12

Light Gauge Steel Frame Construction

Driving self-drilling, self-tapping screws with electric screw guns, framers add diagonal bracing straps to a wall frame made from light gauge steel studs and runner channels. (*Courtesy of United States Gypsum Company*)

To manufacture the members used in *light gauge steel* frame construction, sheet steel is fed from continuous coils through machines at room temperature that cold-work the metal (see Chapter 11) and fold it into efficient structural shapes, producing linear members that are stiff and strong. Thus, these members are referred to as *cold-formed metal framing* to differentiate them from the much heavier hot-rolled shapes that are used in structural steel framing. The term "light gauge" refers to the relative thinness (gauge) of the steel sheet from which the members are made.

The Concept of Light Gauge Steel Construction

Light gauge steel construction is the noncombustible equivalent of wood light frame construction. The external dimensions of the standard sizes of light gauge members correspond closely to the dimensions of the standard sizes of nominal 2-inch (38-mm) framing lumber. These steel members are used in framing as closely spaced studs, joists, and rafters in much the same way as wood light frame members are used, and a light gauge steel frame building may be sheathed, insulated, wired, and nished inside and out in the same manner as a wood light frame building.

The steel used in light gauge members is manufactured to ASTM standard A1003 and is metallic-coated with zinc or aluminum-zinc alloy to provide long-term protection against corrosion. The thickness of the metallic coating can be varied, depending on the severity of the environment in which the members will be placed. For studs, joists, and rafters, the steel is formed into C-shaped *cee sections* (Figure 12.1). The webs of cee members are punched at the factory to provide holes at 2-foot (600-mm) intervals; these are designed to allow wiring, piping, and bracing to pass through studs and joists without the necessity of drilling holes on the construction site. For top and bottom wall plates and for joist headers, *channel sections* are used. The strength and stiffness of a member depend on the shape and depth of the section and the *gauge* (thickness) of the steel sheet from which it is made. A standard range of depths and gauges is available from each manufacturer. Commonly used metal thicknesses for loadbearing members range from 0.097 to 0.033 inch (2.46 0.84 mm) and are as thin as 0.018 inch (0.45 mm) for nonloadbearing members (Figure 12.2).

At least one manufacturer produces nonloadbearing light gauge steel members by passing steel sheet through rollers with mated patterned surfaces, producing a dense array of dimples in the metal of the formed members. The additional cold working of the metal that occurs during the forming process and the nished

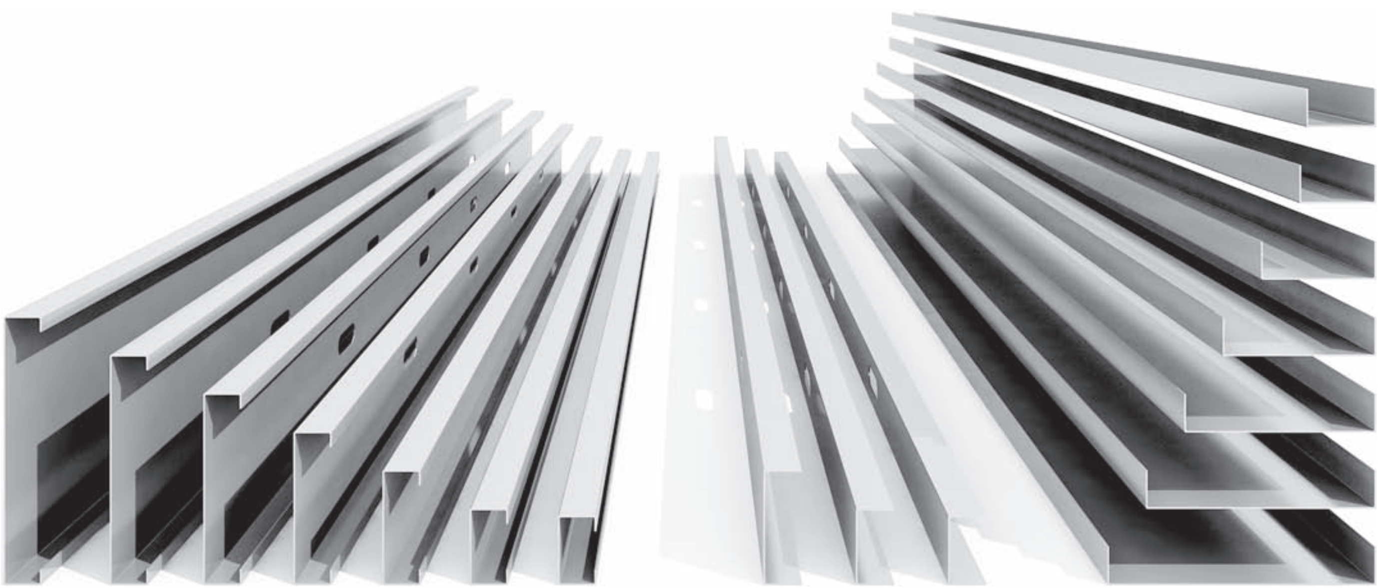


Figure 12.1
Typical light gauge steel framing members. To the left are the common sizes of cee studs and joists. In the center are channel studs. To the right are runner channels.

Considerations of Sustainability in Light Gauge Steel Framing

In addition to the sustainability issues raised in the previous chapter, which also apply here, the largest issue concerning the sustainability of light gauge steel construction is the high thermal conductivity of the framing members. If a dwelling framed with light gauge steel members is framed, insulated, and nished as if it were framed with wood, it will lose heat in winter at about double the rate of the equivalent wood structure. To overcome this limitation, energy codes now require light gauge steel framed buildings constructed in cold regions, including most of the continental United States, to be sheathed with plastic foam insulation panels in order to eliminate the extensive thermal bridging that can otherwise occur through the steel framing members.

Even with insulating sheathing, careful attention must be given to avoid undesired thermal bridges. For example, on a building with a sloped roof, a signi cant thermal bridge may remain through the ceiling joist-rafter connections, as seen in Figure 12.4*b*. Foam sheathing on the inside wall and ceiling surfaces is one possible way to avoid this condition, but adding insulation to the inside of the metal framing exposes the studs and stud cavities to greater temperature extremes and increases the risk of condensation. It also still allows thermal bridging through the screws used to fasten interior gypsum wallboard to the framing. Though small in area, these thermal bridges can readily conduct heat and result in spots of condensation on interior nish surfaces in very cold weather.

patterned surface result in members made from thinner sheet stock that are equal in and strength and stiffness to conventionally formed members produced from heavier gauge material.

For large projects, members may be manufactured precisely to the required lengths. Otherwise, they are furnished in standard lengths. Members may be cut to length on the construction job site with power saws or special shears. A variety of sheet metal angles, straps, plates, channels, and miscellaneous shapes are manufactured as accessories for light gauge steel construction (Figure 12.3).

Light gauge steel members are usually joined with *self-drilling, self-tapping screws*, which drill their own holes and form helical threads in the holes as they are driven. Driven rapidly by hand-held electric or pneumatic tools, these screws are plated with cadmium or zinc to resist corrosion, and they are available in an assortment of diameters and lengths to suit a full range of connection situations. Welding is often employed to assemble panels of light gauge steel framing that are prefabricated in a factory, and it is sometimes used on the building site where particularly strong connections are needed. Other fastening techniques that are widely used include hand-held clinching devices that join members without screws or welds and pneumatically driven pins that penetrate the members and hold by friction.

Figure 12.2
Minimum thicknesses of base sheet metal (not including the metallic coating) for light gauge steel framing members. Traditional gauge designations are also included (note how lower gauge numbers correspond to greater metal thickness). Gauge numbers are no longer recommended for specification of sheet metal thickness due to lack of a uniform standard for the translation between these numbers and actual metal thickness. Sheet metal thickness may also be specified in mils, or thousandths of an inch. For example, a thickness of 0.033 inch can be expressed as 33 mils.

	Minimum Thickness of Steel Sheet	
Gauge	Loadbearing Light Gauge Steel Framing	Nonloadbearing Light Gauge Steel Framing
12	0.097″ (2.46 mm)	
14	0.068″ (1.73 mm)	
16	0.054″ (1.37 mm)	0.054″ (1.37 mm)
18	0.043″ (1.09 mm)	0.043″ (1.09 mm)
20	0.033″ (0.84 mm)	0.030″ (0.75 mm)
22		0.027″ (0.69 mm)
25		0.018″ (0.45 mm)

