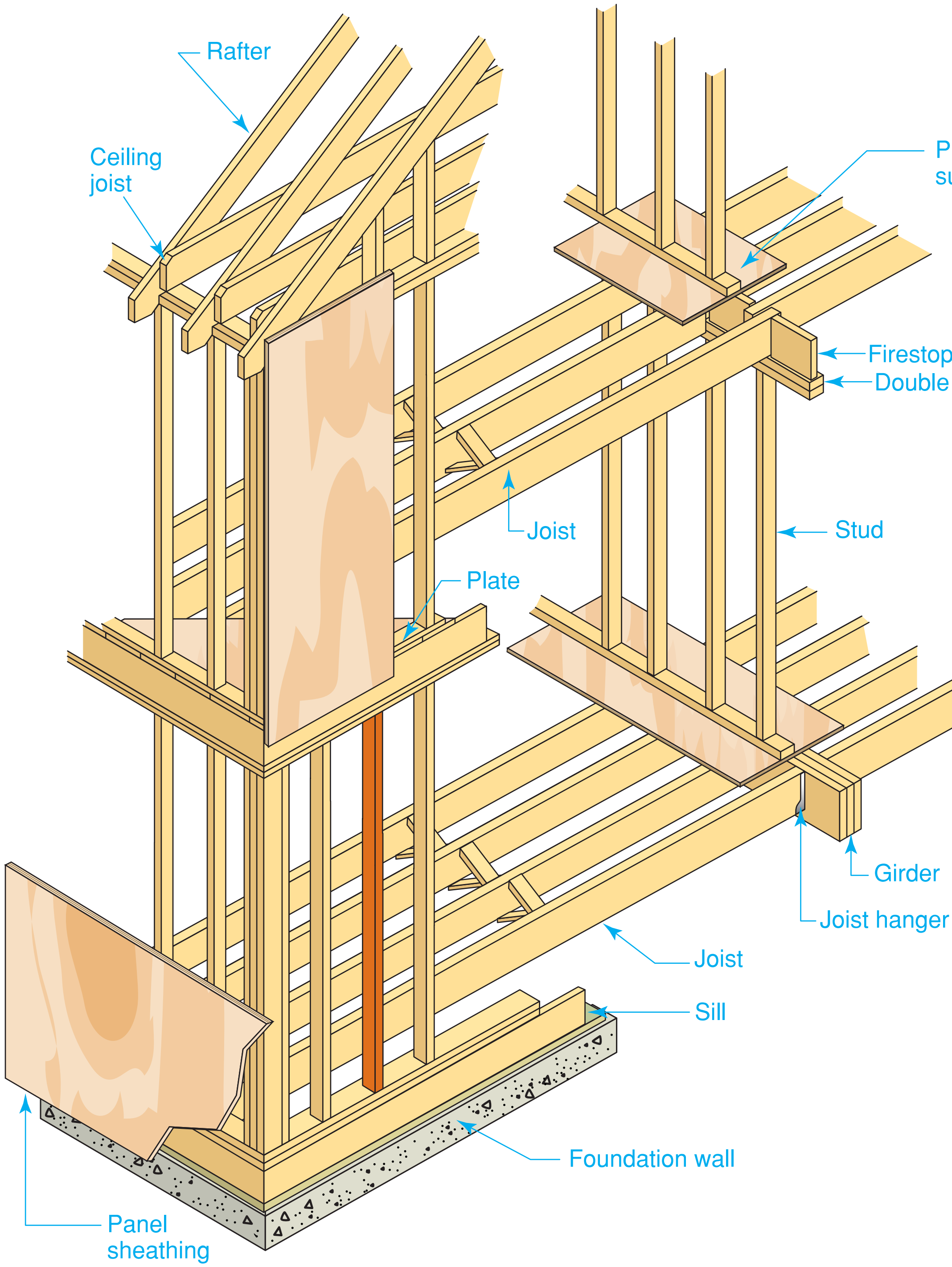


Figure 14-3 Platform-Frame Construction

Short Lengths Wall studs are only long enough to form the walls of one story. Joints are nailed and may be held with framing connectors.

Figure 14-3. The top surface of this platform is called the subfloor. It extends to the outside edges of the building. Each wall is usually assembled flat on top of a subfloor, and then tilted into place.

The general sequence of constructing a multi-story house using platform framing starts with the installation of a foundation. The first level floor joists are installed next and then sheathed. The first level exterior and interior walls follow. The exterior walls should be sheathed before the second level is built, in order to provide rigidity to the frame. The second level floor joists can then be installed and sheathed. Then, the second level walls are framed and sheathed. At this point ceiling joists and rafters are installed, and the roof is sheathed.

Because the floors, walls, and roof are all separate parts, the connections between them can fail if not made properly. This is particularly true in areas affected by severe weather or earthquakes. Most builders, especially in seismic and high-wind zones, improve the strength of connections by using metal framing connectors (see Section 14.2 for more information). However, if its parts are securely connected, a platform frame will be strong and rigid.

Platform-frame construction is easily adapted to prefabrication. Walls can be built elsewhere and then lifted into place on the subfloor. Another advantage of platform-frame construction is that it does not require unusually long lengths of lumber. Building techniques in most parts of the United States have developed almost entirely around platform-frame construction. Because it is the most common method used for one- and two-story houses, this book will focus on its techniques.

Spacing Variations In standard platform-frame construction, wall studs are commonly spaced 16" apart, measured from the center of one stud to the center of the next. This is called 16" on center, or 16" OC. On center is discussed further in Section 14.2. However, floor joists might be spaced at intervals of 12", 16", 19.2", or 24" OC. The result is that structural loads are not always passed directly from one framing member to another. This is not a problem because wall plates distribute the loads. In addition, the number of studs in a typical wall makes up for slight irregularities in the load distribution. This helps to even out the load.

One variation on this system is called in-line framing. In **in-line framing**, all joists, studs, and rafters are given the same spacing, as shown in **Figure 14-4**. This spacing is usually 16" or 24" OC. It creates a direct path for loads, from the rafters right down to the foundation wall. This increases the load-bearing efficiency of the frame and reduces the amount of lumber needed for a house. For example, double-top plates are not required. A single wall plate is adequate.

In-line framing is one element of a more comprehensive system designed to reduce the amount of lumber required to build a house. The system is sometimes called *advanced framing,* but is also known as Optimum Value Engineering (OVE). In addition to in-line framing, the system calls for planning the house in 2' modules and includes details such as two-stud corners.

Post-and-Beam Framing **Post-and-beam framing** is a framing system that relies on fewer but larger pieces of framing members, as shown in **Figure 14-5** on page 374. The framing members are spaced farther apart

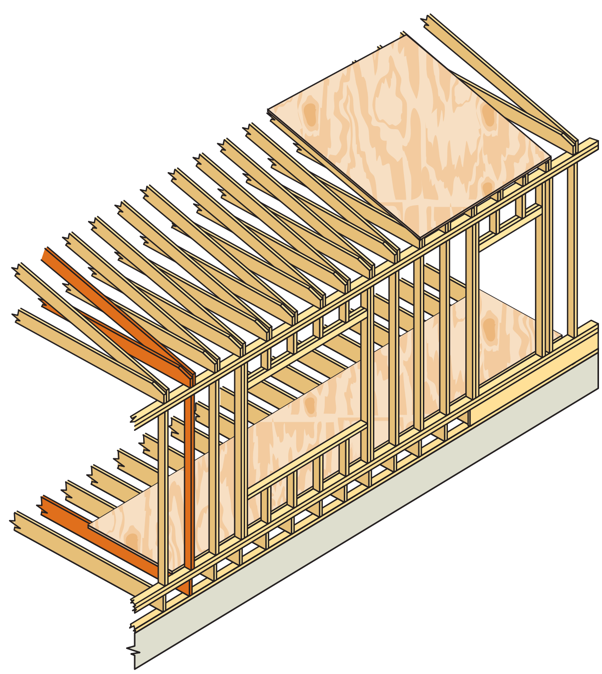


Figure 14-4 In-Line Framing
Parallel Rows Note how rafters, joists, and studs are lined up with each other. Joints are nailed or made with metal framing connectors.

