4 Fasteners

4.1 Introduction

The fastening of wood and steel members is typically accomplished with nails and/or screws. This chapter provides a brief description of the different fasteners used for each material and the recommended fasteners to be used to fasten the two materials together.

4.2 Steel Fastening Methods

Cold-formed steel framing members can be fastened by using any of the following fastening methods:

- Screws
- Powder-Actuated Fasteners
- Clinches
- Pneumatically Driven Pins
- Welds
- Bolts
- Rivets
- Adhesives

4.2.1 Screws

Screws are the most common fasteners used in framing cold-formed steel members (see Figure 4.1). Self-drilling, tapping screws are the most prevalent fastener. Screws are typically applied with a positive-clutch electric screw gun. Clamps (such as locking C clamps) are essential to the steel framer; they hold the steel members together during fastening.

Screws are available in sizes ranging from No. 6 to No. 14, with No. 6 to No. 10 the most common. Lengths typically vary from 1/2 inch (12.7 mm) to as much as 3 inches (76 mm) depending on the application. Screws are generally 3/8 inch (9.5 mm) to 1/2 inch (12.7 mm) longer than the thickness of the connected materials so that a minimum of three threads extends beyond the connected material. For effective drilling, it is important that the drill point be as long as the material thickness to be fastened. The correct fastener type and length of each application should be selected by consulting the screw manufacturer's specifications and catalogs.

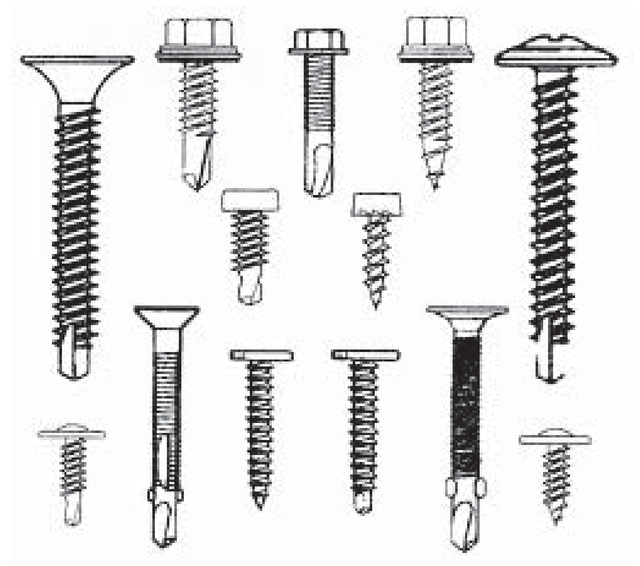


Figure 4.1–Screws

Screw Point Type

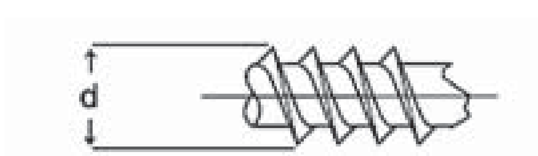
1. Self-drilling tapping screws (see Figure 4.2) are externally threaded fasteners with the ability to drill their own hole and form or cut their own internal mating threads into which they are driven without deforming their own thread and without breaking during assembly. Self-drilling screws are high-strength, one-piece, one-side-installation fasteners. They are typically used with 33-mil (0.8 mm) steel or thicker. They are also used when fastening two or more pieces of steel of any thickness. Self-drilling point styles are listed as No. 2, No. 3, No. 4, and No. 5. The higher the number, the thicker is the material the screw is designed to drill. The self-drilling point style requires more consideration due to the variety of thicknesses and possibility that multiple layers must be joined.
2. Self-piercing tapping screws (see Figure 4.3) are externally threaded fasteners with the ability to self-pierce metallic material, form a sleeve by extruding metallic material, and "tap" their own mating threads when driven. Self-piercing screws are high-strength, one-piece, one-side-installation fasteners with sharp point angles. The self-piercing point style is recommended for connections of 33-mil (0.84 mm) steel thickness and less.

Figure 4.2–Self-Drilling Tapping Screw

Figure 4.3–Self-Piercing Screw

Table 4.1–Screw Body Diameter

Screw Number Designation	Nominal Diameter, d, (inch)
6	0.1380
7	0.1510
8	0.1640
10	0.1900
12	0.2160
¼	0.2500



For SI: 1 inch = 25.4 mm.

Screw Body Diameter

The body diameter of a screw is related to the nominal screw size as shown in Table 4.1. Most connections are made with a No. 8 screw, except when attaching gypsum wallboard, when a No. 6 screw is typically used.

Screw Length

The length of the screw is measured from the bearing surface of the head to the end of the point as shown in Figure 4.4. For example, the length of a flat or countersunk head is measured from the top of the head to the end of the point. A pan head screw length is measured from under the head (bearing surface) to the end of the point.

The length of self-drilling screws may require special consideration since some designs have an unthreaded pilot section or reamer with wings between the threads and the drill point (see Figure 4.5). These features may be necessary for certain applications such as applying wood sheathing to a steel floor joist. The long pilot point or reamer is required to allow the screw to drill through the material before engaging the threads. If the threads engage before the pilot hole is drilled completely, a gap may result in the connection. The result can be a squeaky floor or "screw-pops" through certain finishes.

Threads

Self-piercing and self-drilling screws (see Figures 4.2 and 4.3) intended for cold-formed steel applications generally have a coarse thread (e.g., 10-16x5/8 HWH SD would indicate a 10 diameter, 16 threads per inch, 5/8-inch (16 mm) length, hex washer head, self-drilling screw). Many self-drilling screws have fine threads for use in thicker steel. Manufacturer's recommendations should be followed.

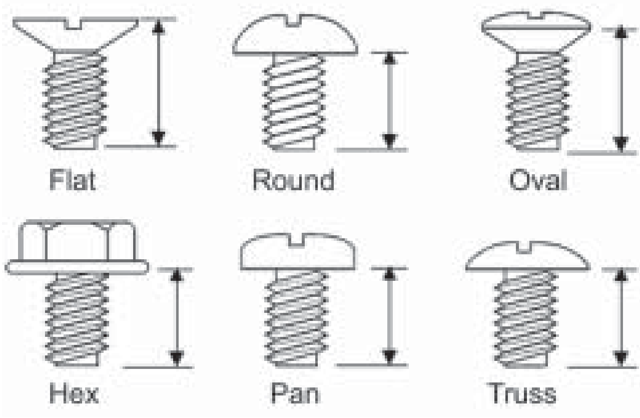


Figure 4.4–Screw Length Measurement

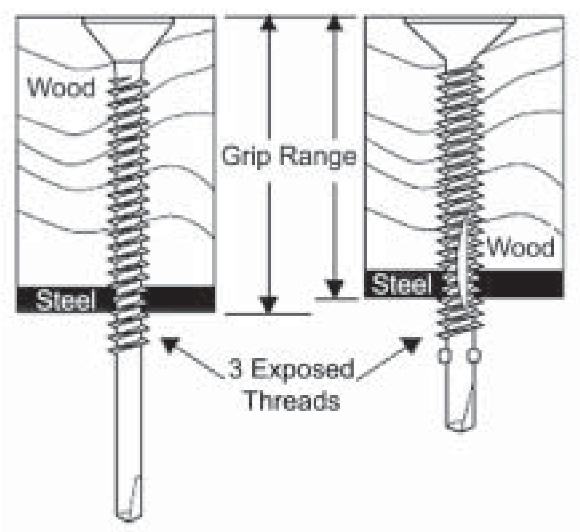


Figure 4.5–Screw Grip Range

Head Styles

Common head styles include flat, oval, wafer, truss, modified truss, hex washer head, pan, bugle, round washer, and pancake (see Figure 4.6). Specialty features may also be on the head, one of which is cutting nibs under the head of a flat head design. Cutting nibs are designed to aid in countersinking the flat head design in dense materials. The drive system may be a phillips, square, or other proprietary design. The specified style may be determined by application, preference, and availability. However, hex head screws are typically used for heavier structural connections, round washer screws for general framing connections, low-profile heads for surfaces to be finished with gypsum board, and bugle head screws for attaching sheathing products.

Screw Body

The body of the screw includes the threads and any designed special features. Special features may include a shank slot, which is a section cut out of the shank for chips of material to have a place to escape, thereby relieving driving torque. The shank slot is located directly above the drill point of the screw.