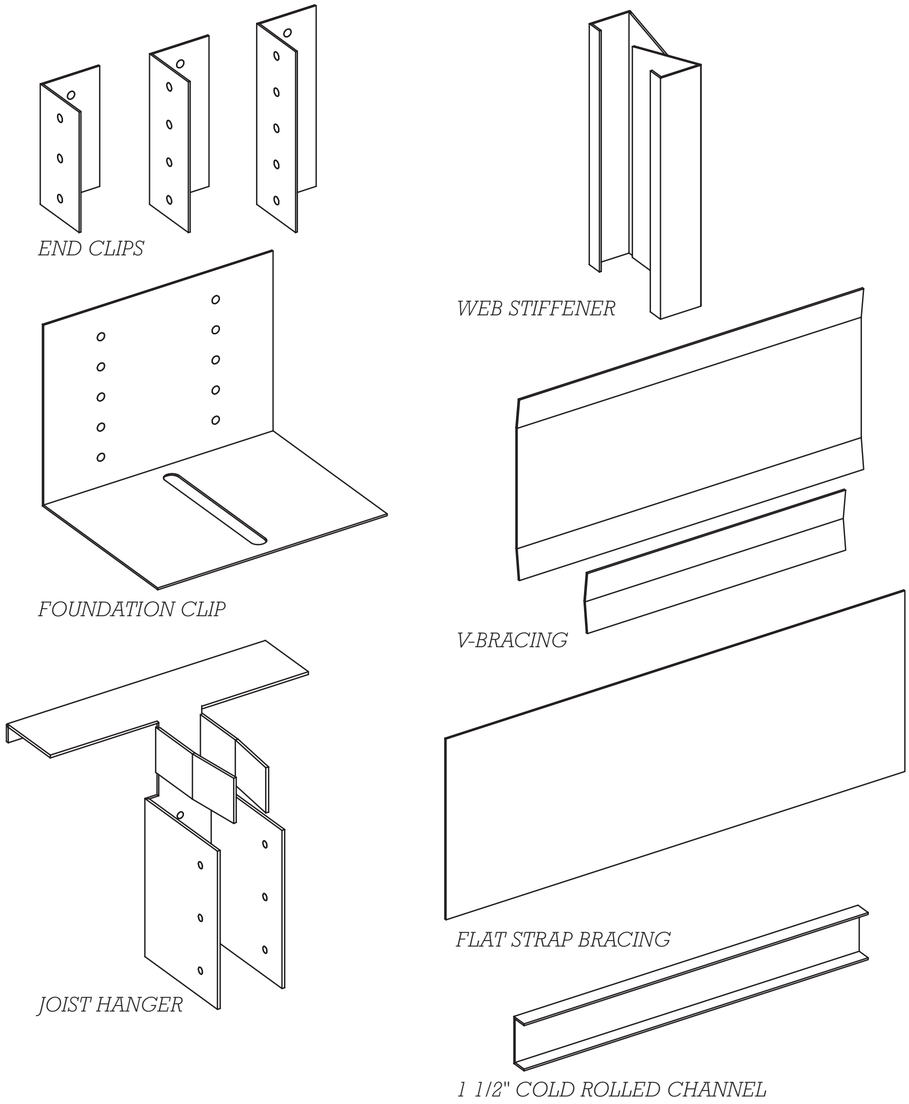
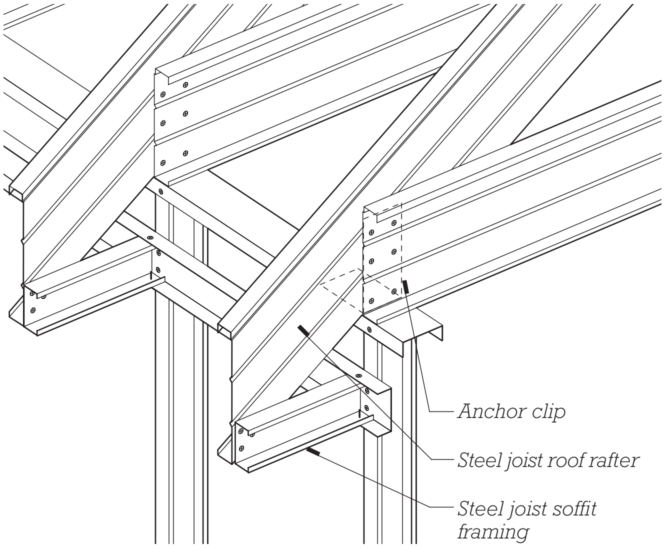


Figure 12.3
Standard accessories for light gauge steel framing. End clips are used to join members that meet at right angles. Foundation clips attach the ground-floor platform to anchor bolts embedded in the foundation. Joist hangers connect joists to headers and trimmers around openings. The web stiffener is a two-piece assembly that is inserted inside a joist and screwed to its vertical web to help transmit wall loads vertically through the joist. The remaining accessories are used for bracing.

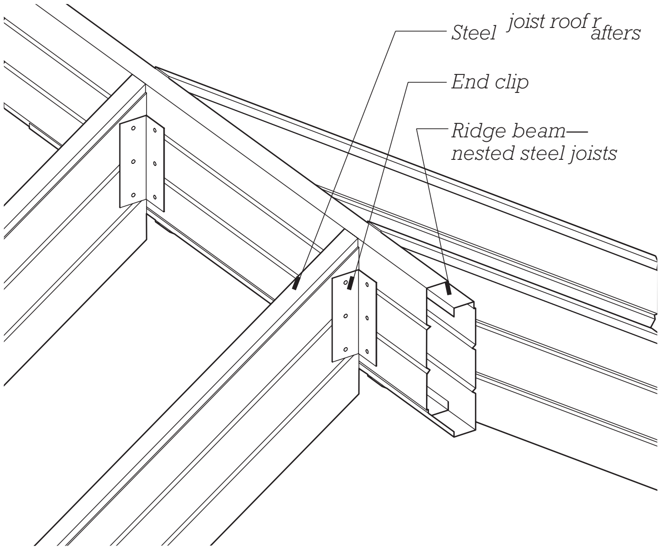
Framing Procedures

The sequence of construction for a building that is framed entirely with light gauge steel members is essentially the same as that described in Chapter 5 for a building framed with nominal 2-inch (38-mm) wood members (Figure 12.4). Framing is usually constructed platform fashion: The ground oor is framed with steel joists. Mastic adhesive is applied to the upper edges of the joists, and wood panel sub ooring is laid down and fastened to the upper anges of the joists with screws. Steel studs are laid at on the sub oor and joined to make wall frames. The wall frames are sheathed either with wood panels or, for noncombustible construction, with *gypsum sheathing panels*, which are similar to gypsum wallboard but with glass mat faces and a water-resistant core formulation. The wall frames are tilted up, screwed down to the oor frame, and braced. The upper- oor platform is framed, then the upper- oor walls. Finally, the ceiling and roof are framed in much the same way as in a wood-framed house. Prefabricated trusses of light gauge steel members that are screwed or welded together are often used to frame ceilings and roofs (Figures 12.15 and 12.16). It is possible, in fact, to frame any building with light gauge steel members that can be framed with nominal 2-inch (38-mm) wood members. To achieve a more re-resistive construction type under the building code, oors of corrugated steel decking with a concrete topping are sometimes substituted for wood panel sub ooring.

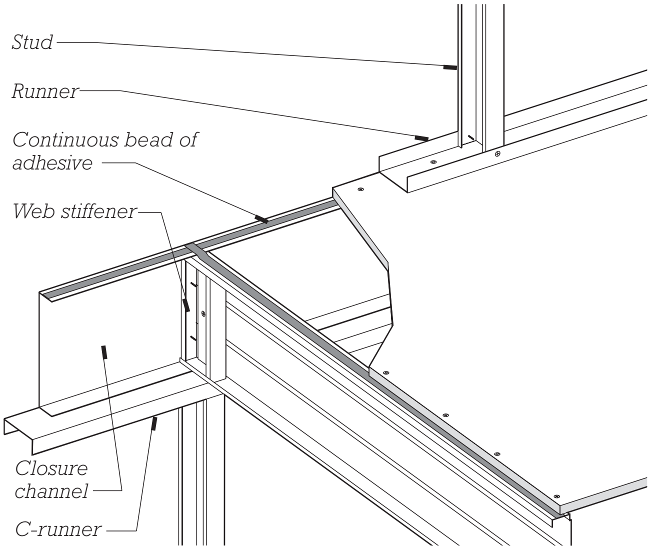
Openings in oors and walls are framed analogously to openings in wood light frame construction, with doubled members around each opening and strong headers over doors and windows (Figures 12.5 12.9). Joist hangers and right-angle clips of



B EAVE



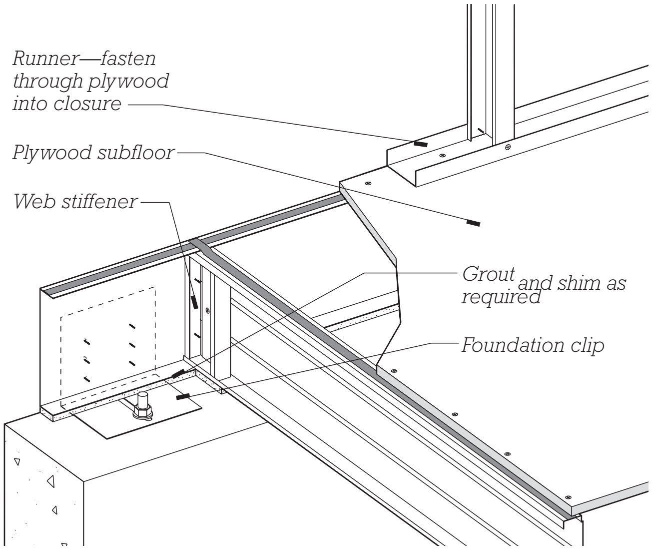
A RIDGE



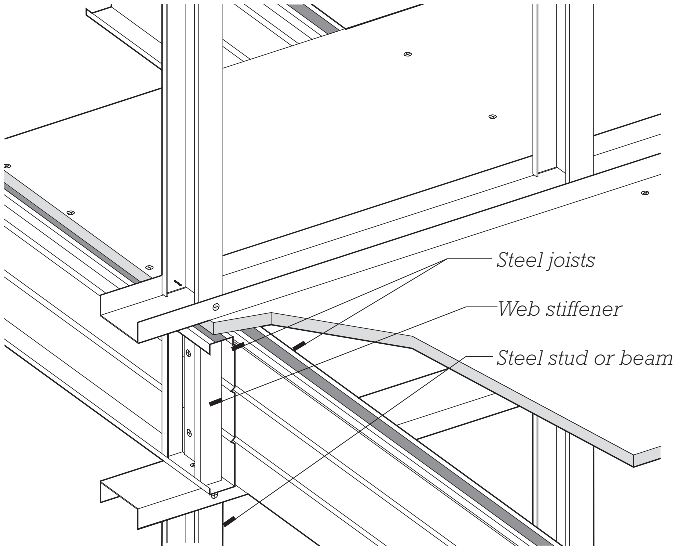
C JOIST BEARING AT UPPER FLOOR

Figure 12.4
Typical light gauge framing details. Each detail is keyed by letter to a circle on the whole-building diagram in the center of the next page to show its location in the frame. (*a*) A pair of nested joists makes a boxlike ridge board or ridge beam. (*b*) Anchor clips are sandwiched between the ceiling joists and rafters to hold the roof framing down to the wall. (*c*) A web stiffener helps transmit vertical forces from each stud through the end of the joist to the stud in the floor below. Mastic adhesive cushions the joint between the subfloor and the steel framing. (*d*) Foundation clips anchor the entire frame to the foundation. (*e*) At interior joist bearings, joists are overlapped back to back and a web stiffener is inserted.