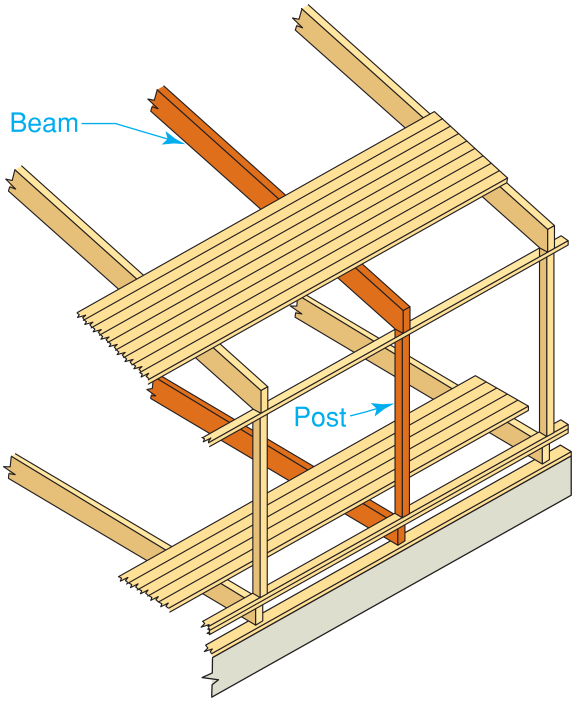


Figure 14-5 Post-and-Beam Framing

Large Dimensions Note the similarities between this system and in-line framing (shown in Figure 14-4).

than those used in conventional framing. Subfloors and roofs are supported by a series of beams spaced up to 8' apart. The ends of the beams are supported by structural timber posts. (*Structural timber* is lumber that is 5×5 or larger. It is used mainly for posts and columns.) The roof sheathing and the subfloor may consist of planks, usually with a 2" nominal thickness, or structural tongue-and-groove (T&G) plywood that is 1⅛" thick. Spaces between posts are framed as needed for attaching exterior and interior finish.

One advantage of post-and-beam framing is the architectural effect provided by the exposed framing in the ceiling. Thick roof planking serves as the finished ceiling as well as the structural support for the roofing. Generally, the planks are selected for appearance. No further ceiling treatment is required.

A variation on this system is often used in portions of the Pacific Northwest and in other areas of mild weather. The first floor is framed using post-and-beam techniques, but the rest of the house is framed using platform framing. This is a cost-efficient method to use when building a house with a crawlspace foundation.

Timber Framing A *timber frame* is a type of post-and-beam frame that rests on a foundation, as shown in **Figure 14-6**. The supporting members are fairly far apart. They are made from either hardwood or softwood timbers. The timbers are surfaced and then connected with interlocking joinery, which are often secured with wooden pegs. This requires a high degree of woodworking skill. Some joints are quite complex, but most are a variation of the mortise and tenon joint.

Construction of a post-and-beam structure starts with a foundation. The entire structural frame is assembled next, including the roof. The frame is self-bracing, which means

Figure 14-6 Timber Framing

Timbers and Joinery The individual pieces of a timber frame are connected with interlocking joints. *What disadvantage does this system have compared to conventional framing?*

Courtesy of Dreaming Creek Timber Framed Homes that it is rigid enough to stand without requiring sheathing. When the frame is complete, it is often covered using structural insulated panels (SIPs). At that point construction follows the same sequence as standard construction, with the installation of doors, windows, mechanicals, and interior finishing.

One of the most desirable aspects of a modern timber frame is the structure, which is typically exposed on the inside of the house, as in **Figure 14-7**. The use of timbers to frame buildings is a technique with a very long history. There has been a revival of interest in timber framing, particularly where nearby forests can provide the timber stock of suitable dimensions.

Structural Insulated Panels Structural insulated panels (SIPs) are used with increasing frequency to form the walls, floors, and roof of a house, such as the one shown in **Figure 14-8** on page 376. A **structural insulated panel** consists of 3½" thick expanded polystyrene (EPS) foam insulation between sheets of exterior plywood or oriented-strand board (OSB). Because their interiors are made of foam insulation, SIPs are sometimes referred to as *foam-core panels.* SIPs are sometimes used along with conventional framing.

Panels usually range in size from 4' × 8' to 8' × 28'. Larger panels are also available. These load-bearing panels are built in a factory and delivered to the job site. There they are fastened together using a system of 2×4 or 2×6 splines, as shown in **Figure 14-9** on page 376. A **spline** is a thin strip of wood used to reinforce a joint. Depending on how they are designed, panel walls may be structural or non-structural. When applied to a timber frame house, for example, they are non-structural because the frame is carrying all the loads.

Figure 14-7 An Exposed Frame

Visible Structure The timber frame is typically exposed to the interior. It has a structural purpose as well as a decorative role.

Courtesy of Dreaming Creek Timber Framed Homes

Figure 14-8 SIP Framing
Panel Walls The use of structural insulated panels speeds the construction process.

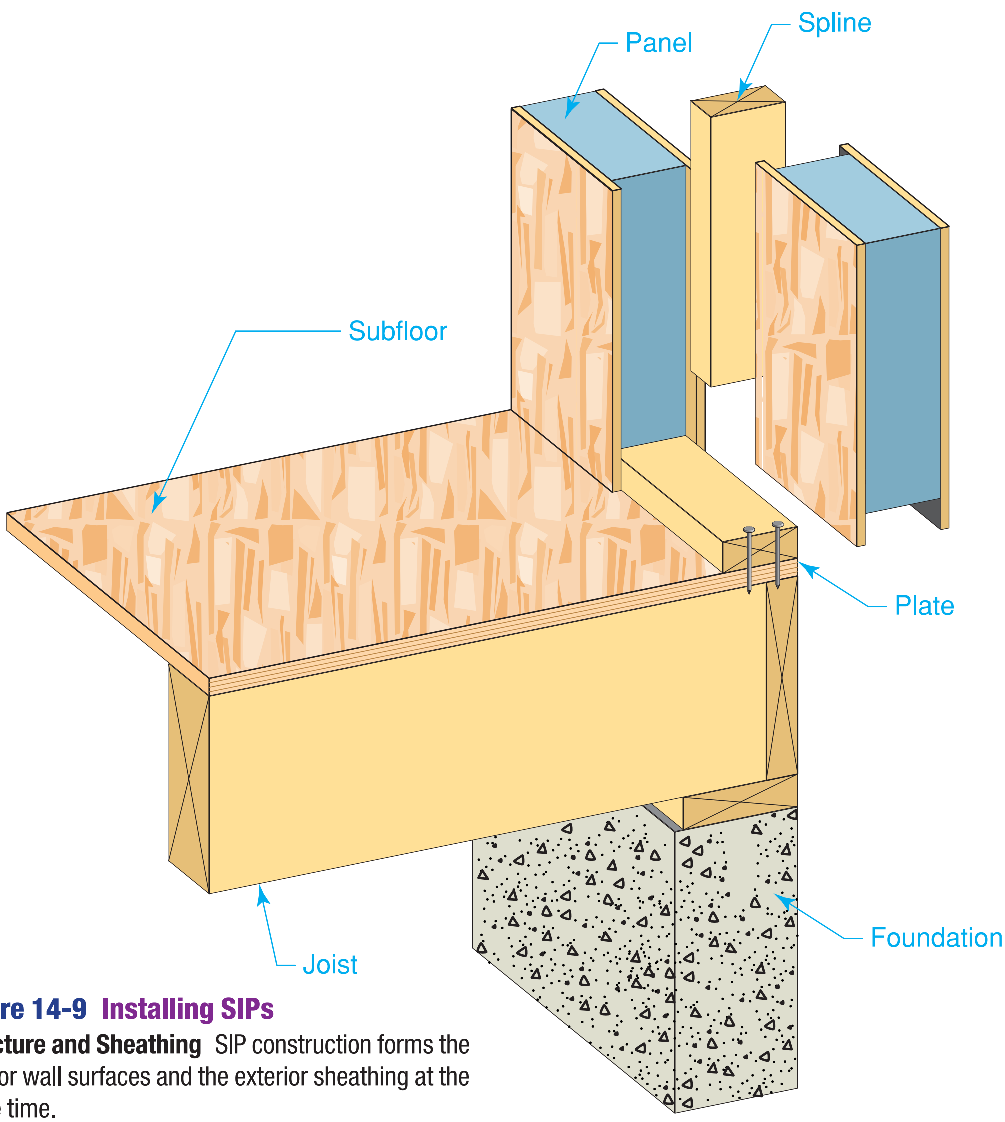


Figure 14-9 Installing SIPs
Structure and Sheathing SIP construction forms the interior wall surfaces and the exterior sheathing at the same time.

Building a house with structural insulated panels has several advantages. First, the shell of the house can be erected very quickly. The house is very strong because there is wood sheathing on the inside as well as on the outside. Some panels also come with an inside skin of drywall. This saves time and work in completing the interior of the house. The panels are energy efficient because they allow very little cold air to leak into the house. Also, the foam within each panel is a very effective insulator. On the negative side, it can be difficult to run wiring through the panels. Plumbing and wiring plans should be developed with this in mind. Also, heavier panels require a crane to lift them into place.

Manufactured Housing

Many houses today are built as *manufactured housing.* This means that the houses are built completely or partially on factory assembly lines. The resulting building is then trucked to the job side and installed. This system is very efficient. Few materials are wasted, and delays caused by weather are minimized.