Drive Types

Drive types are usually determined by availability and preference. Figure 4.7 shows common drive types.

Screw Requirements

For all connections, screws should extend through the steel a minimum of three exposed threads as shown in Figures 4.8 and 4.9. Screws should penetrate individual components of a connection without causing permanent separation between the components. Screws should be installed in a manner such that the threads and holes are not stripped.

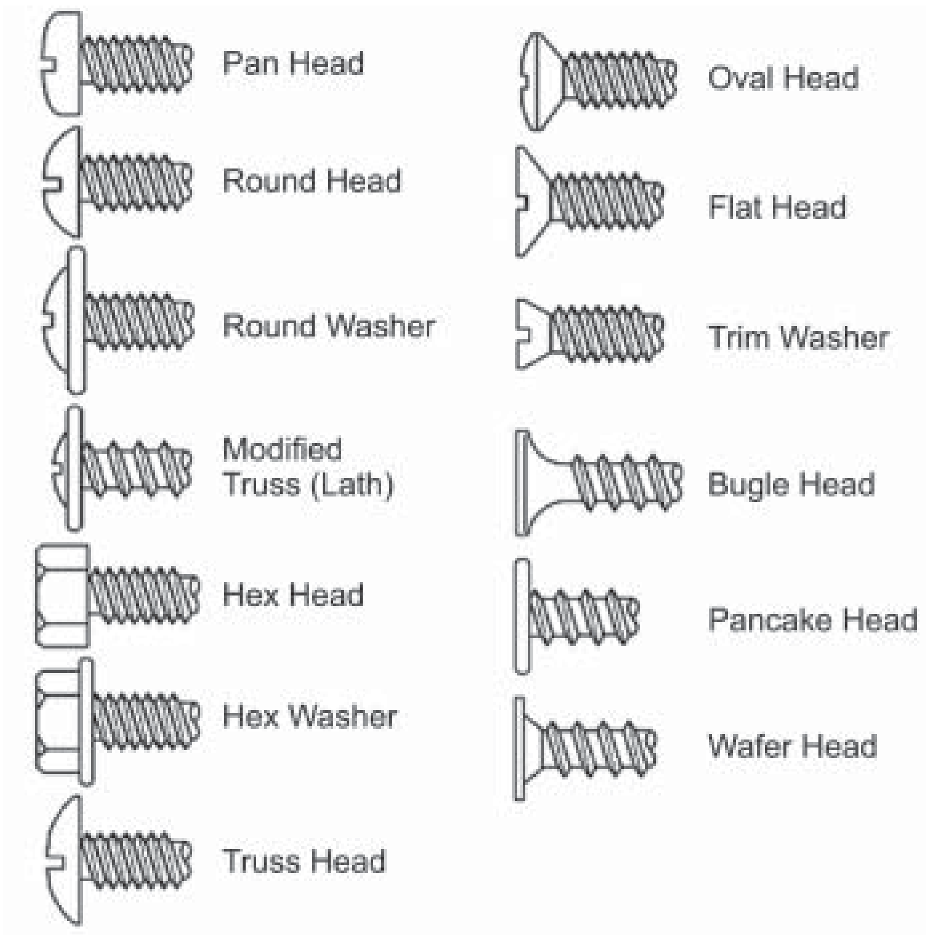


Figure 4.6– Screw Head Types

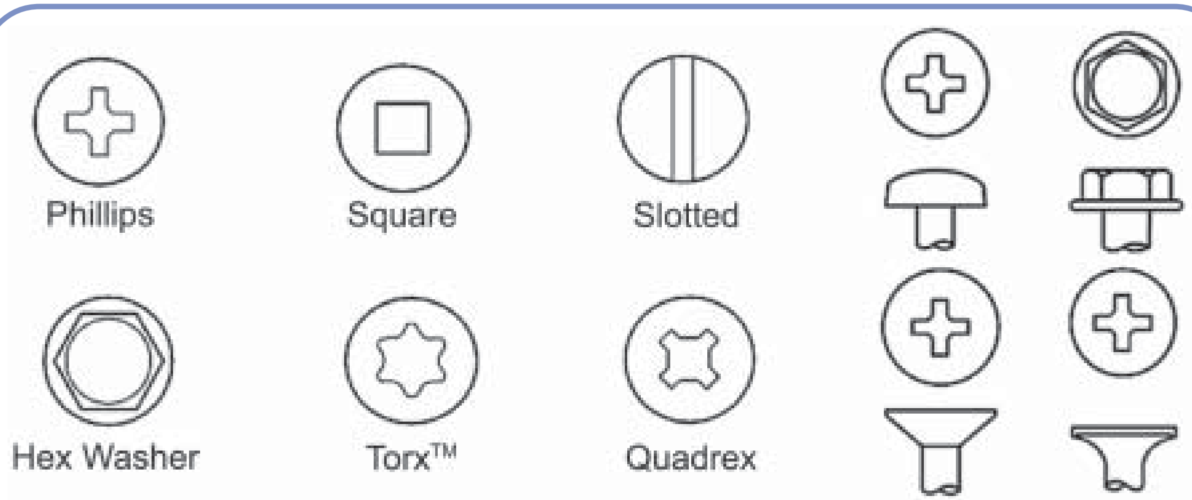


Figure 4.7– Screw Drive Types

Drill Capacity

Drill capacity is defined as the total thickness the screw is designed to drill. If a fastener is chosen with a drill point that is too large, the result may be a stripped connection. If the drill point is too small, the screw may fracture and break. The drive type and head style are typically related to individual preference but may be a consideration for each application. An example of a misapplication is the use of a hex washer head in a framing connection. If drywall is specified as the finish material, the hex washer head will cause a bulge in the drywall finish.

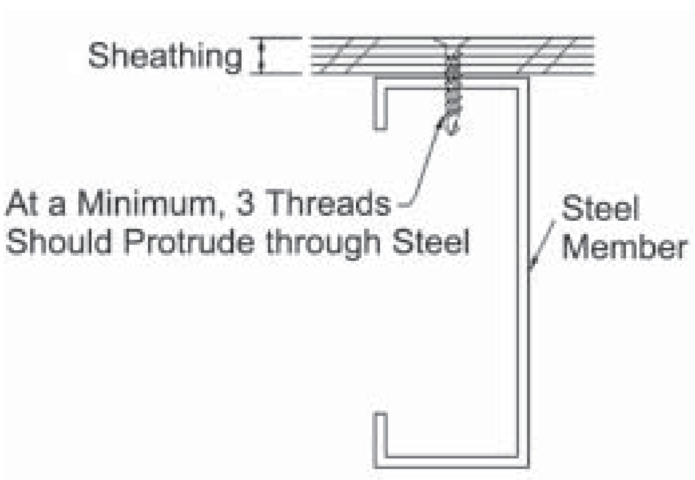


Figure 4.8–Fastening Sheathing to Steel

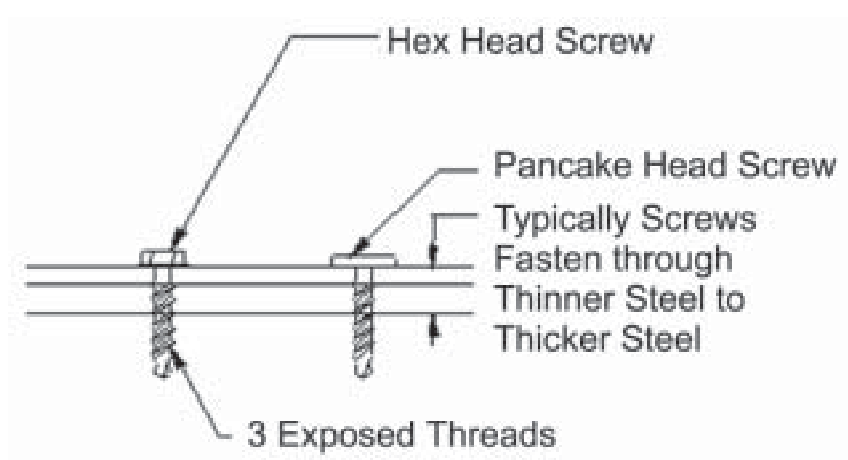


Figure 4.9–Fastening Steel to Steel

Design Values

Screw capacity is determined in accordance with the AISI Design Specification. Tables 4.2a and 4.2b provide a summary of the design capacities (shear and pullout) for screws that are typically used in residential and light commercial applications.