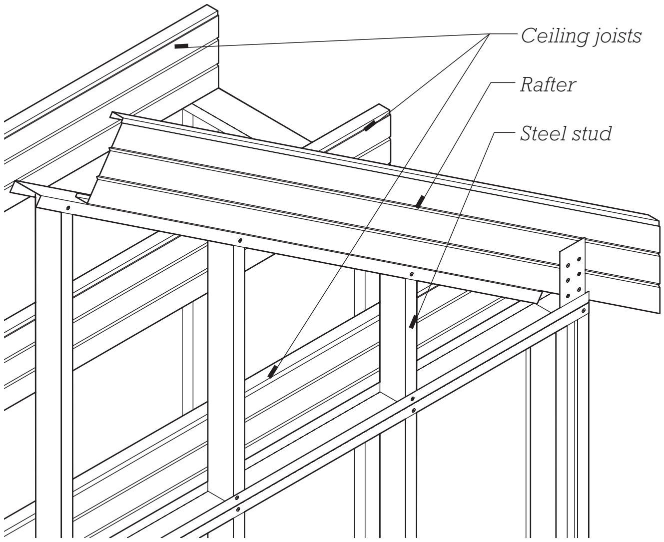
(continued)



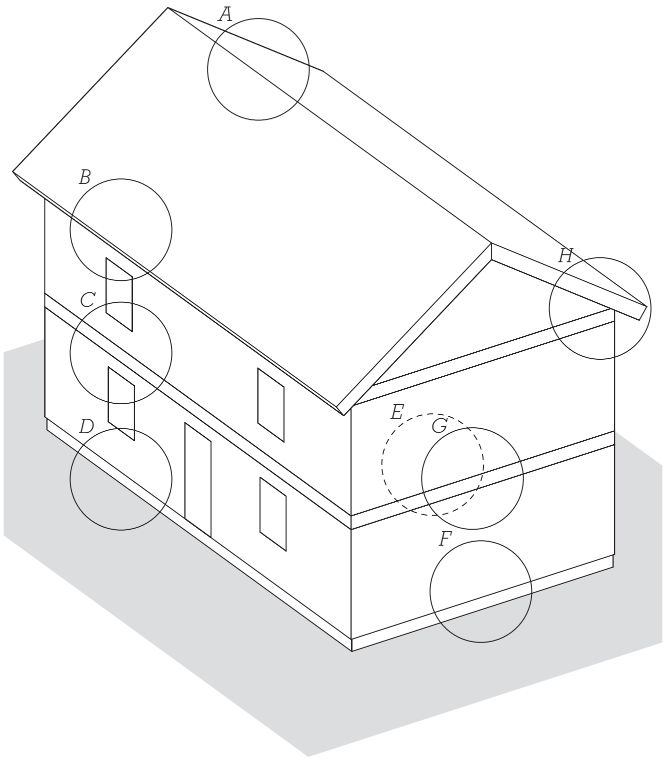
D JOIST BEARING AT FOUNDATION

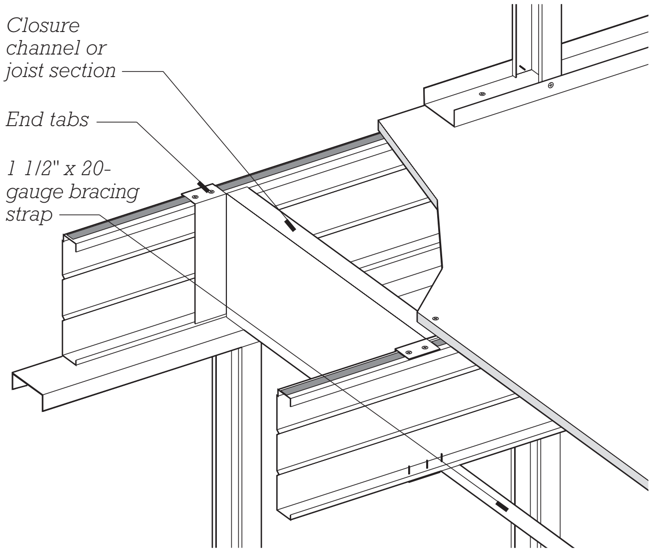


E INTERIOR JOIST BEARING

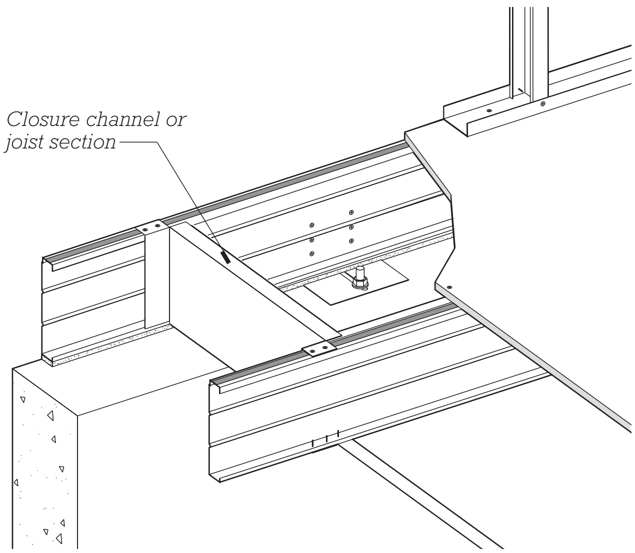


H GABLE END FRAMING





G JOIST PARALLEL TO END WALL



F JOIST PARALLEL TO FOUNDATION

FIGURE 12.4 (*continued*)
(*f*, *g*) Short crosspieces brace the last joist at the end of the building and help transmit stud forces through to the wall below. (*h*) Like all these details, the gable end framing is directly analogous to the corresponding detail for a wood light frame building as shown in Chapter 5.

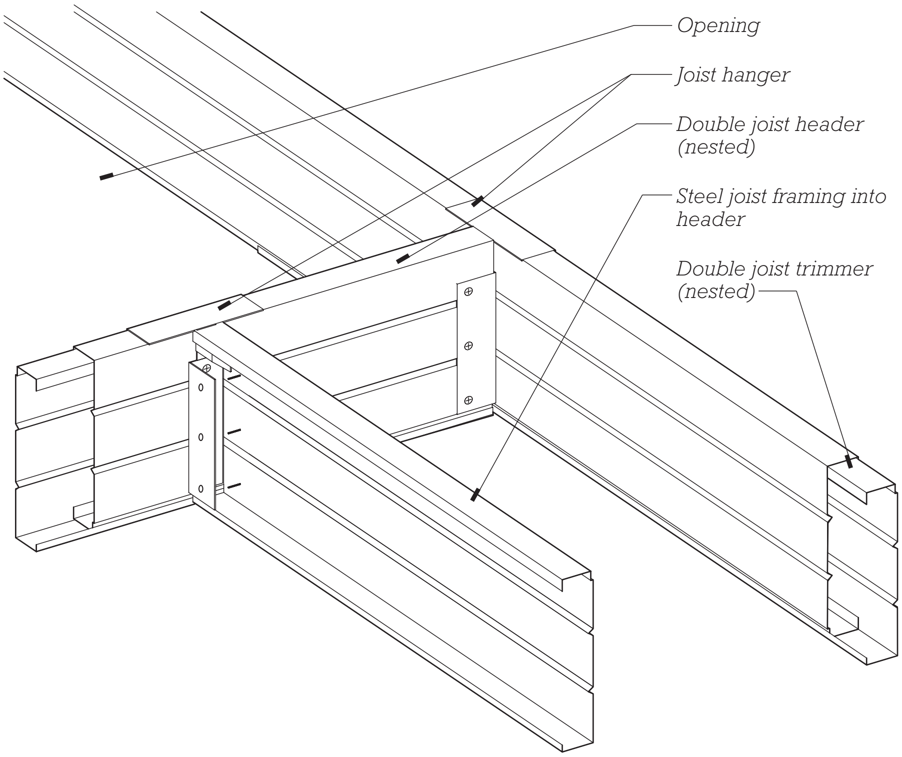


FIGURE 12.5
Headers and trimmers for floor openings are doubled and nested to create a strong, stable box member. Only one vertical flange of the joist hanger is attached to the joist; the other flange would be used instead if the web of the joist were oriented to the left rather than the right.