Manufactured housing has evolved over time. Prefabricated roof trusses became common in the 1950s, and were a precursor to prefabricated houses. The next step was the development of factory-built wall panels. These were used to speed construction of the house shell. Later, entire portions of a house could be built in the factory, and then trucked to the job site for assembly on top of a foundation.

The structural aspects of a manufactured house are often similar to those of site-built houses. There may be a wood frame, for example, as well as structural elements that serve as joists and rafters. However, the assembly methods and the actual materials are often quite different from those found on a job site.

Special Framing Techniques

Areas that have hazards such as severe weather and earthquakes have stricter building codes than other areas. Carpenters and builders must take extra steps to strengthen house framing. This is true no matter what type of framing system is used.

Wind Resistance Many U.S. regions, such as the Gulf Coast, are exposed to hurricanes and high winds, as shown in **Figure 14-10** on page 378. In these areas, building codes require special techniques, such as using metal straps to secure the roof framing to the wall framing, as shown in **Figure 14-11** on page 379. Gable roofs are more easily damaged by high winds than hip roofs or flat roofs. Strengthening a gable end may require special structural bracing. Follow local building codes carefully when building in a region subject to high winds.

Earthquake Resistance The ground moves violently during an earthquake. This may deform the structure of a house or even push it off its foundation. After the ground stops moving, the house will continue to move for a short time. This movement puts great strain on

JOB SAFETY

LIFTING WITH A CRANE Building components such as wood timbers and SIPs are often too heavy to lift into place by hand. Small cranes may be used instead. Ensure that any object being lifted by crane is properly balanced and secured. Attach a guide rope to the object to prevent it from swinging out of control.

Go to glencoe.com for this book's OLC for more on job safety.

Science: Earth & Space Science

Hurricanes A hurricane is a severe tropical cyclone. What are the characteristics of a hurricane? Do you live in a hurricane-prone area?

Starting Hint U.S. government Web sites may be a good place to find the answer.

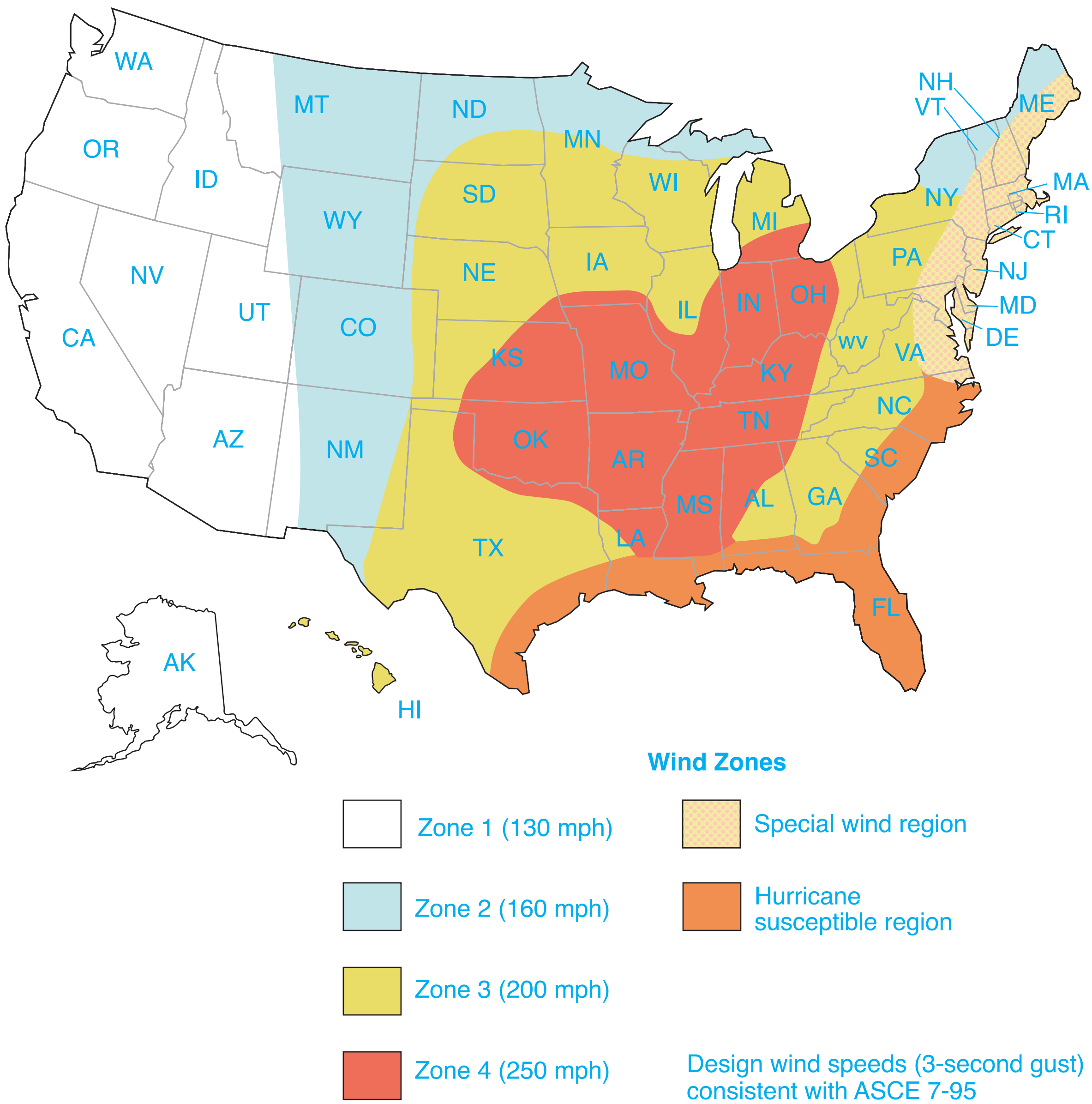


Figure 14-10 Wind Zones

Danger Areas This is a general guide to wind hazard areas. The International Residential Code book contains more detailed maps.

structural materials and connections. In earthquake areas (seismic zones), building codes require additional construction features. These are designed to make the structure more rigid and to hold it securely to the foundation.

Shear walls are a type of wall commonly used to strengthen houses in seismic zones. A **shear wall** is a wall designed to resist lateral (sideways) forces. Using a specific nail spacing to attach sheathing is one way to create a shear wall. Most exterior walls of a house can be designed as shear walls. It is **crucial** to provide shear strength at the corners of a house. The top of a shear wall must be fastened to the second-floor framing. The bottom of the wall must be fastened to the sill plate. The sill plate must be bolted securely to the foundation. A sheathing panel should be set in place vertically in order to be able to make these connections. If

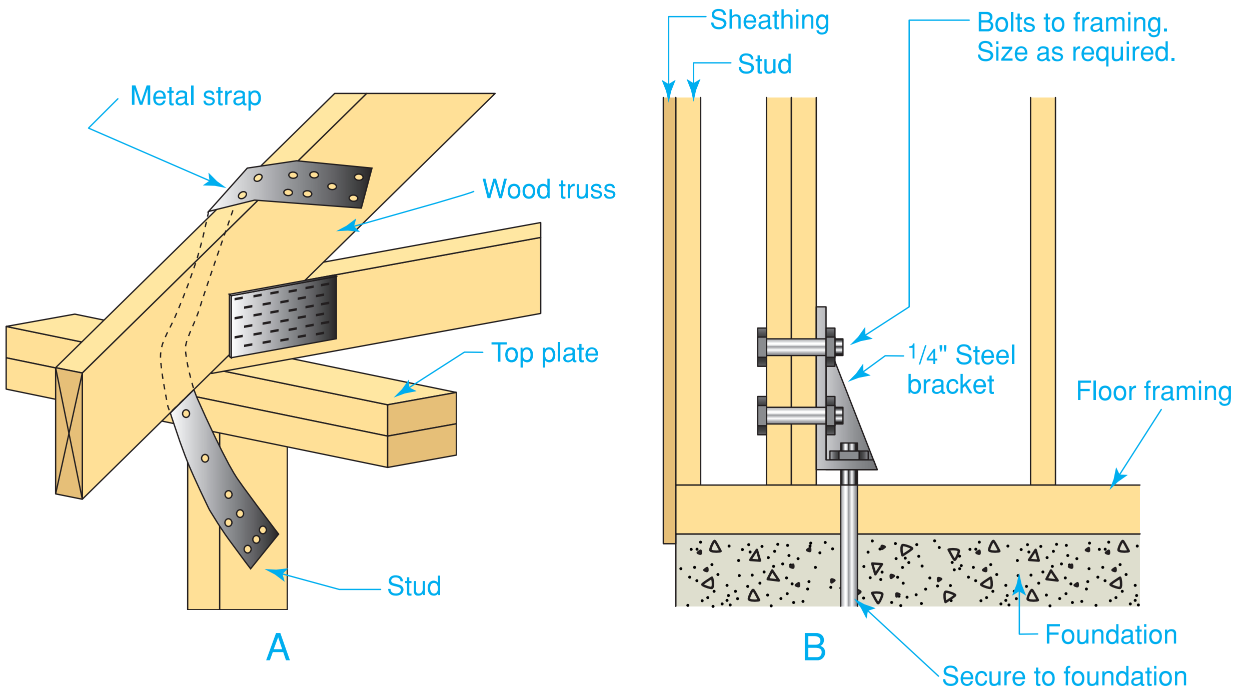


Figure 14-11 Hurricane Straps and Hold-Down Anchors

Strong Connections **A.** Metal hurricane straps can be used to reinforce the connection between roof and wall framing. **B.** Hold-down anchors are steel brackets that prevent walls from toppling.

a 4×8 panel will not reach, a 4×9 or 4×10 panel or solid blocking at joints may be required. The panel must be nailed to the framing according to local codes.