Table 4.2a–Allowable Loads for Screw Connections (Pa)[1,2,3,4] 33 ksi Steel with a 3.0 Safety Factor

Material				#6 Screw		#8 Screw		#10 Screw		#12 Screw	
Thickness (mil)	Design Thickness[5] (inch)	Steel Strength		DIA. = 0.138		DIA. = 0.164		DIA. = 0.190		DIA. = 0.216	
		F_u (ksi)	F_y (ksi)	SHEAR (lb.)	PULLOUT (lb.)	SHEAR (lb.)	PULLOUT (lb.)	SHEAR (lb.)	PULLOUT (lb.)	SHEAR (lb.)	PULLOUT (lb.)
18	0.0188	45	33	60	33	66	39				
27	0.0283	45	33	111	50	121	59				
30	0.0312	45	33	129	55	141	65	151	76		
33	0.0346	45	33	151	61	164	72	177	84	190	97
43	0.0451	45	33	224	79	244	94	263	109	280	124
54	0.0566	45	33			344	118	370	137	394	156
68	0.0713	45	33					523	173	557	196
97	0.1017	45	33							902	284

For SI: 1 inch = 25.4 mm, 1 lb. = 4.448 N.
[1]*Screw allowable loads are based on the 1996 AISI Specification* [19].
[2]*Values include a 3.0 factor of safety.*
[3]*The nominal strength of the screw must be at least 3.75 times the allowable loads.*
[4]*When connecting materials of different steel thicknesses or tensile strength (F_u), the lowest applicable values should be used.*
[5]*Minimum thickness represents 95 percent of the design thickness and is the minimum acceptable thickness delivered to the job site.*

Table 4.2b–Allowable Loads for Screw Connections (Pa)[1,2,3,4]
50 ksi Steel with a 3.0 Safety Factor

Material				#6 Screw		#8 Screw		#10 Screw		#12 Screw	
Thickness (mil)	Design Thickness[5] (inch)	Steel Strength		DIA. = 0.138		DIA. = 0.164		DIA. = 0.190		DIA. = 0.216	
		F_u (ksi)	F_y (ksi)	SHEAR (lb.)	PULLOUT (lb.)	SHEAR (lb.)	PULLOUT (lb.)	SHEAR (lb.)	PULLOUT (lb.)	SHEAR (lb.)	PULLOUT (lb.)
18	0.0188	65	50	87	48	95	57				
27	0.0283	65	50	161	72	175	85				
30	0.0312	65	50	186	79	203	94	219	109		
33	0.0312	65	50	218	88	237	105	255	121	274	140
43	0.0346	65	50	324	115	353	136	380	158	408	182
54	0.0451	65	50			496	171	534	198	573	228
68	0.0566	65	50					755	249	811	288
97	0.0713	65	50							1303	410

For SI: 1 inch = 25.4 mm, 1 lb. = 4.448 N.
[1]*Screw allowable loads are based on the 1996 AISI Specification* [19].
[2]*Values include a 3.0 factor of safety.*
[3]*The nominal strength of the screw must be at least 3.75 times the allowable loads.*
[4]*When connecting materials of different steel thicknesses or tensile strength (F_u), the lowest applicable values should be used.*
[5]*Minimum thickness represents 95 percent of the design thickness and is the minimum acceptable thickness delivered to the job site.*

Screw Designation

Screws are typically designated by their diameter, thread, head style, point type, and length as shown in Figure 4.10.

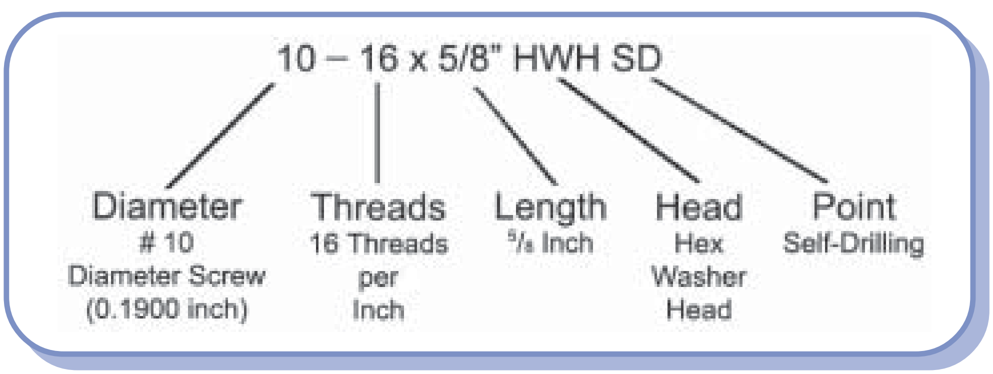


Figure 4.10–Typical Screw Designation

4.2.2 Pneumatically Driven Pins

Pneumatic pins and nails are designed with spiral grooves or knurls on the nail shaft to penetrate the steel (see Figure 4.11). As with wood framing, drive pins and nails are used with air guns. Wood sheathing (such as subflooring) can be fastened to steel members with drive pins. Care should be taken to follow manufacturer's recommendations to avoid problems such as squeaky floors. Additional guidance on pneumatically driven pins is provided in the Light Gauge Steel Engineers Association Tech Note *Pneumatically Driven Pins for Wood Based Panel Attachment* [20].

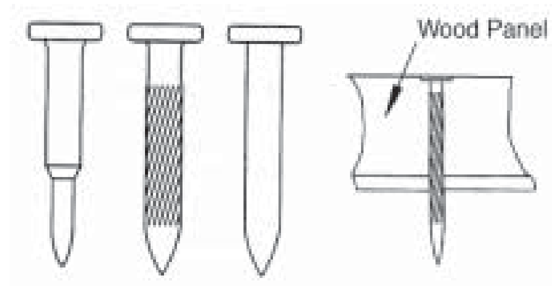


Figure 4.11–Pneumatically Driven Pins

4.2.3 Bolts

Bolts are typically used to anchor cold-formed steel members to foundations. The most common anchors used in steel construction are anchor bolts, mudsill anchors, anchor straps, mushroom spikes, and powder-actuated anchors. Washers and nuts should be properly installed and tightened where required. Bolts connecting CFS to concrete shall have boltholes spaced a minimum of three bolt diameters on-center. The distance from the center of the bolthole to the edge of the connecting member shall not be less than one and one-half bolt diameters.

- **Mudsill Anchors.** Anchors that fit in the bottom track to hold the wall down, usually available from specialty fastener companies, such as Simpson Strong-Tie®, or fabricated in the field.
- **Anchor Straps.** Steel straps that are embedded in the slab and bend up to attach to the wall studs.
- **Mushroom Spikes.** Expansion bolts that expand in predrilled concrete holes, typically used to hold down bottom track or rim joists.
- **Powder-Actuated Fasteners.** Pins fired by a special gun to hold the bottom track down to the foundation.

4.2.4 Welds

Welds are not common in residential steel construction but are used in light commercial and mid-rise construction. Field welding of thin steel members (less than 43 mil in thickness) is not recommended. Factory welds are common because they are usually performed in a controlled environment. Welded areas (see Figure 4.12) must be treated with a corrosion-resistant coating, such as a zinc-rich paint, to maintain acceptable durability of the welded connection. Additional guidance on welding of cold-formed steel members is provided in the Light Gauge Steel Engineers Association Tech Note *Welding Cold-Formed Steel* [21].

Welded areas shall be treated with zinc-enriched paint or other approved treatment to retain the corrosion resistance of the welded area.