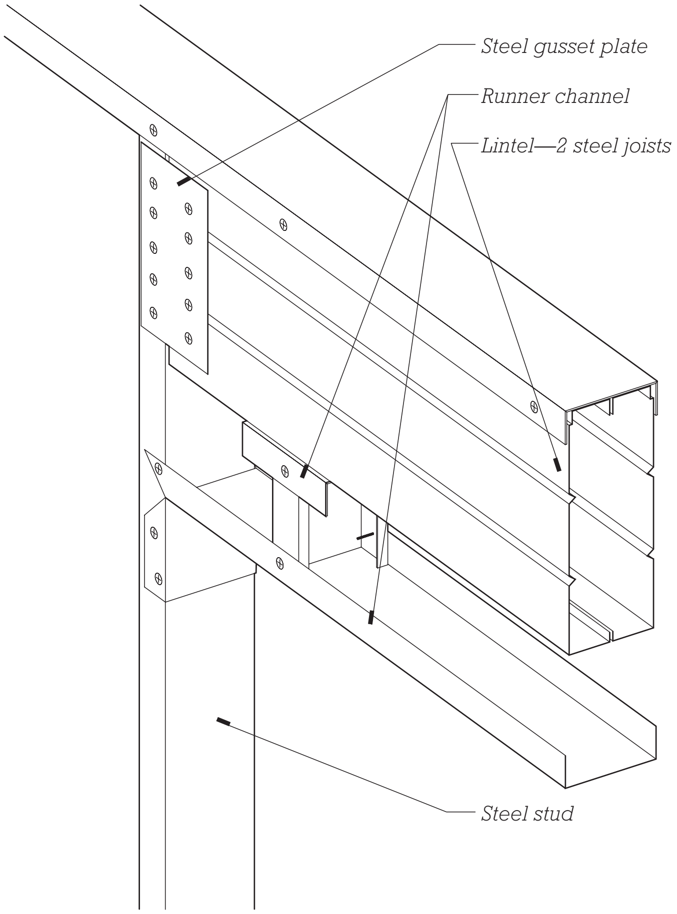
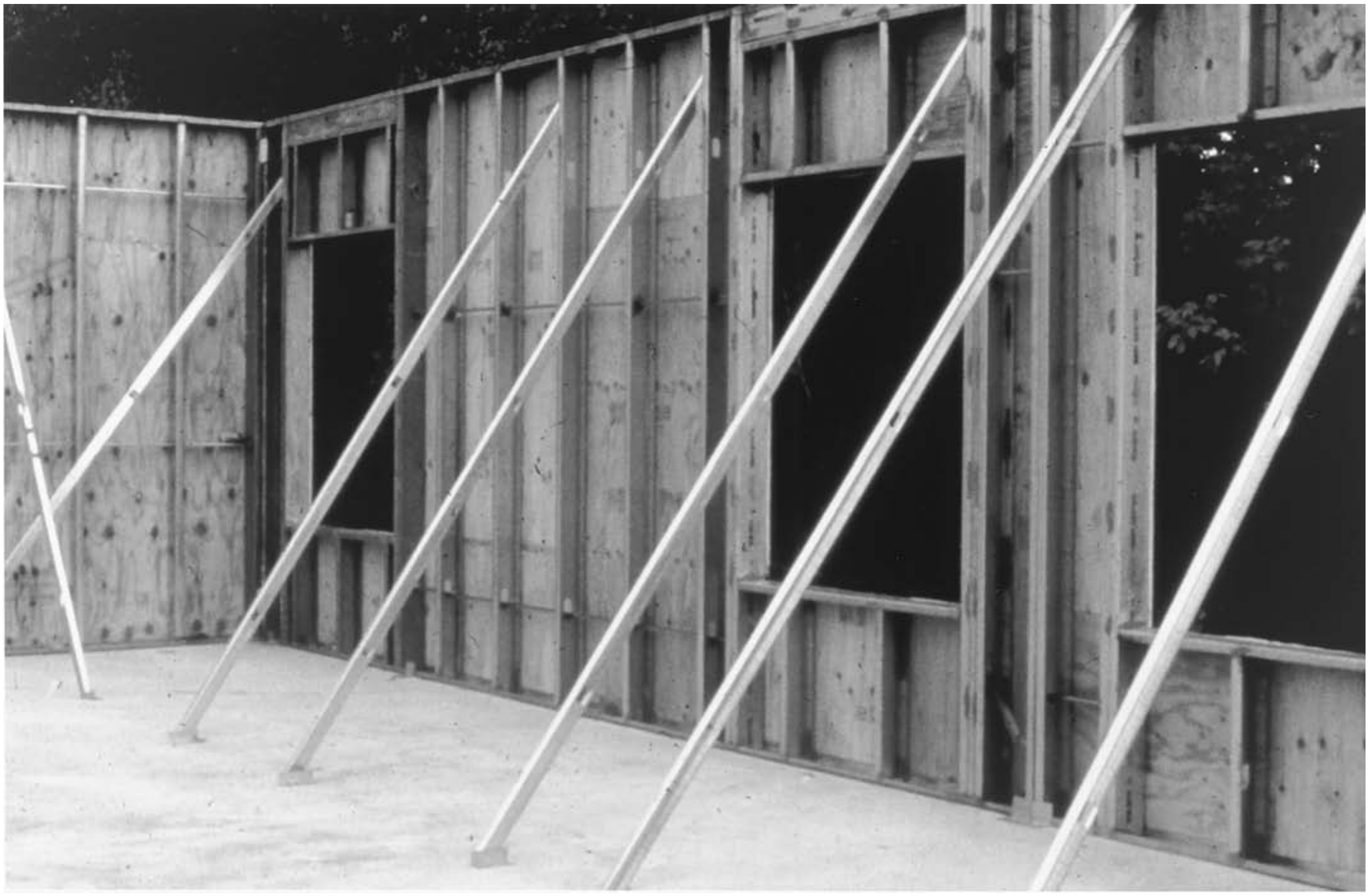


FIGURE 12.6
A typical window or door head detail. The header is made of two joists placed with their open sides together. The top plate of the wall, which is a runner channel, continues over the top of the header. Another runner channel is cut and folded at each end to frame the top of the opening. Short studs are inserted between this channel and the header to maintain the rhythm of the studs in the wall.

Figure 12.7
Diagonal strap braces stabilize upper-floor wall framing for an apartment building. *(Courtesy of United States Gypsum Company)*

Figure 12.8
Temporary braces support the walls at each level until the next floor platform has been completed. Cold-rolled channels pass through the web openings of the studs; they are welded to each stud to help stabilize them against buckling. *(Courtesy of Unimast Incorporated—www.unimast.com)*



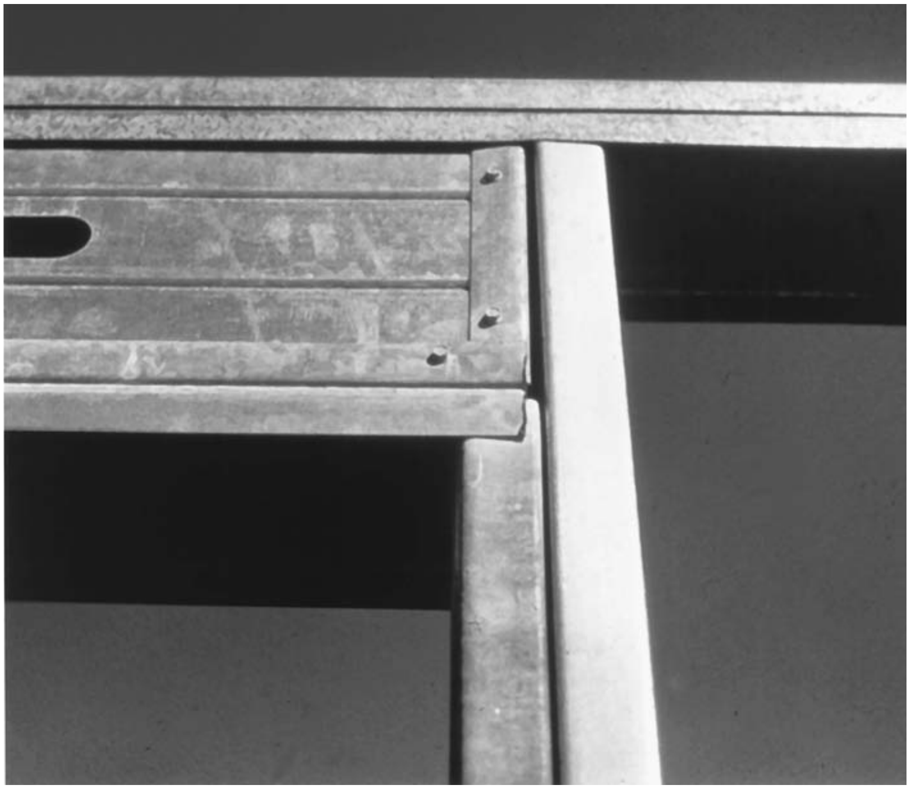


Figure 12.9
A detail of a window header. Because a supporting stud has been inserted under the end of the header, a large gusset plate such as the one shown in Figure 12.6 is not required. *(Courtesy of Unimast Incorporated—www.unimast.com)*