To provide added security, seismic connectors called *hold-down anchors* can be installed at each corner of the house, or as required by local codes.These steel brackets, shown in **Figure 14-11**, prevent walls from tipping over. They are attached to the foundation with anchor bolts, and to the framing with lag screws or machine bolts.

Reading Check

Recall *What is sheathing?*

Structural Design

What is a design value?

When a load is placed on lumber, stresses are created inside the wood. A **load** is a force that creates stresses on a structure. Weight is one type of load, but wind is also a load. Wind creates stress when it pushes against the walls. The size and spacing of joists, studs, and rafters are determined by the way wood responds to stress.

Design Values

How wood will behave can be calculated once its species and grade are known. The results of laboratory stress tests on wood are summarized in tables of design values. A **design value** is a number assigned to how well a particular wood resists stresses. Part of a design value table is shown in **Table 14-1** on page 380. This is shown only as an example. *Always read the footnotes that accompany the table.*

Carpenters and builders should have a basic understanding of what design values mean. Design values are based on the following stress factors shown in **Figure 14-12** on page 381.

Extreme Fiber Stress in Bending (F_b) When a load is applied to a joist, header, or beam, it bends. This produces tension stresses in the wood farthest from the load and compression stresses closest to the load. (**Figure 14-12A**).

Tension Parallel to Grain (F_t) When the ends of a piece of wood are pulled in opposite directions, tension along the grain results. (**Figure 14-12B**). This might occur in a floor joist attached to two walls that are bowing outward.

Horizontal Shear (F_v) Shear stresses occur where two portions of the wood are trying to slide past each other in opposite directions. (**Figure 14-12C**). A deep, heavily loaded beam might experience shear stresses near the centerline of the wood.

Table 14-1: Design Values for Beams and Stringers[a]

5" and thicker, width more than 2" greater than thickness[b] Grades described in sections 53.00 and 70.00 of *Western Lumber Grading Rules*

Species or Group	Grade	Extreme Fiber Stress in Bending *Single Member F_b*	Tension Parallel to Grain *F_t*	Horizontal Shear[c] *F_v*	Compression		
					Perpendicular *$F_{c\perp}$*	Parallel to Grain *F_c*	Modulus of Elasticity *E*
Douglas Fir-Larch	Dense Select Structural	1,900	1,100	170	730	1,300	1,700,000
	Dense No.1	1,550	775	170	730	1,100	1,700,000
	Dense No. 2	1,000	500	170	730	700	1,400,000
	Select Structural	1,600	950	170	625	1,100	1,600,000
	No. 1	1,350	675	170	625	925	1,600,000
	No. 2	875	425	170	625	600	1,300,000
Douglas Fir-South	Select Structural	1,550	900	165	520	1,000	1,200,000
	No. 1	1,300	625	165	520	850	1,200,000
	No. 2	825	425	165	520	550	1,000,000
Hemlock-Fir	Select Structural	1,300	750	140	405	925	1,300,000
	No. 1	1,050	525	140	405	750	1,300,000
	No. 2	675	350	140	405	500	1,100,000
Mountain Hemlock	Select Structural	1,350	775	170	570	875	1,100,000
	No. 1	1,100	550	170	570	725	1,100,000
	No. 2	725	375	170	570	475	900,000
Sitka Spruce	Select Structural	1,200	675	140	435	825	1,300,000
	No. 1	1,000	500	140	435	675	1,300,000
	No. 2	650	325	140	435	450	1,100,000
Spruce-Pine-Fir (South)	Select Structural	1,050	625	65	335	675	1,200,000
	No. 1	900	450	65	335	575	1,200,000
	No. 2	575	300	65	335	350	1,000,000
Western Cedars	Select Structural	1,150	700	70	425	875	1,000,000
	No. 1	975	475	70	425	725	1,000,000
	No. 2	625	325	70	425	475	800,000
Western Hemlock	Select Structural	1,400	825	170	410	1,000	1,400,000
	No. 1	1,150	575	170	410	850	1,400,000
	No. 2	750	375	170	410	550	1,100,000
Western Woods (and White Woods	Select Structural	1,050	625	65	335	675	1,100,000
	No. 1	900	450	65	335	575	1,100,000
	No. 2	575	300	65	335	350	900,000

[a]Design Values in pounds per square inch. See Sections 100.00 through 180.00 in the *Western Lumber Grading Rules*.
[b]When the depth of a sawn lumber member exceeds 12", the design value for extreme fiber stress in bending (F_b) shall be multiplied by a size factor in Table J.
[c]All horizontal shear values are assigned in accordance with ASTM standards, which include a reduction to compensate for any degree of shake, check, or split that might develop in a piece.

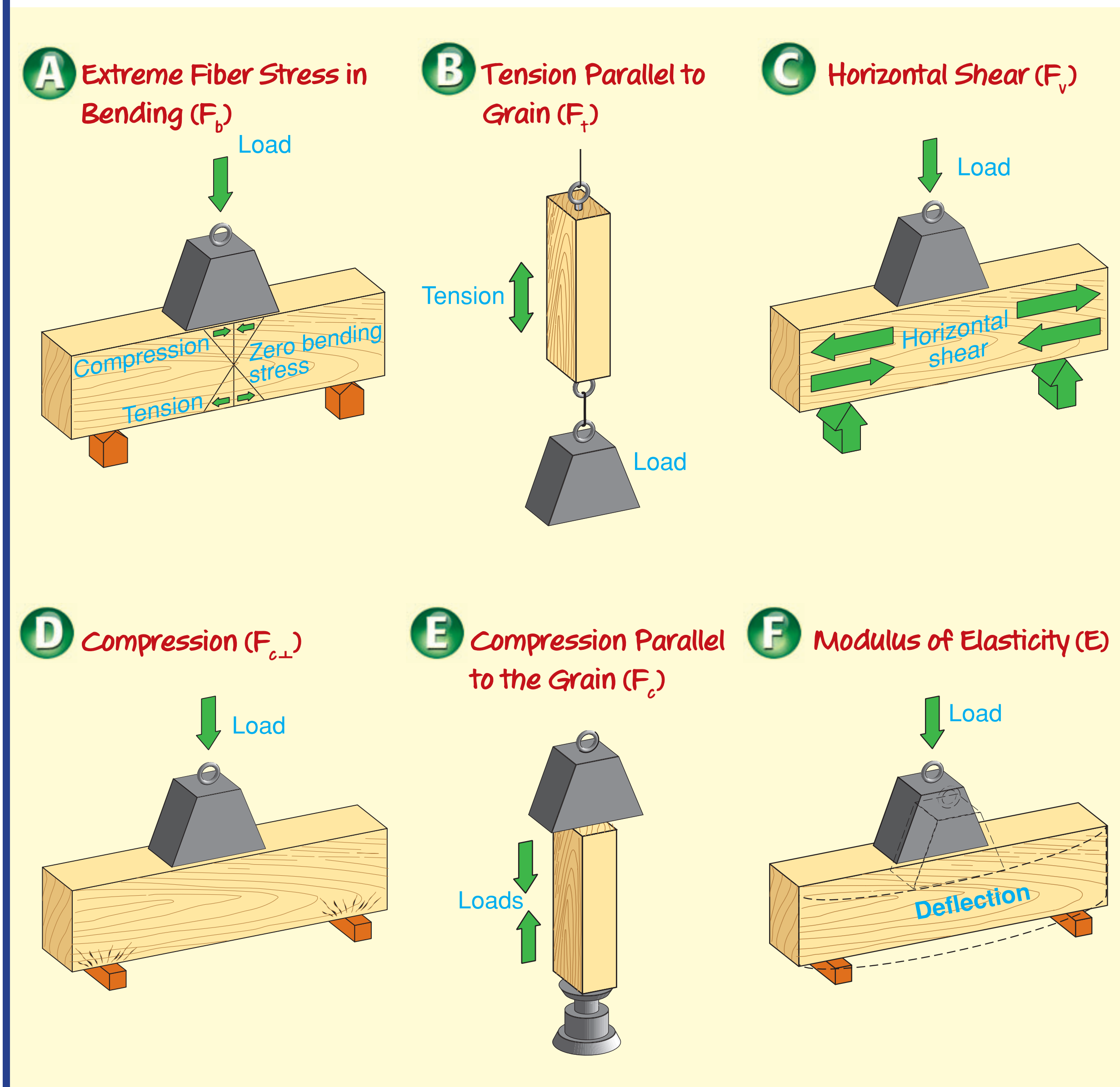
Compression Perpendicular to the Grain ($F_{c\perp}$) This occurs when the wood rests on supports. An example would be a joist (**Figure 14-12D**). Any load on the wood tends to crush wood fibers at the bearing points. This problem can be reduced by increasing the bearing area.