Figure 4.12–Welding of Cold-Formed Steel Framing

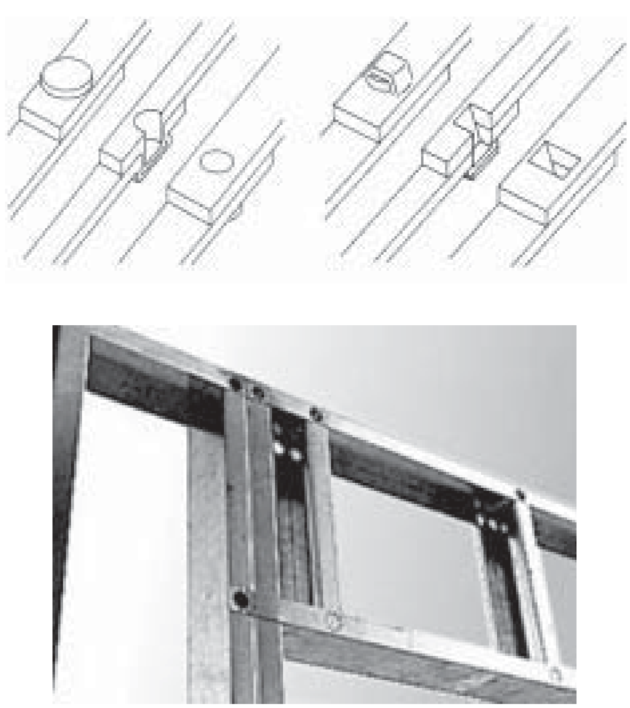


Figure 4.13–Clinches

4.2.5 Clinches

Clinching is a method of joining two pieces of sheet metal by pressing them together into a die that forms a connection similar to a rivet. This technology, although not new, has only recently been used for attaching residential steel framing members. Clinched connections are especially popular in factory settings and panelized construction. Figure 4.13 illustrates some clinched joints that are currently available.

The majority of clinched connections are made with pneumatic or hydraulic tools, although manual clinchers are available. A clincher makes a connection by driving a punch into a die through overlapping material. When the material is forced to the bottom of the die, the die begins to mushroom and then expands to allow full development of the connection. When the punch reaches its final position, it is withdrawn and the die returns to its original shape. The result is a connection similar to that of a rivet. The strength of a clinched connection is approximately the same as that of a self-drilling screw. The clinching process does not harm the galvanized coating on framing members. Many of the currently available clinching tools are limited to use in a warehouse/factory environment. It is usually difficult to loosen connections when necessary. Clinching equipment is currently not widely available.

Additional guidance on clinching of cold-formed steel members is provided in the Light Gauge Steel Engineers Association Tech Note *Clinched (Integral) Fastening of Cold-Formed Steel* [22].

4.2.6 Adhesives

The use of adhesive in residential and light commercial cold-formed steel structural application is not common. Adhesives are primarily used in factory settings and panelized construction. Adhesives are also used between floor joists and floor sheathing and between wall studs and wall covering.

4.2.7 Powder-Actuated Fasteners

Powder-actuated fastener systems consist of specially designed fasteners, installation tools, and powder loads that are designed to function in combination to provide optimum performance. Powder-actuated fasteners need to be used with precision and accuracy to ensure proper application. The use of powder-actuated fastening systems in the construction industry permits significant speed of installation, which results in considerable cost savings. The systems also provide the contractor with the ability to fasten into concrete, masonry, and structural steel without predrilling holes. For most applications, this eliminates time-consuming layout or hole spotting, resulting in faster installation and reduced costs. In addition, powder-actuated fastening systems are completely portable and are ideal for locations that are difficult to access. Today, powder-actuated fastening technology has become the standard method of attachment for many applications in the construction industry.

Always ask for an evaluation report or an approved design if you are considering using a proprietary fastening system or method.

4.2.8 Rivets

Currently, the use of rivets in residential and light commercial cold-formed steel framing is not common.

4.3 Wood Fastening Methods

Dimension lumber framing members can be connected together or to a variety of materials by using any of the following fastening methods:

- Nails
- Pneumatically Driven Nails
- Screws
- Bolts
- Specialty Connection Hardware
- Lag Screws
- Adhesives

In addition, a variety of specialty metal connectors (i.e., joist hangers and strapping) are available for dimension lumber and timber framing. For heavy timber construction, commonly used connections include bolts, drift pins, lag screws, shear plates and rings (used in combination with bolts), and timber rivets. Finally, the metal truss plate (a flat metal plate with preformed teeth) is instrumental to the process of making and designing efficient wood trusses manufactured from dimension lumber. This section presents some basic descriptions and technical information on the above fasteners.

4.3.1 Nails

Several characteristics distinguish one nail from another. Figure 4.14 depicts important nail features for a few types of nails that are essential to woodframe design and construction. This section discusses some of a nail's characteristics relative to structural design; for additional information the reader is referred to *Standard Terminology of Nails for Use with Wood and Wood-Base Materials* (ASTM F547) and *Standard Specification for Driven Fasteners: Nails, Spikes, and Staples* (ASTM F 1667) [23][24].

The most common nail types used in residential wood construction follow:

- **Common nails** are bright, plain-shank nails with a flat head and diamond point. The diameter of a common nail is greater than that of sinkers and box nails of the same length. Common nails are used primarily for rough framing.
- **Sinker nails** are bright or coated slender nails with a sinker head and diamond point. The diameter of the head is smaller than that of a common nail with the same designation. Sinker nails are used primarily for rough framing and applications where lumber splitting may be a concern.
- **Box nails** are bright, coated, or galvanized nails with a flat head and diamond point. They are made of lighter-gauge wire than common nails and sinkers and are commonly used for toe nailing and many other light framing connections where lumber splitting is a concern.
- **Cooler nails** are generally similar to the nails above, but with slightly thinner shanks. They are commonly supplied with ring shanks (i.e., annular threads) as a drywall nail.
- **Power-driven nails** (and staples) are produced by a variety of manufacturers for several types of power-driven fasteners. Pneumatic-driven nails and staples are the most popular power-driven fasteners in residential wood construction. Nails are available in a variety of diameters, lengths, and head styles. The shanks are generally cement-coated (or adhesive) and are available with deformed shanks for added capacity. Staples are also available in a variety of wire diameters, crown widths, and leg lengths. Refer to NER-272 for additional information and design data [25].

Nail lengths and weights are denoted by the **penny weight,** which is indicated by **d.** Given the standardization of common nails, sinkers, and cooler nails, the penny weight also denotes a nail's head and shank diameter. For other nail types, sizes are based on the nail's length and diameter. Table 4.3 arrays dimensions for the nails discussed above. Nail length and diameter are important factors in determining the strength of nailed connections in wood framing. The steel yield strength of the nail may also be important for certain shear connections, yet such information is rarely available for a "standard" lot of nails.

Table 4.3–Nail Types, Sizes, and Dimensions[1]

Type of Nail	Nominal Size (penny weight, d)	Length (inches)	Diameter (inches)
Common	6 d	2	0.113
	8 d	2 1/2	0.131
	10 d	3	0.148
	12 d	3 1/4	0.148
	16 d	3 1/2	0.162
	20 d	4	0.192
Box	6 d	2	0.099
	8 d	2 1/2	0.113
	10 d	3	0.128
	12 d	3 1/4	0.128
	16 d	3 1/2	0.135
Sinker	6 d	1 7/8	0.092
	8 d	2 3/8	0.113
	10 d	2 7/8	0.120
	12 d	3 1/8	0.135
	16 d	3 1/4	0.148
Pneumatic[2]	6 d	1 7/8 to 2	0.092 to 0.113
	8 d	2 3/8 to 2 1/2	0.092 to 0.131
	10 d	3	0.120 to 0.148
	12 d	3 1/4	0.120 to 0.131
	16 d	3 1/2	0.131 to 0.162
	20 d	4	0.131
Cooler	4 d	1 3/8	0.067
	5 d	1 5/8	0.080
	6 d	1 7/8	0.092

For SI: 1 inch = 25.4 mm.
[1]*Based on ASTM F 1667.*
[2]*Based on a survey of pneumatic fastener manufacturer data and NER-272* [25].