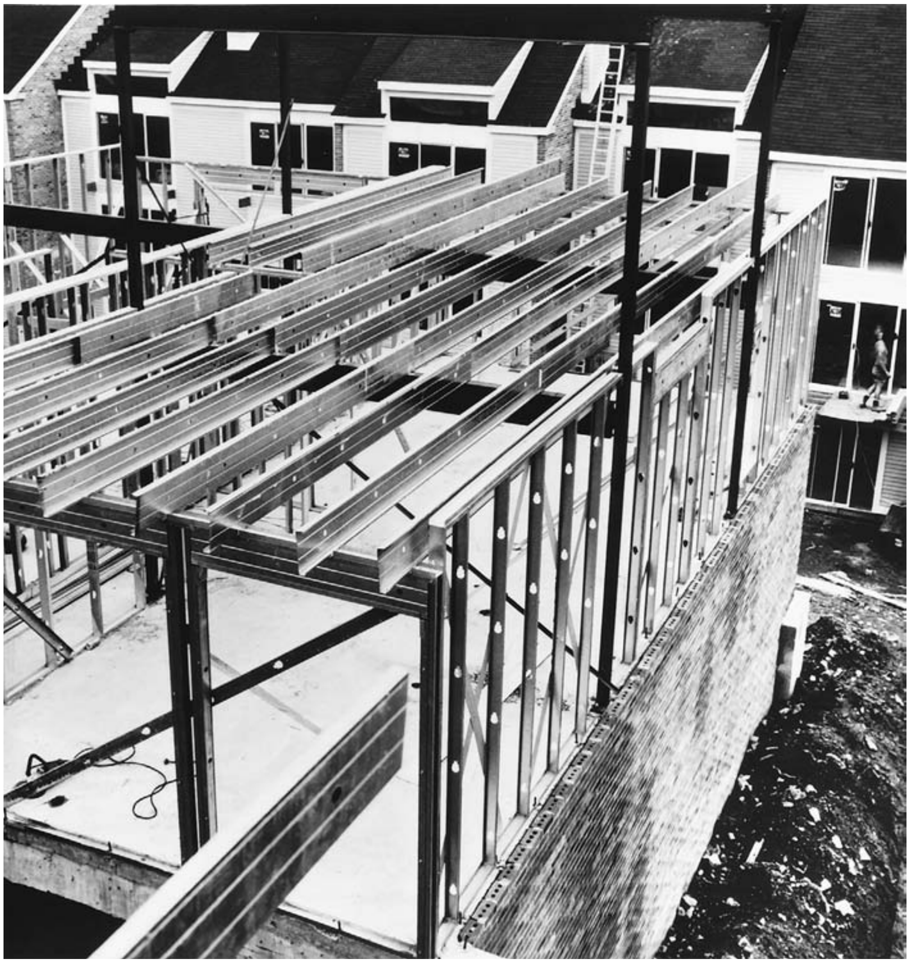


Figure 12.10
Ceiling joists in place for an apartment building. A brick veneer cladding has already been added to the ground floor. *(Courtesy of United States Gypsum Company)*

sheet steel are used to join members around openings. Light gauge members are designed so that they can be *nested* to form a tubular configuration that is especially strong and stiff when used for a ridge board or header (Figures 12.4*a* and 12.5).

Because light gauge steel members are much more prone than their wood counterparts to twisting or buckling under load, somewhat more attention must be paid to their bracing and bridging. The studs in tall walls are generally braced at 4-foot (1200-mm) intervals, either with steel straps screwed to the edges of the studs or with 1½-inch (38-mm) cold-formed steel channels passed through the punched openings in the studs and welded or screwed to an angle clip at each stud (Figure 12.8). Floor joists are bridged with cee-joist blocking between and steel straps screwed to their top and bottom edges. In locations where large vertical forces must pass through floor joists (as occurs where loadbearing studs sit on the edge of a floor platform), steel *web stiffeners* are screwed to the thin webs of the joists to prevent them from buckling (Figure 12.4*c*,*e*). Wall bracing consists of diagonal steel straps screwed to the studs (chapter-opening photo, Figure 12.7). Permanent resistance to buckling, twisting, and lateral loads such as wind and earthquake is imparted largely and very effectively by subflooring, wall sheathing, and interior finish materials.

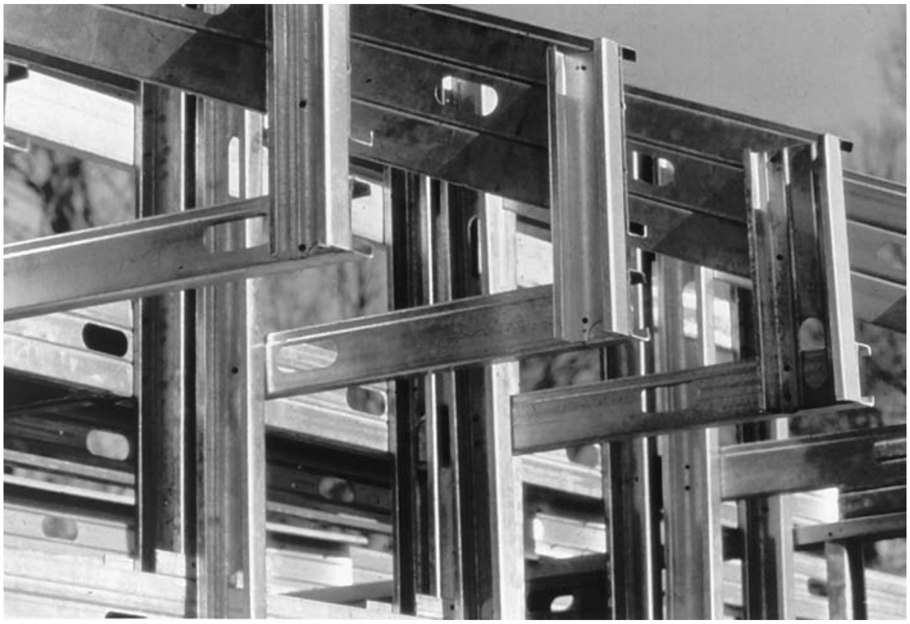


Figure 12.11
A detail of eave framing. *(Courtesy of Unimast Incorporated—www.unimast.com)*

Figure 12.12
A power saw with an abrasive blade cuts quickly and precisely through steel framing members. *(Courtesy of Unimast Incorporated—www.unimast.com)*

Other Common Uses of Light Gauge Steel Framing

Light gauge steel members are used to construct many components of re-resistant buildings whose structures are made of structural steel, concrete, or masonry. These components include interior walls and partitions (Chapter 23), suspended ceilings (Chapter 24), and fascias, parapets, and backup walls for such exterior claddings as masonry veneer, exterior insulation and nish system (EIFS), glass- ber-reinforced concrete (GFRC), metal panels, and various thin stone cladding systems (Chapters 19 and 20; see also Figures 12.13 and 12.14). Light gauge steel members used for framing interior partitions and other nonloadbearing applications are properly referred to and speci ed as *nonstructural metal framing*, as distinct from cold-formed metal framing, the latter term reserved for light gauge steel members used in structural applications and exterior wall cladding systems (even though both types of members are, in fact, cold-formed).

Light gauge steel studs can be combined with concrete to produce thin, but relatively stiff, wall panel systems. Both loadbearing and nonloadbearing panels can be made that are suitable for use in residential and light commercial buildings. A variety of production methods are possible that generally involve casting an approximately 2-inch (50-mm)-thick concrete facing onto a framework of steel studs. The concrete may be sitecast (on the building site) or precast (in a factory). The concrete-to-steel bond may be created by a variety of devices welded or screwed to the studs that then become embedded in the concrete, such as stud anchors, sheet metal shear strips, welded wire reinforcing, or expanded metal. In loadbearing applications, the concrete panels provide shear resistance while the steel studs provide most of the resistance to gravity loads and to wind loads acting perpendicular to the face of the panel.

Figure 12.13
Light gauge steel stud walls frame the exterior walls of a building whose floors and roof are framed with structural steel. *(Courtesy of Unimast Incorporated—www.unimast.com)*

Figure 12.14
The straightness of steel studs is apparent in these tall walls that enclose a building framed with structural steel.
(Courtesy of Unimast Incorporated—www.unimast.com)

FIGURE 12.15
A worker tightens the last screws to complete a connection in a light gauge steel roof truss. The truss members are held in alignment during assembly by a simple jig made of plywood and blocks of framing lumber. *(Courtesy of Unimast Incorporated—www.unimast.com)*

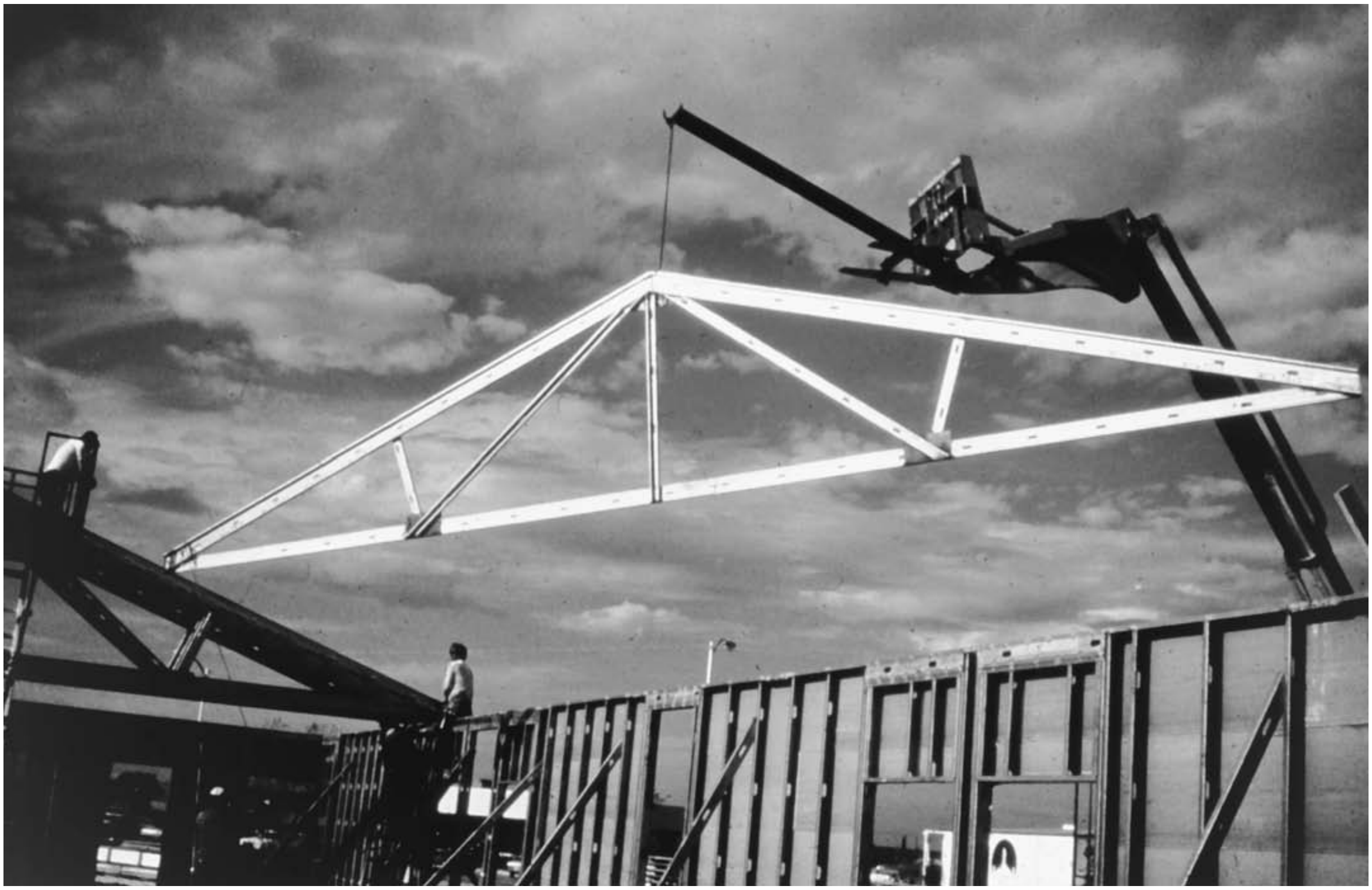


FIGURE 12.16
Installing steel roof trusses. *(Courtesy of Unimast Incorporated—www.unimast.com)*