Compression Parallel to the Grain (F_c) This occurs when loads are supported on the ends of the wood (**Figure 14-12E**). This is typical of studs, posts, and columns. The resulting stresses affect the wood fibers uniformly along the full length of the wood.

Modulus of Elasticity (E) This is the ratio showing the amount that wood will bend in proportion to its load. The actual amount of bending is called *deflection*. An example would be how "springy" a floor is when walked on, as in **Figure 14-12F**.

Figure 14-12 Types of Stresses

The Basic Five These are the common stresses that act on wood.



Span Tables

Carpenters do not need to figure out how a certain wood will behave in a floor or ceiling. Instead, they can refer to a span table, such as the one for floor joists in **Table 14-2**. *This table is a sample only; always check your local building code book for current span tables.* A **span table** lists the maximum spacing allowed between different sizes of joists or rafters. This type of spacing is referred to as on center spacing. **On center (OC)** refers to the distance from the centerline of one structural member to the centerline of the next closest member.

Using span tables, a carpenter can quickly find the right spacing for the species, grade, and dimensions of wood being used. Span tables are included in building code books and in literature from the major lumber trade associations. More complete examples

Table 14-2: Floor Joist Spans

40 lbs. LIVE LOAD. 10 lbs. DEAD LOAD. L/360
Design Criteria: *Strength*– 10 lbs. per sq. ft. dead load plus 40 lbs. per sq. ft. live load.
Deflection– Limited in span in inches divided by 360 for live load only.

		Span (ft. and in.)															
		2×8				2×10				2×12				2×14			
		Spacing on Center															
Species or Group	Grade	12"	16"	19.2"	24"	12"	16"	19.2"	24"	12"	16"	19.2"	24"	12"	16"	19.2"	24"
Douglas Fir-Larch	Sel. Struc.	15-0	13-7	12-10	11-11	19-1	17-4	16-4	15-2	23-3	21-1	19-10	18-6	27-4	24-10	23-5	21-4
	1 & Btr.	14-8	13-4	12-7	11-8	18-9	17-0	16-0	14-9	22-10	20-9	19-1	17-1	26-10	23-4	21-4	19-1
	No. 1	14-5	13-1	12-4	11-0	18-5	16-5	15-0	13-5	22-0	19-1	17-5	15-7	24-7	21-4	19-5	17-5
	No. 2	14-2	12-9	11-8	10-5	18-0	15-7	14-3	12-9	20-11	18-1	16-1	14-9	23-4	20-3	18-5	16-6
	No. 3	11-3	9-9	8-11	8-0	13-9	11-11	10-11	9-9	16-0	13-10	12-7	11-3	17-10	15-5	14-1	12-7
Douglas Fir-South	Sel. Struc.	13-6	12-3	11-7	10-9	17-3	15-8	14-9	13-8	21-0	19-1	17-11	16-8	24-8	22-5	21-1	19-7
	No .1	13-2	12-0	11-3	10-6	16-10	15-3	14-5	12-11	20-6	18-4	16-9	15-0	23-8	20-6	18-9	16-9
	No. 2	12-10	11-8	11-0	10-2	16-5	14-11	13-10	12-5	19-11	17-7	16-1	14-4	22-8	19-8	17-11	16-1
	No. 3	11-0	9-6	8-8	7-9	13-5	11-8	10-7	9-6	15-7	13-6	12-4	11-0	17-5	15-1	13-9	12-4
Hemlock-Fir	Sel. Struc.	14-2	12-10	12-1	11-3	18-0	16-5	15-5	14-4	21-11	19-11	18-9	17-5	25-10	23-6	22-1	20-6
	1 & Btr.	13-10	12-7	11-10	11-0	17-8	16-0	15-1	14-0	21-6	19-6	18-3	16-4	25-3	22-4	20-5	18-3
	No. 1	13-10	12-7	11-10	10-10	17-8	16-0	14-10	13-3	21-6	18-10	17-2	15-5	24-4	21-1	19-3	17-2
	No. 2	13-2	12-0	11-3	10-2	16-10	15-2	13-10	12-5	20-4	17-7	16-1	14-4	22-8	19-8	17-11	16-1
	No. 3	11-0	9-6	8-8	7-9	13-5	11-8	10-7	9-6	15-7	13-6	12-4	11-0	17-5	15-1	13-9	12-4
Spruce-Pine-Fir (South)	Sel. Struc.	13-2	12-0	11-3	10-6	16-10	15-3	14-5	13-4	20-6	18-7	17-6	16-3	24-1	21-11	20-7	19-2
	No. 1	12-10	11-8	11-0	10-2	16-5	14-11	14-0	12-7	19-11	17-10	16-3	14-7	23-0	19-11	18-2	16-3
	No. 2	12-6	11-4	10-8	9-8	15-11	14-6	13-3	11-10	19-4	16-10	15-4	13-9	21-8	18-9	17-2	15-4
	No. 3	10-5	9-0	8-3	7-5	12-9	11-0	10-1	9-0	14-9	12-10	11-8	10-5	16-6	14-4	13-1	11-8
Western Woods	Sel. Struc.	12-10	11-8	11-0	10-2	16-5	14-11	14-0	12-9	19-11	18-1	16-6	14-9	23-4	20-3	18-5	16-6
	No. 1	12-6	11-1	10-1	9-0	15-7	13-6	12-4	11-0	18-1	15-8	14-4	12-10	20-3	17-6	16-0	14-4
	No. 2	12-1	11-0	1-01	9-0	15-5	13-6	12-4	11-0	18-1	15-8	14-4	12-10	20-3	17-6	16-0	14-4
	No. 3	9-6	8-3	7-6	6-9	11-8	10-1	9-2	8-3	13-6	11-8	10-8	9-6	15-1	13-1	11-11	10-8

of span tables are shown in the **Ready Reference Appendix**. Steps in reading a span table are given below.

To simplify span tables, loads on a structure are divided into two types, dead loads and live loads. A **dead load** is the total weight of the building. This includes the structural frame and anything permanently attached, such as wall coverings. A **live load** is weight that is not permanently attached. Examples of live loads include furniture and people. Live loads are determined based on the use of the building.

Step-by-Step Application

Reading a Span Table Use a span table to determine what dimension of floor joist is suitable for use over a span of 18'.

Step 1 Determine the live load category of the building (30 or 40 lbs. per square foot). The designer determines the live load based on the usage of the building. For example, refer to **Table 14-2**, which deals with structures with a live load of 40 psf (pounds per square foot).

Step 2 Locate the "Species or Group" column. Identify the species of wood being considered.

Step 3 Refer to the "Grade" column. Identify the wood grade.

Step 4 Follow the row to the right until you find 18-0 or greater. This is the span you are looking for, in feet and inches.

Step 5 Now, follow the column directly upward to the "Spacing on Center" row. The numbers there will tell you how far apart the joists must be spaced.

Step 6 In the row above that are the lumber dimensions. For example, Hem-Fir (hemlock-fir) joists graded No. 1 would have to be 2×12s in order to span 18'. They could be spaced either 12" or 16" on center (OC), but no further apart.

Go to **glencoe.com** for this book's OLC for additional step-by-step procedures, applications, and certification practice.

Section 14.1 Assessment

After You Read: Self-Check

1. What are the basic pieces that form the structure of a wood-frame house?
2. What are the two basic types of conventional framing?
3. What do design value tables show and what are they used for?
4. What is a *live load*?

Academic Integration: Science

5. **Stress Factors** Stress factors include extreme fiber stress in bending, tension parallel to grain, horizontal shear, compression, compression parallel to the grain, and modulus of elasticity. A floor joist has been attached to two outside walls that are bowing outward. Which type of stress is being applied to the floor joist?

   Starting Hint Draw a simple sketch with arrows indicating the direction of the force.

Go to **glencoe.com** for this book's OLC to check your answers.

Section 14.2

Nails & Connectors

Construction Nails

What does the "d" in nail sizing stand for?