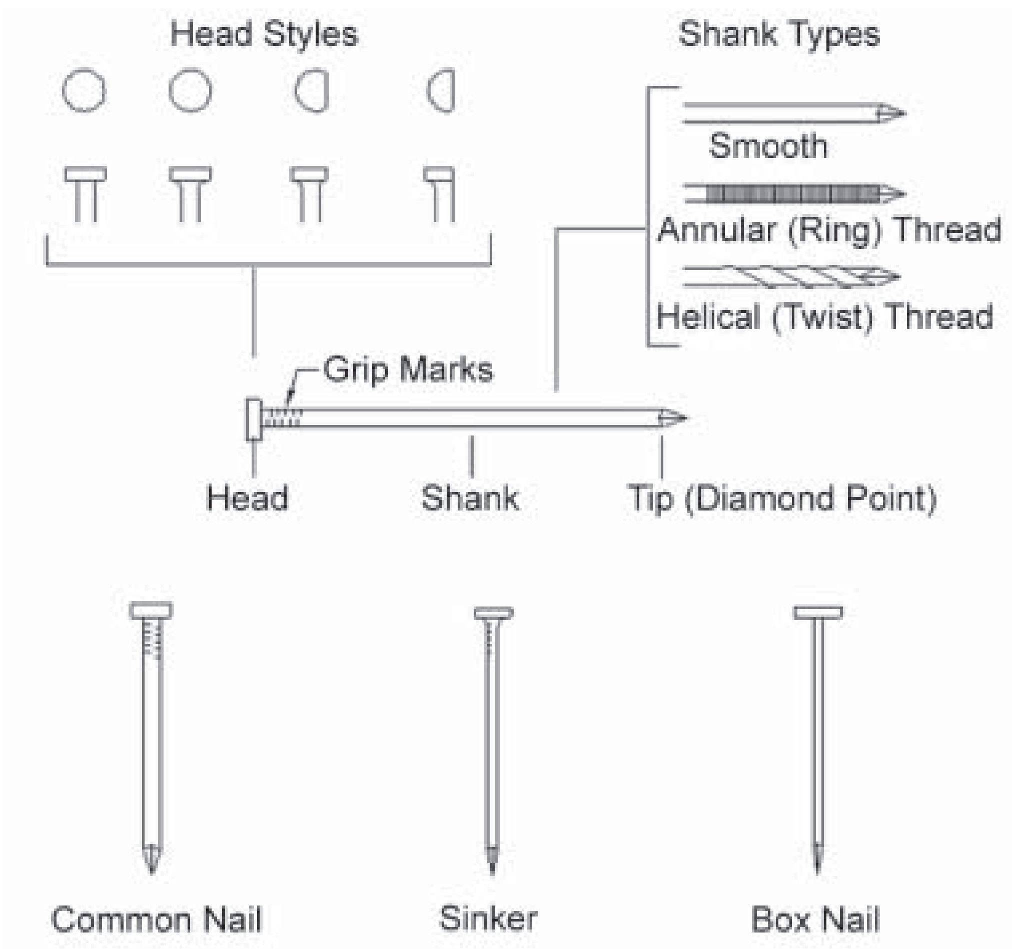


Figure 4.14–Elements of a Nail and Nail Types

There are many types of **nail heads,** although three types are most commonly used in residential wood framing.

- The **flat nail head** is the most common head. It is flat and circular, and its top and bearing surfaces are parallel but with slightly rounded edges.
- The **sinker nail head** is slightly smaller in diameter than the flat nail head. It also has a flat top surface; however, the bearing surface of the nail head is angled, allowing the head to be slightly countersunk.
- **Pneumatic nail heads** are available in the above types; however, other head types such as a half-round or D-shaped heads are also common.

The **shank,** as illustrated in Figure 4.14, is the main body of a nail. It extends from the head of the nail to the point. It may be plain or deformed. A plain shank is considered a "smooth" shank, but it may have "grip marks" resulting from the manufacturing process. A deformed shank is most often either threaded or fluted to provide additional withdrawal or pullout resistance. Threads are annular (i.e., ring shank), helical, or longitudinal deformations rolled onto the shank, creating ridges and depressions. Flutes are helical or vertical deformations rolled onto the shank. Threaded nails are most often used to connect wood to wood while fluted nails are used to connect wood to concrete (i.e., sill plate to concrete slab or furring strip to concrete or masonry). Shank diameter and surface condition both affect a nail's capacity.

The **nail tip,** as illustrated in Figure 4.14, is the end of the shank–usually tapered–that is formed during manufacturing to expedite nail driving into a given material. Among the many types of nail points, the **diamond point** is most commonly used in residential wood construction. The diamond point is a symmetrical point with four approximately equal beveled sides that form a pyramid shape.

A **cut point** used for concrete cut nails describes a blunt point. The point type can affect nail drivability, lumber splitting, and strength characteristics.

The **material** used to manufacture nails may be steel, stainless steel, heat-treated steel, aluminum, or copper, although the most commonly used materials are steel, stainless steel, and heat-treated steel. **Steel** nails are typically formed from basic steel wire. **Stainless steel** nails are often recommended in exposed construction near the coast or for certain applications such as cedar siding to prevent staining. Stainless steel nails are also recommended for permanent wood foundations. **Heat-treated** steel includes annealed, case-hardened, or hardened nails that can be driven into particularly hard materials such as extremely dense wood or concrete.

Various nail **coatings** provide corrosion resistance, increased pullout resistance, or ease of driving. Some of the more common coatings in residential wood construction are described below.

- **Bright.** Uncoated and clean nail surface.
- **Cement-coated.** Coated with a heat-sensitive cement that prevents corrosion during storage and improves withdrawal strength depending on the moisture and density of the lumber and other factors.
- **Galvanized.** Coated with zinc by barrel-tumbling, dipping, electroplating, flaking, or hot-dipping to provide a corrosion-resistant coating during storage and after installation for either performance or appearance. The coating thickness increases the diameter of the nail and improves withdrawal and shear strength.

4.3.2 Pneumatically Driven Nails

Nails for nail guns and pneumatic tools come in two forms:

- Some manufacturers clip the nail head to form clips with the nail shanks side by side, allowing more nails per clip and reducing the frequency of reloading.
- Other manufacturers use plastic to hold the individual nails far enough apart to allow for full heads.

Nails made for pneumatic tools are not all the same. Nails produced by one manufacturer may not fit another manufacturer's tool. Pneumatic nails are typically collated or arranged into strips or rolls with the nails joined by plastic or paper strips or fine wire. Collated nails are available in a variety of metals such as copper, galvanized, or steel and are identified or classified by their head shape, shank type, and length.

4.3.3 Screws

Although screws are widely used in the residential wood construction market, their use is not as common as nails. Screws are mostly used to fasten floor sheathing to wood joists and gypsum board to wall studs. Unlike screws used for steel-framed members, wood screws are coarse threads and do not have a drill point. Table 4.4 summarizes traditional wood screws.

4.3.4 Bolts

Bolts are often used for "heavy" connections and to secure wood to other materials such as steel or concrete. Bolts are typically used to anchor wood members to foundations, ledger plates to wall framing, or in wood decks. In many construction applications, however, special power-driven fasteners are used in place of bolts. Refer to Figure 4.15 for an illustration of some typical bolt types and connections for residential use.

In residential wood construction, bolted connections are typically limited to wood-to-concrete connections unless a home is constructed in a high-hazard wind or seismic area and hold-down brackets are required to transfer shear wall overturning forces. Foundation bolts, typically embedded in concrete or grouted masonry, are commonly referred to as **anchor bolts, J-bolts,** or **mud-sill anchors**. Another type of bolt sometimes used in residential construction is the

Table 4.4–Wood Screws

Gauge		2	3	4	5	6	7	8	9	10	12	14
Head-Bore Size (inch)		11/64	13/64	13/64	1/4	9/32	5/16	11/32	23/64	25/64	7/16	1/2
Pilot-Hole Size (inch)	Hardwood	1/16	1/16	5/64	5/64	3/32	7/64	7/64	1/8	1/8	9/64	5/32
	Softwood	1/16	1/16	1/16	1/16	5/64	3/32	3/32	7/64	7/64	1/8	9/64
Square-Drive Bit Size		#0			#1			#2			#3	
Phillips-Head Point Size		#1			#2						#3	
Available Lengths (inch)												
1/4		●	●	●								
3/8		│	│	│	●							
1/2		▼	│	│	│	●	●					
5/8			▼	│	│	│	│	●				
3/4				▼	▼	│	│	│				
1						│	│	│	●	●	●	
1 1/8						│	│	│	│	│	│	●
1 1/4						│	│	│	│	│	│	│
1 3/8						│	│	│	│	│	│	│
1 1/2						▼	▼	│	│	│	│	│
1 5/8								│	│	│	│	│
1 3/4								│	│	│	│	│
2								▼	│	│	│	│
2 1/4									▼	▼	│	│
2 1/2											▼	│
2 3/4												▼

For SI: 1 inch = 25.4 mm.

structural bolt, which connects wood to steel or wood to wood. Low-strength ASTM A307 bolts are commonly used in residential construction as opposed to high-strength ASTM A325 bolts, which are more common in commercial applications. Bolt diameters in residential construction generally range from 1/4 to 3/4 inch (6 to 13 mm), although 1/2- to 5/8-inch-diameter (13 to 16 mm) bolts are most common, particularly for connecting a 2x wood sill to grouted masonry or concrete.