For Preliminary Design of a Light Gauge Steel Frame Structure

Estimate the depth of rafters on the basis of the horizontal (not slope) distance from the outside wall of the building to the ridge board in a gable or hip roof and the horizontal distance between supports in a shed roof. Estimate the depth of a rafter at 1/24 of this span, rounded up to the nearest 2-inch (50-mm) dimension.

The depth of light gauge steel **roof trusses** is usually based on the desired roof pitch. A typical depth is one-quarter of the width of the building, which corresponds to a 6/12 pitch.

Estimate the depth of light gauge steel **floor joists** as 1/20 of the span, rounded up to the nearest 2-inch (50-mm) dimension.

For **loadbearing studs**, add up the total width of floor and roof slabs that contribute load to the stud wall. A 3 5/8 -inch (92-mm) or 4-inch (102-mm) stud wall can support a combined width of approximately 60 feet (18 m), and a 6-inch (152-mm) or 8-inch (203-mm) stud wall can support a combined width of approximately 150 feet (45 m).

For **exterior cladding backup walls**, estimate that a 3 5/8 -inch (92-mm) stud may be used to a maximum height of 12 feet (3.7 m), a 6-inch (150-mm) stud to 19 feet (5.8 m), and an 8-inch (100-mm) stud to 30 feet (9.1 m). For brittle cladding materials such as brick masonry, select a stud that is 2 inches (50 mm) deeper than these numbers would indicate.

All framing members are usually spaced at 24 inches (600 mm) o.c.

These approximations are valid only for purposes of preliminary building layout and must not be used to select final member sizes. They apply to the normal range of building occupancies such as residential, office, commercial, and institutional buildings. For manufacturing and storage buildings, use somewhat larger members.

For more comprehensive information on preliminary selection and layout of structural members, see Edward Edward and Joseph Iano, *The Architect's Studio Companion* (4th ed.), New York, John Wiley & Sons, Inc., 2007.

In situations where noncombustibility is not a requirement, metal and wood light framing are sometimes mixed in the same building. Some builders find it economical to use wood to frame exterior walls, floors, and roof, with steel framing for interior partitions. Sometimes all walls, interior and exterior, are framed with steel, and floors are framed with wood. Steel trusses made of light gauge members may be applied over wood frame walls. In such mixed uses, special care must be taken in the details to ensure that wood shrinkage will not create unforeseen stresses or damage to finish materials. Steel framing also may be used in lieu of wood where the risk of damage from termites is very high.

Advantages and Disadvantages of Light Gauge Steel Framing

Light gauge steel framing shares most of the advantages of wood light framing: It is versatile and flexible; requires only simple, inexpensive tools; furnishes internal cavities for utilities and thermal insulation; and accepts an extremely wide range of exterior and interior finish materials. Additionally, steel framing may be used in buildings for which noncombustible construction is required by the building code, thus extending its use to larger buildings and those whose uses require a higher degree of resistance to fire.

Steel framing members are significantly lighter in weight than the wood members to which they are structurally equivalent, an advantage that is often enhanced by spacing steel studs, joists, and rafters at 24 inches (600 mm) o.c. rather than 16 inches (400 mm) o.c. Light gauge steel joists and rafters can span slightly longer distances than nominal 2-inch (50-mm) wood members of the same depth. Steel members tend to be straighter and more uniform than wood members, and they are much more stable dimensionally because they are unaffected by changing humidity. Although they may corrode if exposed to moisture over an extended period of time, particularly in oceanfront locations, steel framing members cannot fall victim to termites or decay.

Compared to walls and partitions of masonry construction, equivalent walls and partitions framed with steel studs are much lighter in weight, easier to insulate, and accept electrical wiring and pipes for plumbing and heating much more readily. Steel framing, because it is a dry process, may be carried out under wet or cold weather conditions that would make masonry construction difficult. Masonry walls tend to be much stiffer and more resistant to the passage of sound than steel-framed walls, however.

The thermal conductivity of light gauge steel framing members is much higher than that of wood. In cold regions, light gauge steel framing should be detailed with *thermal breaks,* that is, materials with high resistance to the flow of heat, such as foam plastic sheathing or insulating edge spacers between studs and sheathing, to prevent the rapid loss of heat through the steel members. Without such measures, the thermal performance of the wall or roof is greatly reduced, energy losses increase substantially, and moisture condensation within the framing cavity or on interior building surfaces may occur, with attendant damage to materials, growth of mold and mildew, and discoloration of surface nishes. Special attention must be given to designing details to block excessive heat ow in every area of the frame. At the eave of a steel-framed house, for instance, the ceiling joists readily conduct heat from the warm interior ceiling along their length to the cold eave unless insulating edge spacers or foam insulation boards are used between the ceiling nish material and the joists.

Light Gauge Steel Framing and the Building Codes

Although light gauge steel framing members will not burn, they will lose their structural strength and stiffness rapidly if exposed to the heat of re. They must therefore be protected from re in accordance with building code requirements. With suitable protection provided by gypsum sheathing and gypsum wallboard or plaster, light gauge steel construction may be classi ed as either Type I or Type II Construction in the building code table shown in Figure 1.2, enabling its use for a wide range of building types and sizes.

In its International Residential Code for One- and Two-Family Dwellings, the International Code Council has incorporated *prescriptive requirements* for steel-framed residential construction. In many cases, these requirements, with their structural tables and standard details, allow builders to design and construct light gauge steel-framed houses without having to employ an engineer or architect, just as they are able to do with wood light frame construction.

Finishes for Light Gauge Steel Framing

Any exterior or interior nish material that is used in wood light frame construction may be applied to light gauge steel frame construction. Whereas nish materials are often fastened to a wood frame with nails, only screws may be used with a steel frame. Wood trim components are applied with special nish screws, analogous to nish nails, which have very small heads.

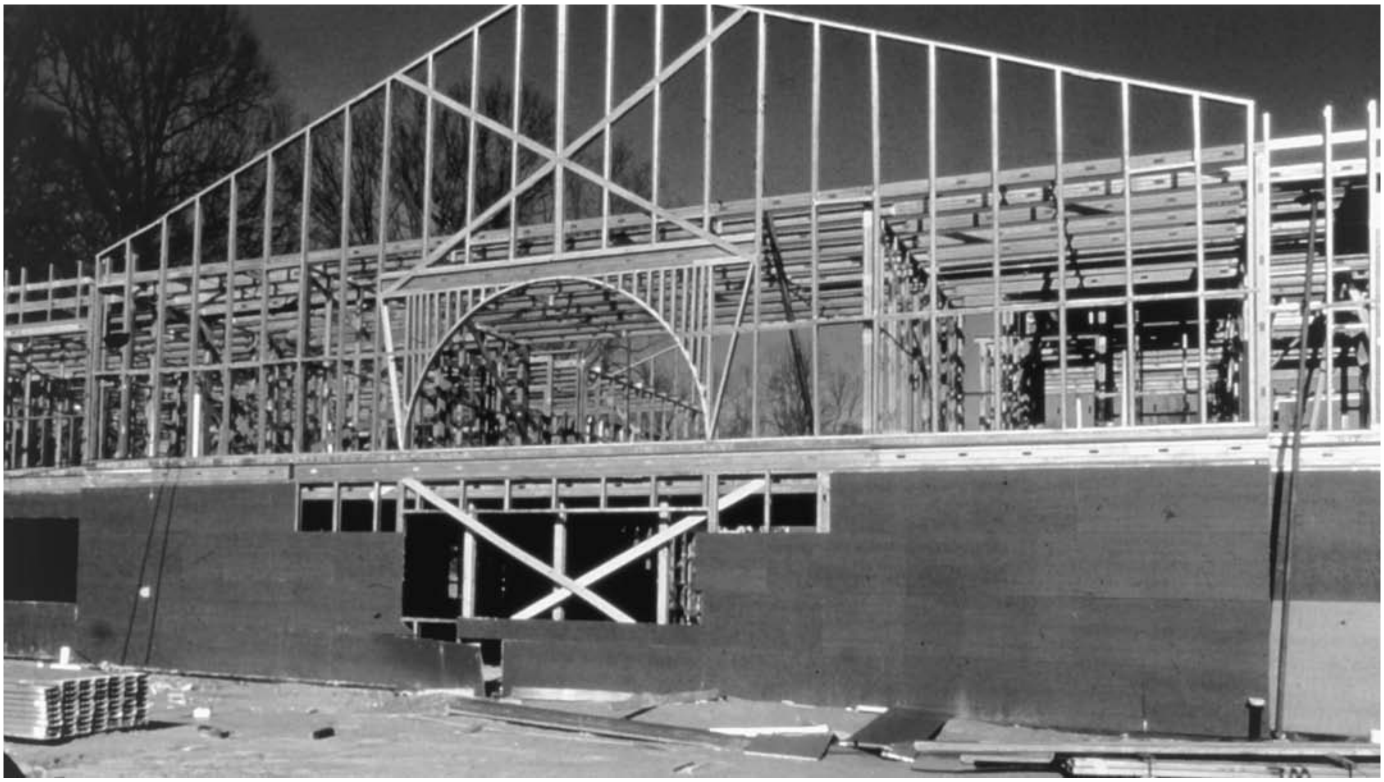


Figure 12.17
Gypsum sheathing panels have been screwed onto most of the ground-floor walls of this large commercial building. *(Courtesy of Unimast Incorporated—www.unimast.com)*