Creating a strong structural frame for a house depends on good materials and correct structural design. Good connections are also important. Without them, even the best materials would not **function** properly. Screws, staples, and adhesives are often used to assemble the framework of a house. However, *nailing* is still the primary connection method, though builders are increasingly relying on metal framing connectors as well. These two connection methods will be discussed in this section.

There are literally hundreds of different types of nails. They are made from many different materials, but nails made of mild steel are used most in building construction. The most commonly used types are shown in **Figure 14-13**.

Nail Anatomy

The basic parts of a nail are the head, shank, and point. Each of these parts can vary according to the type of use the nail is intended for.

Head The head of a nail determines how easily it can be pulled through the material. Nails typically have a round head, although nails driven by pneumatic tools may be shaped in other ways. Nails with large heads, such as common nails and roofing nails, will not pull through under normal conditions. These nails are intended for structural uses where the visibility of the head is not objectionable. Brads and finish nails have small heads, and can easily be pulled through most material. They do not have much holding power, and are primarily used in finish work.

Shank The shank of a nail is the portion below the head. The type of shank determines how well the nail will resist withdrawal. *Withdrawal* refers to forces that can pull the nail headfirst out of the wood. These forces are applied parallel to the nail shank.

There are two basic types of nail shanks. *Smooth-shank* nails are used for general construction. The shank provides good holding power in a variety of woods. Most framing and roofing nails are smooth-shank nails. *Deformed-shank* nails are best for

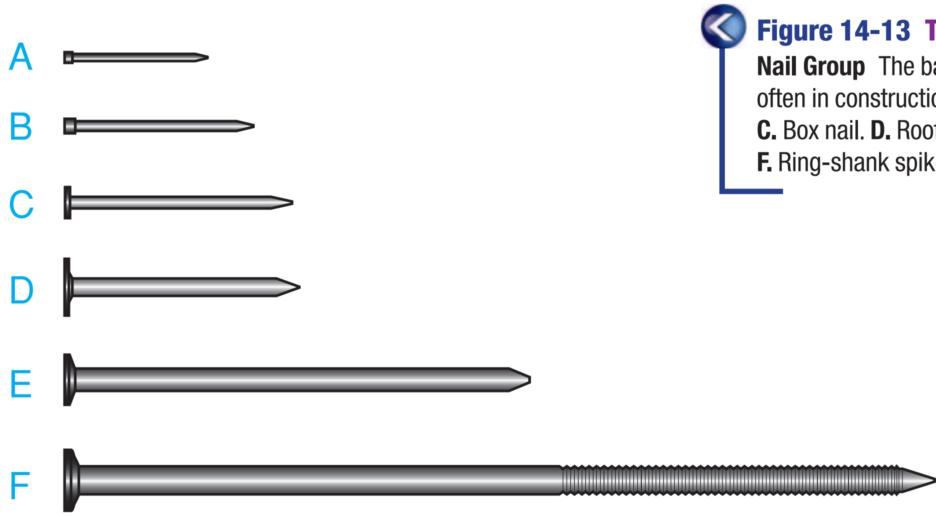


Figure 14-13 Types of Nails

Nail Group The basic types of nails used most often in construction: **A.** Wire brad. **B.** Finish nail. **C.** Box nail. **D.** Roofing nail. **E.** Common nail. **F.** Ring-shank spike applications that require extra holding power. The shank features a series of ridges or a spiral, which increases withdrawal resistance. One new type of nail has a spiral pattern near the head, a ridged pattern near the point, and a smooth shank in between. The combination increases withdrawal resistance without reducing the nail's strength. A shank's diameter determines how well the nail will resist shear. *Shear* refers to forces acting perpendicular to the nail. They cause the nail to bend. The larger the nail's diameter, the greater its resistance to shear.

Point The point of a nail determines how likely it will be to split the wood and how easy it will be to drive. Nails with sharp points are easy to drive but are more likely to split the wood. Nails with relatively blunt points are not as likely to split the wood. A blunt point tends to crush or sever the wood fibers as it enters, where a sharper point tends to wedge them apart. A compromise between sharp and blunt is a four-sided tapered cut called a *diamond point.* This is the point found on most nails used for framing.

Nail Sizes

Nails are classified by pennyweight, abbreviated "d." For example, a 16d nail is pronounced "sixteen-penny." The origins of this system are unclear but it is generally thought to have begun in England. The "d" is the abbreviation for the Latin word *denarius,* a small Roman coin similar to a modern penny. Note that the penny number of a nail refers to its length, not its cost or its weight. The larger the number, the longer the nail, as shown in **Figure 14-14**. Also, the longer the nail, the larger its diameter.

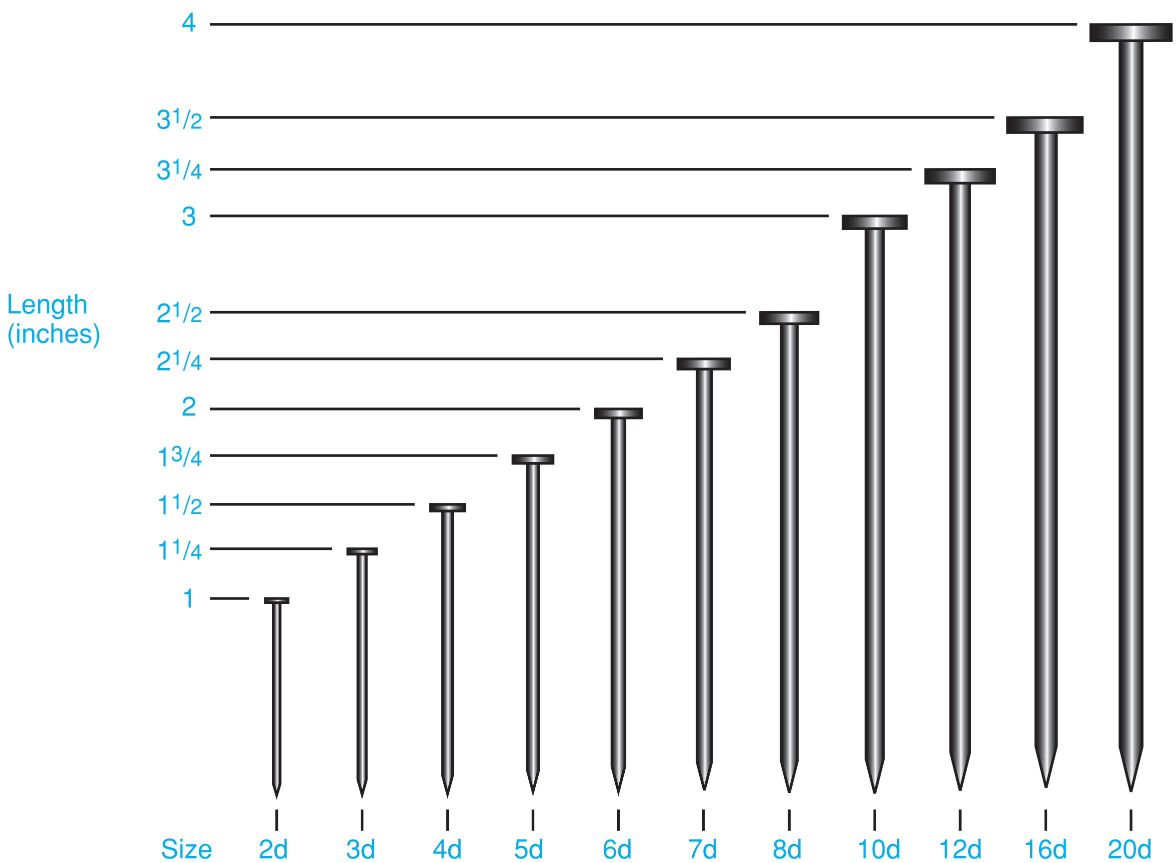


Figure 14-14 Relative Nail Sizes

Penny Is Length These are the lengths of nails most often used in construction.

Builder's Tip

PREVENTING SPLITS When nailing close to the end of a board, carpenters often blunt the tip of a nail slightly by tapping it with a hammer. This reduces the chance that it will split the wood.

Using Nails In order to hold a connection properly, the correct size and type of nail must be used. Carpenters must also be sure to use the correct number of nails. Using fewer nails than specified results in a weakened connection. However, in many cases the same problem occurs when too many nails are used. This is because the additional nails tend to create weakened areas of wood that will eventually split. The number and type of nail used for each type of connection in a house is specified in the building code. **Table 14-3** shows some of the more common nailing requirements. Consult tables in the code book called "nailing schedules" for more information about nailing.

Reading Check

Recall *What is a shank?*

Metal Framing Connectors

How should a joist hanger be installed?