Bolts, unlike nails, are installed in predrilled holes. If holes are too small, the possibility of splitting the wood member increases during installation of the bolt. If bored too large, the bolt holes encourage nonuniform dowel (bolt) bearing stresses and slippage of the joint when loaded. NDS Section 8.1 [13] specifies that bolt holes should range from 1/32 to 1/16 inch (0.8 to 1.6 mm) larger than the bolt diameter to prevent splitting and to ensure reasonably uniform dowel bearing stresses.

4.3.5 Specialty Connection Hardware

Many manufacturers fabricate specialty connection hardware. The load capacity of a specialty connector is usually provided in the manufacturer's product catalogue. Thus, the designer can select a standard connector based on the design load determined for a particular joint or connection. However, the designer should carefully consider the type of fastener to be used with the connector; sometimes a manufacturer requires or offers proprietary nails, screws, or other devices. It is also recommended that the designer verify the safety factor and strength adjustments used by the manufacturer. In some cases, as with nailed and bolted connections in the NDS, the basis is a serviceability limit state (i.e., slip or deformation) and not ultimate capacity.

A few examples of specialty connection hardware are illustrated in Figure 4.16 and discussed below.

- **Sill anchors** are used in lieu of foundation anchor bolts. Many configurations are available in addition to the one shown in Figure 4.16.
- **Joist hangers** are used to attach single or several joists to the side of girders or header joists.
- **Rafter clips** and **roof tie-downs** are straps or brackets that connect roof framing members to wall framing to resist roof uplift loads associated with high-wind conditions.
- **Hold-down brackets** are brackets that are bolted, nailed, or screwed to wall studs or posts and anchored to the construction below (i.e., concrete, masonry, or wood) to "hold down" the end of a member or assembly (i.e., shear wall).
- **Strap ties** are prepunched straps or coils of strapping that are used for a variety of connections to transfer tension loads.
- **Splice plates** or **shear plates** are flat plates with prepunched holes for fasteners to transfer shear or tension forces across a joint.
- **Epoxy-set anchors** are anchor bolts that are drilled and installed with epoxy adhesives into concrete after the concrete has cured and sometimes after the framing is complete so that the required anchor location is obvious.

4.3.6 Lag Screws

Lag screws are available in the same diameter range as bolts; the principal difference between the two types of connectors is that a lag screw has screw threads that taper to a point. The threaded portion of the lag screw anchors itself in the main member that receives the tip. Lag screws (often called lag bolts) function as bolts in joints where the main member is too thick to be economically penetrated by regular bolts. They are also used when one face of the member is not accessible for a "through-bolt." Holes for lag screws must be carefully drilled to one diameter and depth for the shank of the lag screw and to a smaller diameter for the threaded portion. Lag screws in residential applications are generally small in diameter and may be used to attach garage door tracks to wood framing, steel angles to wood framing supporting brick veneer over wall openings, various brackets or steel members to wood, and wood ledgers to wall framing.