FIGURE 12.18
Waferboard (a wood panel product similar to OSB) sheaths the walls of a house framed with light gauge steel studs, joists, and rafters. *(Courtesy of Unimast Incorporated—www.unimast.com)*

METALS IN ARCHITECTURE

Metals are dense, lustrous materials that are highly conductive of heat and electricity. They are generally *ductile*, meaning that they can be hammered thin or drawn into wires. They can be lique ed by heating and will resolidify as they cool. Most metals corrode by oxidation. Metals include the strongest building materials presently in common use, although stronger materials based on carbon or aramid bers are beginning to appear more frequently in building construction applications.

Most metals are found in nature in the form of oxide ores. These ores are re ned by processes that involve heat and reactant materials or, in the case of aluminum, electrolysis.

Metals may be classi ed broadly as either ferrous, meaning that they consist primarily of iron, or nonferrous (all other metals). Because iron ore is an abundant mineral and is relatively easy to re ne, ferrous metals tend to be much less expensive than nonferrous ones. The ferrous metals are also the strongest, but most have a tendency to rust. Nonferrous metals in general are considerably more expensive on a volumetric basis than ferrous metals, but unlike ferrous metals, most of them form thin, tenacious oxide layers that protect them from further corrosion under normal atmospheric conditions. This makes many of the nonferrous metals valuable for nish components of buildings. Many of the nonferrous metals are also easy to work and attractive to the eye.

Modifying the Properties of Metals

A metal is seldom used in its chemically pure state. Instead, it is mixed with other elements, primarily other metals, to modify its properties for a particular purpose. Such mixtures are called *alloys*. An alloy that combines copper with a small amount of tin is known as bronze. A very small, closely controlled amount of carbon mixed with iron makes steel. In both of these example, the alloy is stronger and harder than the metal that is its primary ingredient. Several alloys of iron (several different steels, to be more speci c) are mentioned in Chapter 11. Some of these steel alloys have higher strengths and some form self-protecting oxide layers because of the in uence of the alloying elements they contain. Similarly, there are many alloys that consist primarily of aluminum; some are soft and easy to form, others are very hard and springy, still others are very strong, and so on.

The properties of many metals can also be changed by *heat treatment*. Steel that is *quenched*, that is, heated red-hot and then plunged in cold water, becomes much harder but very brittle. Steel can be *tempered* by heating it to a moderate degree and cooling it more slowly, making it both hard and strong. Steel that is brought to a very high temperature and then cooled very slowly, a process called *annealing*, will become softer, easier to work, and less brittle. Many aluminum alloys can also be heat treated to modify their characteristics.

Cold working is another way of changing the properties of a metal. When steel is beaten or rolled thinner at room temperature, its crystalline structure is changed in a way that makes it much stronger and somewhat more brittle. The highest-strength metals used in construction are steel wires and cables used to prestress concrete. Their high strength (about four times that of normal structural steel) is the result of drawing the metal through smaller and smaller ori ces to produce the wire, a process that subjects the metal to a high degree of cold working. Cold-rolled steel shapes with substantially higher strengths than hot-rolled structural steel are used as reinforcing and as components of open-web joists. The effects of cold working are easily reversed by annealing. Hot rolling, which is, in effect, a self-annealing process, does not increase the strength of metal.

To change the appearance of metal or to protect it from oxidation, it can be coated with a thin layer of another metal. Steel is often *galvanized* by coating it with zinc to protect against corrosion, as described below. *Electroplating* is widely used to coat metals such as chromium and cadmium onto steel to improve its appearance and protect it from oxidation. An electrolytic process is used to *anodize* aluminum, adding a thin oxide layer of controlled color and consistency to the surface of the metal. To protect them and enhance their appearance, metals are frequently nished with nonmetallic coatings such as paints, lacquers, high-performance organic coatings, porcelain enamel, and thermosetting powders.

Fabricating Metals

Metals can be shaped in many different ways. *Casting* is the process of pouring molten metal into a shaped mold; the metal retains the shape of the mold as it cools. *Rolling*, which may be done either hot or cold, forms the metal by squeezing it between a series of shaped rollers. *Extrusion* is the process of squeezing heated but not molten metal through a shaped die to produce a long metal piece with a shaped pro le matching the cutout in the die. *Forging* involves heating a piece of metal until it becomes soft, then beating it into shape. Forging was originally done by hand with a blacksmith s forge, hammer, and anvil, but most forging is now done with powerful hydraulic machinery that forces the metal into shaped dies. *Stamping* is the process of squeezing sheet metal between two matching dies to give it a desired shape or texture. *Drawing* produces wires by pulling a metal rod through

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a series of progressively smaller ori ces in hardened steel plates until the desired diameter is reached. These forming processes have varying effects on the strength of the resulting material: Cold drawing and cold rolling will harden and strengthen many metals. Forging imparts a grain orientation to the metal that closely follows the shape of the piece for improved structural performance. Casting tends to produce somewhat weaker metal than most other forming processes, but it is useful for making elaborate shapes (like lavatory faucets) that could not be manufactured economically in any other way. Recent developments in steel casting enable the production of castings that are as strong as rolled steel shapes.

Metals can also be shaped by *machining*, which is a process of cutting unwanted material from a piece of metal to produce the desired shape. Among the most common machining operations is *milling*, in which a rotating cutting wheel is used to cut metal from a workpiece. To produce cylindrical shapes, a piece of metal is rotated against a stationary cutting tool in a *lathe*. Holes are produced by *drilling*, which is usually carried out either in a *drill press* or a lathe. Screw threads may be produced in a hole by the use of a helical cutting tool called a *tap*, and the external threads on a steel rod are cut with a *die*. (The threads on mass-produced screws and bolts are formed at high speed by special rolling machines.) Grinding and polishing machines are used to create and nish at surfaces. Sawing, shearing, and punching operations, described in Chapter 11, are also common methods of shaping metal components.

An economical method of cutting steel of almost any thickness is with a *flame cutting torch* that combines a slender, high-temperature gas ame with a jet of pure oxygen to burn away the metal. *Plasma cutting* with a tiny supersonic jet of superheated gas that blows away the metal can give more precise cuts at thicknesses of up to 2 inches (50 mm), and *laser cutting* gives high-quality results in thin metal plates.

Sheet metal is fabricated with its own particular set of tools. Shears are used to cut metal sheets, and folds are made on large machines called *brakes*.

Joining Metal Components

Metal components may be joined either mechanically or by fusion. Most mechanical fastenings require drilled or punched holes for the insertion of screws, bolts, or rivets. Some small-diameter screws that are used with thin metal components are shaped and hardened so that they are capable of drilling and tapping as they are driven. Many sheet metal components, especially roo ng sheet and ductwork, are joined primarily with interlocking, folded connections.

High-temperature fusion connections are made by *welding*, in which a gas ame or electric arc melts the metal on both sides of the joint and allows it to ow together with additional molten metal from a welding rod or consumable electrode. *Brazing* and *soldering* are lower-temperature processes in which the parent metal is not melted. Instead, a different metal with a lower melting point (bronze or brass in the case of brazing and a lead-tin alloy in the most common type of solder) is melted into the joint and bonds to the pieces that it joins. A fully welded connection is generally as strong as the pieces it connects. A soldered connection is not as strong, but it is easy to make and works well for connecting copper plumbing pipes and sheet metal roo ng. As an alternative to welding or soldering, adhesives are occasionally used to join metals in certain nonstructural applications.

Common Metals Used in Building Construction

The ferrous metals include cast iron, wrought iron, steel, and stainless steel. **Cast iron** contains relatively large amounts of carbon and impurities. It is the most *brittle* (subject to sudden failure) ferrous metal. **Wrought iron** is produced by hammering semimolten iron to produce a metal with long bers of iron interleaved with long bers of slag. It has very low iron content, making it stronger in tension and much less brittle than cast iron. Both cast iron and wrought iron found signi cant use in early metal structures. But with the introduction of economical steel-making processes, the roles of both of these earlier metals were largely taken over by steel. Even the ornamental metalwork that we refer to today as wrought iron is frequently made of mild steel. **Steel** is discussed in some detail in Chapter 11, and its many uses are noted throughout this book. In general, all these ferrous metals are very strong, relatively inexpensive, easy to form and machine, and must be protected from corrosion.

Stainless steel, made by alloying steel with other metals, primarily chromium and nickel, forms a self-protecting oxide coating that makes it highly resistant to corrosion. It is harder to form and machine than mild steel and is more costly. It is available in attractive nishes that range from matte textures to a mirror polish. Stainless steel is frequently used in the manufacture of fasteners, roo ng and ashing sheet, hardware, railings, and other ornamental metal items.