At one time in modern platform framing, all wood-to-wood connections were secured by nails alone. Because of differences in the skills of carpenters, the strength of the connections varied. In order to strengthen connections and make them more uniform, metal framing connectors were developed. A metal **framing connector** is a formed metal bracket that is installed at framing connections using nails. Connectors are often used to install engineered lumber. Some engineered products, such as I-joists, are difficult or impossible to secure without the use of

Table 14-3: Nail Details for Framing

Description of Building Elements	Number and Type of Fastener*
Joist to sill or girder, toe nail	3-8d
1" × 6" subfloor or less to each joist, face nail	2-8d
2" subfloor to joist or girder, blind and face nail	2-16d
Sole plate to joist or blocking, face nail 16" OC	16d
Top or sole plate to stud, end nail	2-16d
Stud to sole plate, toe nail	3-8d or 2-16d
Double studs, face nail 24" OC	10d
Double top plates, face nail 24" OC	10d
Sole plate to joist or blocking at braced wall panels 16" OC	3-16d
Double top plates, minimum 24-inch offset of end joints, face nail in lapped area	8-16d (3½" × 0.135")
Blocking between joists or rafters to top plate, toe nail	3-8d
Rim joist to top plate, toe nail 6" OC	8d
Top plates, laps at corners and intersections, face nail	2-10d
Built-up header, two pieces with ½" spacer 16" OC along each edge	16d
Continued header, two pieces 16" OC along each edge	16d
Ceiling joists to plate, tow nail	3-8d
Continuous header to stud, toe nail	4-8d
Ceiling joist, laps over partitions, face nail	3-10d
Ceiling joist to parallel rafters, face nail	3-10d
Rafter to plate, toe nail	2-16d
Built-up corner studs 24" OC	10d
Roof rafters to ridge, valley or hip rafters: toe nail face nail	 4-16d 3-16d
Rafter ties to rafters, face nail	3-8d
Collar tie to rafter, face nail, or 1¼" × 20 gauge ridge strap	3-10d

*All nails are smooth-common, box, or deformed shank.

metal framing connectors. Connectors are very important where severe conditions can be expected, such as high winds or earthquakes. For example, the connector shown in **Figure 14-15**, ties the wall framing to the roof framing. It is aptly called a *tie*.

Manufacture

A metal framing connector not only makes wood-to-wood junctions stronger, it makes wood-to-masonry and wood-to-concrete connections stronger as well. Some ornamental connectors are meant to be exposed. However, most will never be seen after the building is completed. These are made from various gauges of galvanized steel, as shown in **Table 14-4**.

Metal connectors are galvanized after they have been formed into a specific shape. Galvanizing deposits a layer of zinc on all sides. This protects the metal by slowing corrosion (the formation of rust). The thickness of the zinc coating is indicated by a code. The standard zinc coating is G 60. This means that the zinc is 0.005" thick on each side of the steel. A connector with a G 90 coating would have a layer of zinc one-and-one-half times as thick as one with a G 60 coating. Some connectors have a G 185 coating. If even greater corrosion resistance is required, stainless steel connectors should be considered. They must be installed using stainless steel nails because other nails would rust.

Table 14-4: Thickness of Galvanized Steel Used for Framing Connectors

Gauge	In Decimal Inches	In Millimeters	In Approximate Fractions of an Inch
7	0.186	4.8	3/16
10	0.138	3.5	1/8
11	0.123	3.1	1/8
12	0.108	2.7	3/32
14	0.078	2.0	3/32
16	0.063	1.6	1/16
18	0.052	1.3	1/16
20	0.040	1.0	1/32
22	0.034	0.8	1/32

Note: Actual steel dimensions will vary from nominal dimensions according to industry tolerances.

Figure 14-15 Hurricane Tie

Stronger Joints This connector ties walls to roof framing. It can be used where a stud is directly beneath a rafter.

Types of Connectors

A wide variety of connectors is available. The best source of information about a connector is the manufacturer. Framing connectors are widely accepted by building codes. However, you should always make sure that the use you are planning for is approved by the manufacturer and by local codes.

REGIONAL CONCERNS

Corrosion-Resistant Connectors Salt spray from the ocean increases the speed of corrosion. The amount of salt spray in the air may be a significant factor as far as 3,000' inland. Builders in these areas should use metal connectors that have extra corrosion resistance. Check local codes to see how far inland the "corrosion zone" extends.

Go to glencoe.com for this book's OLC for more information about regional concerns.

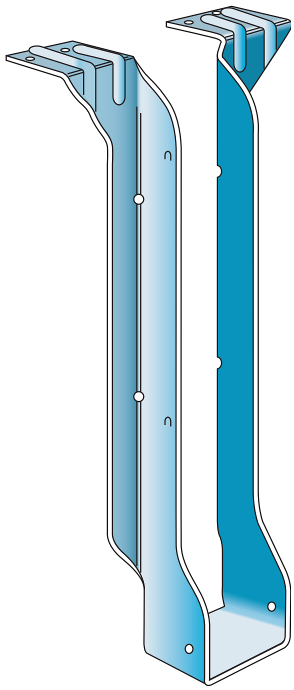
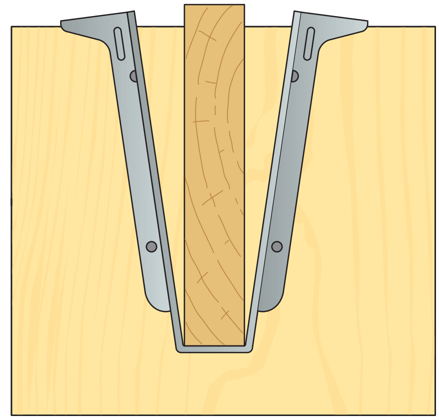


Figure 14-16 A Joist Hanger

Joist Support A joist hanger secures a joist to an intersecting framing member.



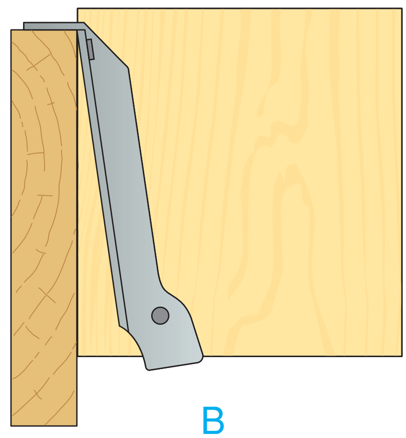


Figure 14-17 Improper Installation

Avoid This An overspread hanger **A.** raises the height of the joist. If the hanger is "kicked out" from the header **B.** but not overspread, the floor may squeak.

Standard Joist Hangers Perhaps the most common metal connector is the joist hanger, shown in **Figure 14-16**. These sturdy brackets are used where floor or ceiling joists meet another framing member, such as a beam. Standard hangers are made from 18-gauge galvanized metal and are intended for use with solid lumber joists. They are typically installed with 10d common nails. However, always follow the manufacturer's recommendations for the type and size of nail. Special *joist-hanger nails* may also be supplied by the manufacturer. They are the same diameter as a 10d nail but shorter.

To install a joist hanger, first nail it to a beam. Then slip the joist into the hanger. Finally, hammer nails through the holes in the hanger and into the joist. Proper installation is important. If the sides of the hanger are spread too wide, the joist will be raised slightly, as shown in **Figure 14-17**. This can cause a lump in the floor sheathing. If the seat of the hanger is "kicked out" from the beam, settling later on may cause the floor to squeak.

The most common mistake made when installing joist hangers is to use too few nails. The connection depends on nails for shear strength. Undernailing can cause the connection to fail when loads are placed on

Builder's Tip

POSITIONING JOISTS To ensure that the tops of all floor joists are in exactly the same plane, a joist hanger can be nailed to the end of each joist first. Hold the joist in the desired position, then secure the hanger to the beam.

Figure 14-18 Flush Edges

Alignment A joist hanger must be positioned so that the top of the joist is flush with other joists. The position of the joist's lower edge is less critical. *Why is the top edge more important?*

it. Check the manufacturer's instructions carefully. Use all the nails recommended.

Joist hangers are available in sizes to fit most common framing situations. Headers, for example, may be hung from a pair of joist hangers. Even large glulam beams and solid timbers may be secured with joist hangers. They can be used when the top edge of a joist must be at the same level as the top edge of an intersecting beam. They are also used when the bottom edges of the intersecting members must be flush, as in **Figure 14-18**.