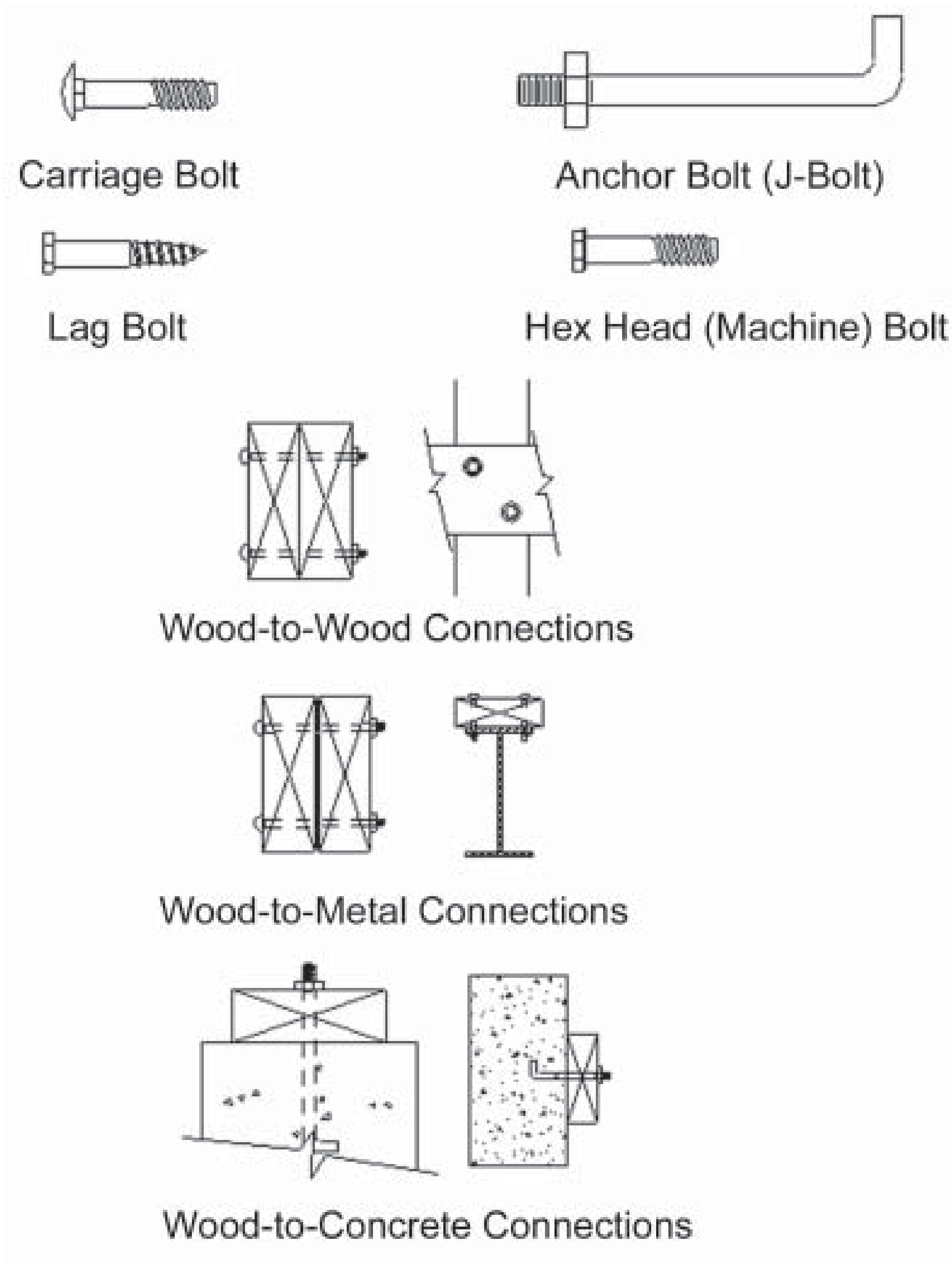


Figure 4.15–Bolt and Connection Types

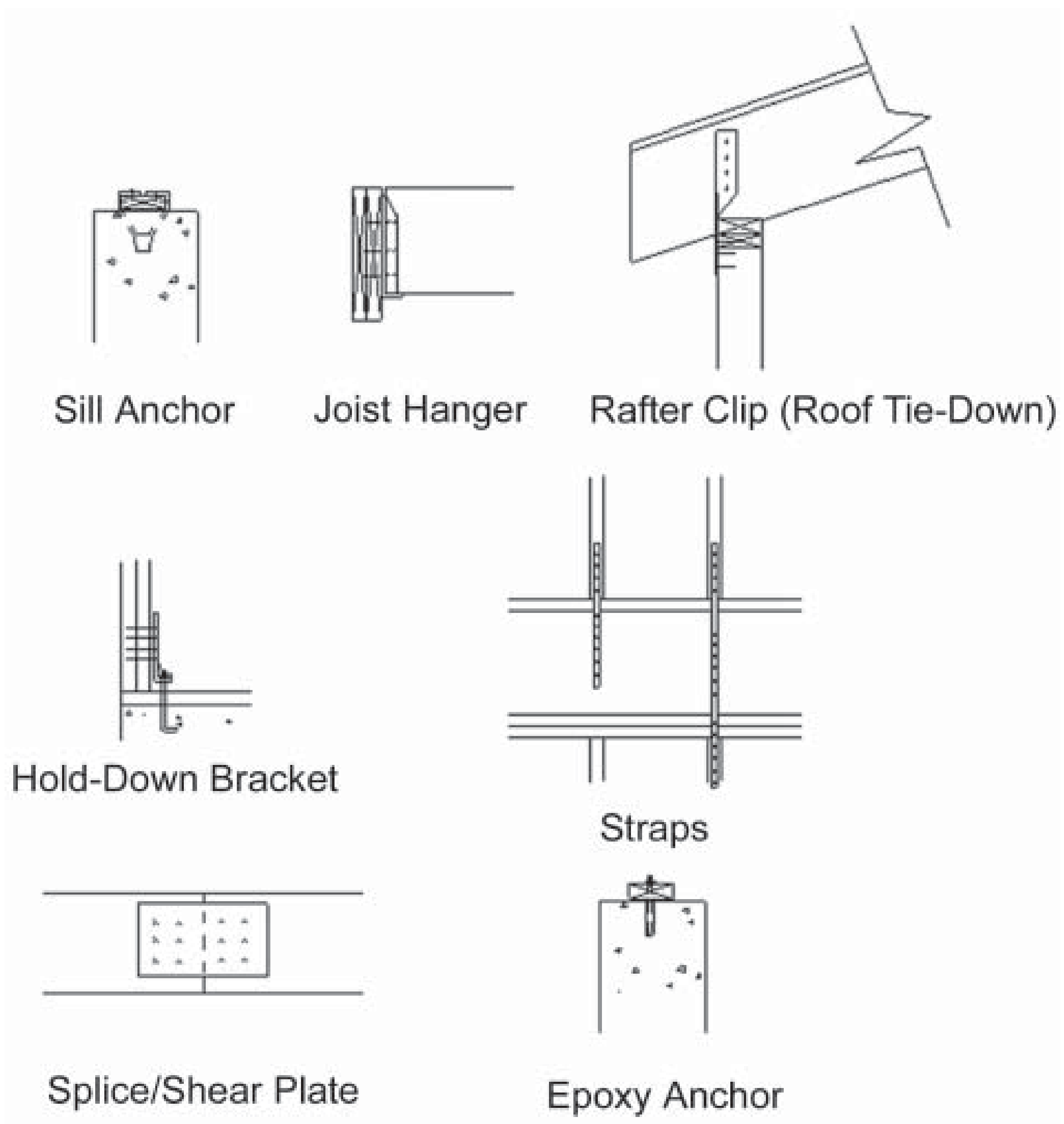


Figure 4.16–Specialty Connector Hardware

4.3.7 Adhesives

The use of adhesive as a structural connection in wood structural applications is not common. Adhesives are primarily used in factory settings and panelized construction (such as in manufactured homes). Adhesives are also used between floor joists and floor sheathing and between wall studs and wall covering.

4.4 Wood-to-Steel Fasteners

4.4.1 Wood Structural Sheathing to Steel Connections

Wood structural sheathing (such as plywood or OSB) is typically fastened to steel framing (i.e., studs or joists) with minimum No. 8 self-drilling tapping screws. Screws connecting structural sheathing to steel members should have a minimum head diameter of 0.292 inch (7 mm) with countersunk heads. The screws should be installed with a minimum edge distance of 3/8 inch (9 mm). The screw size is based on the steel thickness as specified in Table 4.5 and screw point style as shown in Figure 4.17. A pilot point self-drilling tapping screw is a specially designed screw used to attach plywood to steel joists. The screw has threads that start approximately 3/4 inch (19 mm) up from the drill point to ensure that the spinning screw goes through the plywood and does not climb the drive. Instead, the screw penetrates the steel, and the screw threads engage in the metal for a tight fit.

No. 8 self-drilling screws with pilot points are generally used on plywood floors fastened to steel joists. Self-drilling screws with bugle heads are designed to countersink slightly in finishing material without crushing the material or tearing the surface or in the plywood sheathing. Bugle head screws leave a flat, smooth surface for easy finishing. Wafer head screws have larger heads than flat head screws and are typically used to connect soft materials to steel joists. Flat head screws are designed to countersink and sit flush without causing wood floors or finishes to splinter or split.

Table 4.5–Suggested Screw Sizes for Steel-to-Steel and Structural Floor Sheathing-to-Steel Connections

Screw Size	Point Style[1] (inches)	Total Thickness of Steel [2] (inches)
6	2	0.036 – 0.100
8	2	0.036 – 0.100
10	2	0.090 – 0.110
12	2	0.050 – 0.140
14	2	0.060 – 0.120
18	2	0.060 – 0.120
8	3	0.100 – 0.140
10	3	0.110 – 0.175
12	3	0.090 – 0.210
14	3	0.110 – 0.250
12	4	0.175 – 0.250
¼	4	0.175 – 0.250
12	4 ½	0.145 – 0.312
12	5	0.250 – 0.500
¼	5	0.250 – 0.500

For SI: 1 inch = 25.4 mm.
[1] For screw point style, refer to Figure 4.19.
[2] The combined thickness of all connected steel members.

Table 4.6 provides ultimate lateral and withdrawal loads for sheet metal screws connecting plywood to cold-formed steel. Figure 4.18 illustrates the wood sheathing to steel connection.

Table 4.6–Plywood to 54 Mil (14 Gauge) Cold-Formed Steel Connection Capacity Using Sheet Metal Screws[1]

Plywood Thickness (inch)	Ultimate Lateral Load (lb.)				Average Ultimate Withdrawal Load (lb.)			
	Screw Size							
	#8	#10	#12	#14	#8	#10	#12	#14
1/4	360	380	400	410	130	150	170	180
1/2	700	890	900	920	350	470	500	520
3/4	700	950	1300	1390	660	680	800	900

Values are reproduced from APA Technical Note E830C [26].
For SI: 1 inch = 25.4 mm, 1 lb. = 4.448 N.
[1]*Values are based on plywood panels of all-Group 1 construction. For plywood panels of other species groups, the values in this table should be adjusted per Table 4.7.*

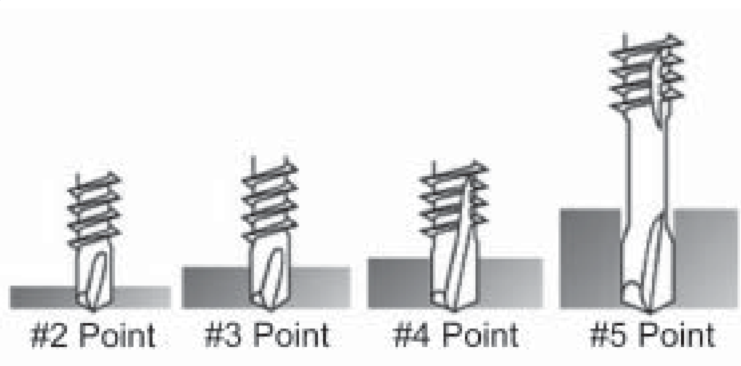


Figure 4.17–Screw Point Style

Table 4.7–Load Adjustments for Screws into Plywood for Species Group Noted[1,2]

	Plywood Group		
	All-Group 1	All-Group 2	All-Group 3,4, and 5
Lateral	100%	78%	78%
Withdrawal	100%	60%	47%

[1]*Adjustments based on the species groups for plywood shown in Voluntary Product Standard PS1* [17] *and the equations in U.S. Agricultural Handbook No. 72* [27].
[2]*Face, back, and core veneer must be of the same species group. When species group is unknown, assume all-Group 4.*