Stainless steel is available in different alloys distinguished, most importantly, by their level of corrosion resistance. *Type 304 stainless steel* is the type most commonly speci ed and provides adequate corrosion resistance for most applications. Type 304 stainless steel may also be referred to as Type 18-8, the two numbers referring to the percentages of chromium and nickel, respectively, in this alloy. *Type 316 stainless steel*, with higher nickel content and the addition of small amounts of molybdenum, is more corrosion resistant than Type 304. It is frequently specified for use in marine environments where salt-laden air can lead to the accelerated corrosion of less resistant stainless steel alloys. *Type 410 stainless steel* has a lower chromium content and is less corrosion resistant than the 300 series alloys. However, this alloy also has a different metallic crystal structure that, unlike the 300 series alloys, allows it to be hardened through heat treatment. Self-drilling, self-tapping stainless steel fasteners, whose threads must be tough enough to cut through structural steel or concrete, are frequently made of hardened Type 410 stainless steel.

Aluminum (spelled and pronounced *aluminium* in the British Commonwealth) is the nonferrous metal most often used in construction. Its density is about one-third that of steel and it has moderate to high strength and stiffness, depending on which of a multitude of alloys is selected. It can be hardened by cold working, and some alloys can be heat treated for increased strength. It can be hot- or cold-rolled, cast, forged, drawn, and stamped, and is particularly well adapted to extrusion (see Chapter 21). Aluminum is self-protecting from corrosion, easy to machine, and has thermal and electrical conductivities that are almost as high as those of copper. It is easily made into thin foils that find wide use in thermal insulating and vapor-retarding materials. With a mirror finish, aluminum in foil or sheet form reflects more heat and light than any other architectural material. Typical uses of aluminum in buildings include roofing and flashing sheet, ductwork, curtain wall components, window and door frames, grills, ornamental railings, siding, hardware, electrical wiring, and protective coatings for other metals, chiefly steel. Aluminum powder is used in metallic paints, and aluminum oxide is used as an abrasive in sandpaper and grinding wheels.

Copper and copper alloys are widely used in construction. Copper is slightly more dense than steel and is bright orange-red in color. When it oxidizes, it forms a self-protecting coating that ranges in color from blue-green to black, depending on the contaminants in the local atmosphere. Copper is moderately strong and can be made stronger by alloying or cold working, but it is not amenable to heat treatment. It is ductile and easy to fabricate. It has the highest thermal and electrical conductivity of any metal used in construction. It may be formed by casting, drawing, extrusion, and hot or cold rolling. The primary uses of copper in buildings are roofing and flashing sheet, piping and tubing, and wiring for electricity and communications. Copper is an alloying element in certain corrosion-resistant steels, and copper salts are used as wood preservatives.

Copper is the primary constituent of two versatile alloys, bronze and brass. **Bronze** is a reddish-gold metal that traditionally consists of 90 percent copper and 10 percent tin. Today, however, the term "bronze" is applied to a wide range of alloys that may also incorporate such metals as aluminum, silicon, manganese, nickel, and zinc. These various bronzes are found in buildings in the form of statuary, bells, ornamental metalwork, door and cabinet hardware, and weatherstripping. **Brass** is formulated of copper and zinc plus small amounts of other metals. It is usually lighter in color than bronze, more of a straw yellow, but in contemporary usage the line between brasses and bronzes has become rather indistinct, and the various brasses occur in a wide range of colors, depending on the formulation. Brass, like bronze, is resistant to corrosion. It can be polished to a high luster. It is widely used in hinges and doorknobs, weatherstripping, ornamental metalwork, screws, bolts, nuts, and plumbing faucets (where it is usually plated with chromium). On a volumetric basis, brass, bronze, and copper are expensive metals, but they are often the most economical materials for applications that require their unique combination of functional and visual properties. For greater economy, they are frequently plated electrolytically onto steel for such uses as door hinges and locksets.

Zinc is a blue-white metal that is low in strength, relatively brittle, and moderately hard. Zinc alloy sheet is used for roofing and flashing. Alloys of zinc are also used for casting small hardware parts such as doorknobs, cabinet pulls and hinges, bathroom accessories, and components of electrical fixtures. These *die castings*, which are usually electroplated with another metal such as chromium for appearance, are not especially strong, but they are economical and they can be very finely detailed.

The most important use of zinc in construction is for galvanizing, the application of a zinc coating to prevent steel from rusting. The zinc itself forms a self-protecting gray oxide coating, and even if the zinc is accidentally scratched through to the steel beneath, the zinc interacts electrochemically with the exposed steel to continue to protect the steel from corrosion—a phenomenon called *galvanic protection*. *Hot-dip galvanizing*, in which the steel parts are submerged in a molten zinc bath to produce a thick coating, is the most durable form of galvanizing. Much less durable is the thin coating produced by *electrogalvanizing*. Threaded steel fasteners and other small parts may be *mechanically galvanized*, in which zinc is fused to the steel at room temperature in a tumbler that contains zinc dust, impact media (such as ball bearings, for example), and other materials. Mechanical galvanizing produces a coating that

METALS IN ARCHITECTURE (*CONTINUED*)

is especially uniform and consistent in thickness. Steel sheet for architectural roofing is also frequently coated with an aluminum-zinc alloy coating. The aluminum provides a superior protective oxide coating, and the zinc provides galvanic protection if the coating becomes damaged and the base steel exposed. (For a more detailed discussion of galvanic action, see pages 698–700.)

Tin is a soft, ductile silvery metal that forms a self-protecting oxide layer. The ubiquitous “tin can” is actually made of sheet steel with an internal corrosion-resistant coating of tin. Tin is found in buildings primarily as a constituent of terne metal, an alloy of 80 percent lead and 20 percent tin that was used in the past as a corrosion-resistant coating for steel or stainless steel roofing sheet. Today, zinc-tin alloy coated steel and stainless steel sheets are available for use as roofing metals that are close in appearance and durability to traditional terne metal.

Chromium is a very hard metal that can be polished to a brilliant mirror finish. It does not corrode in air. It is often electroplated onto other metals for use in ornamental metalwork, bathroom and kitchen accessories, door hardware, and plumbing and lighting fixtures. It is also a major alloying ingredient in stainless steel and many other metals, to which it imparts hardness, strength, and corrosion resistance. Chromium compounds are used as colored pigments in paints and ceramic glazes.

Magnesium is a strong, remarkably lightweight metal (less than one-quarter the density of steel) that is much used in aircraft but remains too costly for general use in buildings. It is found on the construction site as a material for various lightweight tools and as an alloying element that increases the strength and corrosion resistance of aluminum.

Titanium is also low in density, about half the weight of steel, very strong, and one of the most corrosion-resistant of all metals. It is a constituent in many alloys, and its oxide has replaced lead oxide in paint pigments. Titanium is also a relatively expensive metal and has only recently begun to appear on the construction in the form of roofing sheet metal.

CSI/CSC

MasterFormat Sections for Light Gauge Steel Frame Construction

05 40 00	COLD-FORMED METAL FRAMING
05 41 00	Structural Metal Stud Framing
05 42 00	Cold-Formed Metal Joist Framing
04 44 00	Cold-Formed Metal Trusses
06 10 00	ROUGH CARPENTRY
06 16 00	Sheathing
	Gypsum Sheathing
09 20 00	PLASTERING AND GYPSUM BOARD
09 22 16	Non-Structural Metal Framing

SELECTED REFERENCES

1. American Iron and Steel Institute. AISI Cold-Formed Steel Design Manual. 1996, Chicago.

This is an engineering reference work that contains structural design tables and procedures for light gauge steel framing.

2. International Code Council. International Residential Code for One- and Two-Family Dwellings. Falls Church, VA, 2002.

This code incorporates full design information and other code provisions, applicable throughout most of the United States, for light gauge steel frame residential construction.

Web Sites

Light Gauge Steel Frame Construction

Author s supplementary web site: **www.ianosbackfill.com/12_light_gauge_steel_frame_construction**

Center for Cold-Formed Steel Structures: **web.umr.edu/~ccfss/research&abstracts.html**

Dietrich Metal Framing: **www.dietrichindustries.com**

Steel Framing Alliance: **www.steelframingalliance.com**

United States Gypsum: **www.usg.com**

Key Terms and Concepts

light gauge steel
cold-formed metal framing
cee section
channel section
gauge
self-drilling, self-tapping screw
gypsum sheathing panel
nested member
web stiffener
nonstructural metal framing
thermal break
prescriptive requirement
ductile
alloy
heat treatment
quench
temper
anneal
cold working
galvanize
electroplating
anodize
casting
rolling
extrusion
forging
stamping
drawing
machining
milling
lathe
drilling
drilling
drill press
tap
die
ame cutting torch
plasma cutting
laser cutting
brake
welding
brazing
soldering
brittle
Types 304, 316, 410 stainless steel
die casting
galvanic protection
hot-dip galvanizing
electrogalvanizing
mechanical galvanizing

Review Questions

1. How are light gauge steel framing members manufactured?

2. How do the details for a house framed with light gauge steel members differ from those for a similar house with wood platform framing?

3. What special precautions should you take when detailing a steel-framed building to avoid excessive conduction of heat through the framing members?

4. If a building framed with light gauge steel members must be totally noncombustible, what materials would you use for sub ooring and wall sheathing?

5. What is the advantage of a prescriptive building code for light gauge steel framing?

6. Compare the advantages and disadvantages of wood light frame construction and light gauge steel frame construction.

Exercises

1. Convert a set of details for a wood light frame house to light gauge steel framing.

2. Visit a construction site where light gauge steel studs are being installed. Grasp an installed stud that has not yet been sheathed at chest height and twist it clockwise and counterclockwise. How resistant is the stud to twisting? How is this resistance increased as the building is completed?

3. On this same construction site, make sketches of how electrical wiring, electric xture boxes, and pipes are installed in metal framing.