I-Joist Hangers Because the shape of I-joists might allow them to tip from side to side in a standard joist hanger, choose hangers

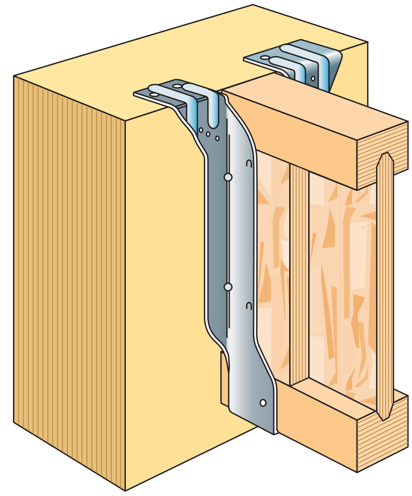


Figure 14-19 Web Stiffener

Extra Support Web stiffeners fit between the joist hanger and the I-joist. They prevent the web from buckling at stress points.

with care. If the sides of the hanger do not extend at least ⅜" up the sides of the I-joist's top flange, install a web stiffener. This will prevent the I-joist from tipping from side to side, as shown in **Figure 14-19**. I-joist hangers are designed specifically for use with I-joists, and web stiffeners may not be needed.

When I-joists are attached to an intersecting I-joist, the joist hangers should be *backed*. To back joist hangers means placing backer blocks against the web, between the flanges of the supporting I-joist. Nails are driven into the blocks for extra support.

Builder's Tip

ENSURING MAXIMUM STRENGTH Metal brackets, anchors, and straps increase a structure's ability to resist severe weather and earthquakes. However, to be effective they must be installed *exactly* according to the manufacturer's specifications. It is particularly important to use the correct number and size of nails.

Figure 14-20 Connectors

Reinforcement Metal framing ties connect and reinforce materials.

Tie Plate

Metal ties are being used here to connect various parts of a truss.

Railing Ties

Railing ties are first connected to the post. Galvanized screws may be used instead of nails because the connection is not load-bearing.

Post Base

A post base holds the wood slightly above the top of the pier to reduce the chance of rot.

Ties and Straps *Metal framing ties* are also used to hold pieces of wood together or to reinforce a joint. The most common form of tie is a flat strap, shown in **Figure 14-20A**. The straps are perforated so they can be nailed in place without pre-drilling. They may also be bent to fit various angles.

A tie in an angular shape can be used to join wood members at right angles. Such ties do not carry structural loads. They simply hold the pieces of wood together. An example is the tie that connects deck railings to deck posts. The post holds the railing up. The tie simply holds them together. An advantage of this connection is that it removes the need for surface-nailing. It also reduces the chance that water will penetrate the area around the nails.

Arnold & Brown; Tim Fuller

Other Metal Connectors The wide variety of metal connectors makes them useful from foundation to roof. Metal post bases can be embedded in concrete slabs or piers, as shown above. The base holds the wood post slightly above the level of the concrete. This reduces the possibility of rot. When the post is bolted to the post base, it is securely tied to its foundation.

Various types of metal clips and bracket can be used to tie rafters and trusses to a top plate. Metal connectors such as these are sometimes required in areas affected by earthquakes or fierce weather. For example, metal hurricane clips that connect top plates to rafters prevent a roof from lifting off in high winds.

Nails for Framing Connectors

Most structural framing connectors are used in situations where the nails that fasten them are exposed to shear stresses. It is very important that the nails used are able to withstand this shear stress. Otherwise, the connection may fail even if the connector itself does not. For this reason, drywall screws should never be used because they do not have the necessary shear strength that nails have. Use only nails in most framing connectors. In some instances, bolts are also appropriate.

The length of nail required varies with the type of connection. The manufacturer's instructions include nail schedules. However, when 16d nails are specified, this generally refers to common nails, not 16d sinkers. (*Sinkers* are nails that are slightly thinner and shorter than common nails.) Some manufacturers provide special nails, sometimes called joist-hanger nails, for use with their connectors. Their larger diameter, as compared with standard nails of similar length, improves their shear strength.

Pneumatic nailers can be used to fasten metal connectors into place. However, you must be careful to place the nail through existing holes in the connector. A nail that pierces the metal elsewhere reduces the connector's strength. Some pneumatic nailers are specially designed for use when installing framing connectors. They are sometimes called *hardware framing nailers*. A hardened metal probe in the nose of the tool locates the connector hole and guides the nail into it as it is driven.

Some connectors have angled holes for nails, which increases the strength of the connection. However, they must be installed by driving the nails with a hammer, not a pneumatic nailer.

Section 14.2 Assessment

After You Read: Self-Check

1. How are a common nail and a finish nail different?
2. What is the purpose of a deformed nail shank?
3. What is galvanizing and what is its purpose?
4. Name the types of metal framing connectors.

Academic Integration: Science

5. **Matching Materials to Regional Needs** The proper use of metal framing connectors is very important in regions where earthquake hazards and high winds are common. Summarize the reason for this in one or two sentences. Then, contact a company that makes metal framing connectors and gather information about connectors designed for one of these two hazards. Determine which types of connections are used in your region and why. Summarize your findings in a one-page report.

Go to glencoe.com for this book's OLC to check your answers.

CHAPTER 14

Review and Assessment

Chapter Summary

Section 14.1

Balloon-frame and platform-frame construction make use of many individual pieces of wood. Platform-frame construction is the most common system used to build houses. Other framing methods include post-and-beam framing, timber framing, and the use of structural insulated panels. The design of wood framing is based on laboratory tests of wood samples. The wood is given a rating based on its resistance to stresses. Test results are summarized in tables of design values.

Section 14.2

Choosing the correct nail is very important when assembling wood framing. Metal framing connectors improve the strength of joints. Types of connectors include standard joist hangers, I-joist hangers, and ties and straps. Always use the type and size of nail recommended for the installation of framing connectors.

Review Content Vocabulary and Academic Vocabulary

1. Use each of these content vocabulary and academic vocabulary words in a sentence or diagram.

Content Vocabulary

- balloon-frame construction (p. 370)
- platform-frame construction (p. 370)
- in-line framing (p. 373)
- post-and-beam framing (p. 373)
- structural insulated panel (p. 375)
- spline (p. 375)
- shear wall (p. 378)
- load (p. 379)
- design value (p. 379)
- span table (p. 382)
- on center (OC) (p. 382)
- dead load (p. 383)
- live load (p. 383)
- framing connector (p. 386)

Academic Vocabulary

- crucial (p. 378)
- function (p. 384)

Speak Like a Pro

Technical Terms

2. Work with a classmate to define the following terms used in the chapter: *sheathing* (p. 370), *ribands* (p. 370), *advanced framing* (p. 373), *structural timber* (p. 374), *manufactured housing* (p. 377), *hold-down anchors* (p. 379), *smooth-shank* (p. 384), *deformed-shank* (p. 384), *diamond point* (p. 385), *tie* (p. 387), *joist hanger* (p. 388), *backed* (p. 389), *sinkers* (p. 391), *hardware framing nailers* (p. 391).

Review Key Concepts

3. Summarize the process of balloon-frame construction.

4. Identify the six stresses structural lumber must resist.

5. Restate how SIPs are used in framing.

6. Explain what information is found on a span table.

7. List examples of a live load and a dead load.

8. Explain when a joist hanger is used during framing.

Critical Thinking

9. **Compare and Contrast** Describe the difference between in-line framing and standard platform frame construction.

Academic and Workplace Applications

STEM Mathematics

10. **Problem Solving** A rectangular building built with platform framing uses 24 joists set 19.2" O.C. What is the length in feet of the floor of the building?

Math Concept To solve this problem, you need to multiply the distance between each joist by the *number of spaces between joists*, not the number of joists. For help solving this problem, sketch the layout of the floor to figure out the number of spaces.

Step 1: Multiply the distance between each joist by the number of spaces between joists.

Step 2: Convert inches to feet.

21st Century Skills

11. **Information Literacy** Obtain a copy of the building code for your area. The reference section of your local library may have a copy. Locate references to the fire safety of foam plastic insulation, such as the type of foam plastic insulation used in structural insulated panels (SIP). What is this material made of? What safety precautions must be taken when using this material during construction? Summarize your findings in a one-page list or report.

21st Century Skills

12. **Problem Solving** Use the six-step problem solving process to describe how to prevent one type of framing damage caused by severe weather. Create a graphic organizer or list and fill in the steps of the problem-solving process.

1. **State the problem clearly.** This helps define what needs to be done.
2. **Collect information.** What is causing the problem? What resources are available?
3. **Develop possible solutions.** Consider several ideas.
4. **Select the best solution.** Look at the advantages and disadvantages of each.
5. **Test what appears to be the best solution.** This will reveal its strengths and weaknesses.
6. **Evaluate the solution.** Is it effective? If not, select another possibility and test that one until you find one that works.

Standardized TEST Practice — CERTIFICATION PREP

Short Answer

Directions Write one or two sentences to answer the following questions. Use a separate piece of paper to record your answers.

13. What are two natural hazards that can cause damage to housing frames?

____

____

14. What two features make flat straps the most common form of tie?

____

____

15. How does galvanizing protect nails?

____

____

TEST-TAKING TIP

Underline key words in short answer questions. This can help you make sure that you understand the question.

*These questions will help you practice for national certification assessment.