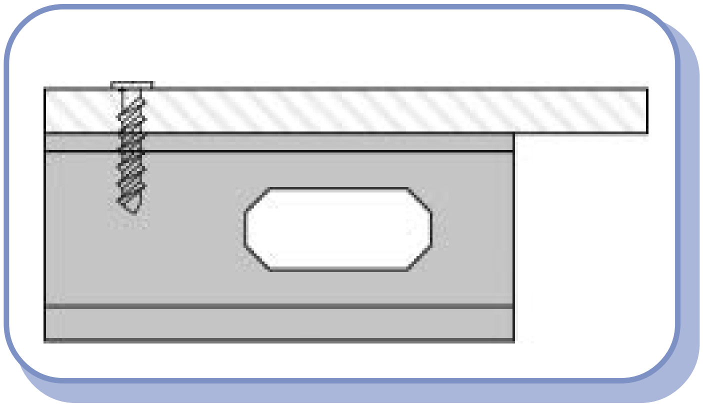


Figure 4.18–Wood Sheathing to Steel Connection

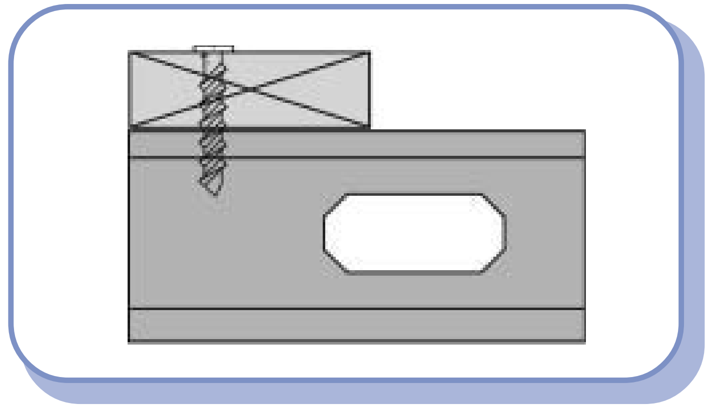


Figure 4.19–Wood to Steel Connection

4.4.2 Wood Structural Members to Steel Connections

Wood structural members (such as top plates) are typically fastened to steel members by using either screws or common nails. Nails are typically used where tension or pullout forces are nonexistent or negligible. Screws can be either self-piercing or self-drilling depending on the thickness of the steel. Refer to Table 4.8 for wood to steel connection capacity. Refer to table 4.9 for fastener type. Figure 4.19 illustrates the wood to steel connection.

Table 4.8–Fastener Capacity for Wood to Steel Connection

Substrate	Fastener	Allowable Loads (lb.)		Nominal Loads (lb.)	
		Shear	Withdrawal	Shear	Withdrawal
OSB only	10D Nail[1]	92	24	331	120
	#8 Screw[2]	115	59	414	295
	#10 Screw[3]	173	61	623	305
OSB and 33 mil Steel	10D Nail[1]	107	42	385	210
	#8 Screw[4]	107	106	385	530
OSB and 54 mil Steel	10D Nail[1]	126	65	454	325
	#8 Screw[4]	128	206	461	1030

For SI: 1 inch = 25.4 mm, 1lb = 4.448N.
[1]0.131" x 3.25" pneumatic nail.
[2]#8 x 3" self tapping, flat head.
[3]#10 x 3" self tapping, flat head.
[4]#8 x 3" self drilling, bugle head.

Table 4.9–Fasteners for Hybrid Connections

Application	Fastener Type
Wood trim over single layer gypsum board to 20 to 25 gauge (33 - 18 mil) steel studs or runners	No. 6 or 7 x 1" Trim head sharp point screws
Wood trim over double layer gypsum board to 20 to 25 gauge (33 - 18 mil) steel studs or runners	No. 6 or 7 x 2 1/4" Trim head sharp point screws
Wood trim over single layer gypsum board to 20 to 25 gauge (33 - 18 mil) steel studs or runners	No. 6 or 7 x 1 5/8" Trim head self drilling screws
Wood trim over single layer gypsum board to 14 to 20 gauge (68 - 33 mil) steel studs or runners	No. 6, 7, or 8 x 2 1/4" Trim head self drilling screws
Wooden cabinets through single layer gypsum board to steel studs	1 5/8" Oval head screws
Wooden cabinets through double layers gypsum board to steel studs	2 1/4" to 3 3/4" Oval head screws
3/8" to 3/4" Plywood to steel joists	1 15/16" Self tapping bugle head pilot point screws
Plywood or wood to 16 to 20 gauge (54 - 33 mil) steel	Flat head pilot point self drilling screws
Plywood to 12 to 16 gauge (97 - 54 mil) steel	Thin wafer head winged self drilling screws Flat head winged self drilling screws
20 gauge (33 mil) or thinner metal studs to OSB or plywood	No. 8 x 1" long Pancake head wood screw with a No. 2 Phillips head or 8 x 1", 1/4" Hex head wood grip
18 gauge (43 mil) or thicker metal studs to wood	Drill a pilot hole in the steel and use wood screws

For SI: 1 inch = 25.4 mm.

4.5 Steel-to-Wood Fasteners

4.5.1 Steel Structural Members to Wood Connections

Steel structural members (such as L-headers) are typically fastened to wood members by using either screws or pneumatic nails. Nails are usually used when pullout or tension forces are negligable or not present. When screws are used, they must be coarse thread screws. Refer to table 4.9 for fastener type. Refer to Tables 4.10 through 4.12 for steel to wood connection capacity. Figure 4.20 illustrates a steel to wood connection.

Table 4.10–Screw Capacity–Metal to Plywood Connections[1]

Depth of Threaded Penetration (inch)	Ultimate Lateral Load (lb.)					
	Wood Screws			Sheet Metal Screws		
	#8	#10	#12	#8	#10	#12
1/2	415	500	590	465	565	670
5/8	-	-	-	500	600	705
3/4	-	-	-	590	655	715

Values are reproduced from APA Technical Note E830C [26].
For SI: 1 inch = 25.4 mm, 1 lb. = 4.448 N.
[1]Values are based on 3/16" steel plate. For thinner plates, the values should be reduced.

Table 4.11–Metal to Plywood Connection–Wood and Sheet Metal Screws[1]

Depth of Threaded Penetration (inch)	Average Ultimate Withdrawal Load (lb.)				
	Screw Size				
	#6	#8	#10	#12	#14
3/8	150	180	205	-	-
1/2	200	240	275	315	-
5/8	250	295	345	390	-
3/4	300	355	415	470	-
1	-	-	-	625	775
1-1/8	-	-	-	705	875
2-1/4	-	-	-	-	-

Values are reproduced from APA Technical Note E830C [26].
For SI: 1 inch = 25.4 mm, 1 lb. = 4.448 N.
[1]Values are based on 3/16" steel plate. For thinner plates, the values should be reduced.

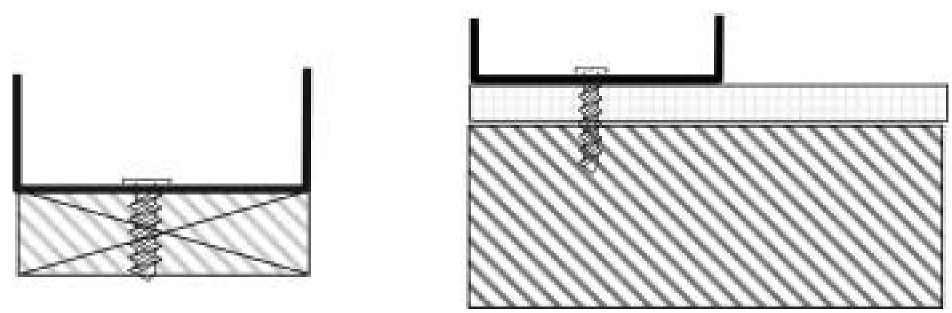


Figure 4.20–Steel to Wood Connection

Table 4.12–Fastener Capacity for Steel to Wood Connection

Steel Thickness	Substrate	Fastener Type	Allowable Loads (lb.)		Nominal Loads (lb.)	
			Shear[6]	Withdrawal[6]	Shear[6]	Withdrawal[6]
33 mil	OSB	10D Nail[1]	74	15	266	75
		#8 Screw[2]	137	70	493	350
	OSB and 2x SPF	10D Nail[1]	185	80	666	400
		#8 Screw[3]	172	63	619	315
54 mil	OSB	#8 Screw[4]	151	66	544	330
	OSB and 2x SPF	#10 Screw[5]	389	202	1400	1010

For SI: 1 inch = 25.4 mm, 1lb = 4.448N.
[1]0.131" x 3.25" pneumatic nail.
[2]#8 x 1.5" self-piercing, wafer head screw.
[3]#8 x 3" self-piercing, wafer head screw.
[4]#8 x 1-5/8" self-drilling, wafer head screw.
[5]Self-drilling, pan head screw.
[6]Values shown are based on SPF lumber with moisture content of 19% or less.