Steelwork in Wood Frames

Once you know the rules, there's no great mystery in working with this useful material

by Eric Bauer

Using structural steel in wood frame construction is not as hard as it looks. It's mostly a matter of recognizing that steel, like wood, has unique characteristics that create their own set of rules. A good craftsman can translate many existing woodworking skills over to steelwork.

Builders who haven't worked much with structural steel assume it is hard to find, expensive, and difficult to handle, but nothing could be further from the truth. In many instances, in fact, steel is the easiest and cheapest material for the job. And it's often no more difficult to handle on site than wood components of the same loading capacity.

The best reason to use steel in residential construction is its high strength-to-size ratio. In other words, you get a large loading capacity from realtively small cross-sectional dimensions (see Figure 1, next page). This means that comparatively small steel beams can span much longer distances and leave more headroom than their wood counterparts. And steel columns can carry enormous loads and still fit within standard wall dimensions.

As with any major structural element, it is foolish to guess at the size of a steel beam required to accept even residential loads. You should always have a professional engineer review your plans whenever you consider using structural steel. This is less expensive than needlessly oversizing a steel beam just to be safe, and the documentation the engineer provides will reduce your liability.

Buying Steel

For structural work, the kind of steel you need is called "hot-rolled" because it is shaped by a series of rollers while still red hot (see "Recipes For Steel"). Hot-rolled steel comes in many different grades, shapes, and sizes (see "Steel Types and Sizes").

Steel supply yards, which are fairly numerous especially near metropolitan areas, usually have the most common shapes and lengths in stock. A small company will be cheaper to deal with because its overhead is lower. Be sure to ask about delivery. Most steel suppliers will deliver to your site, but they may add transportation costs to the price of the material, particularly on special orders or oversize pieces.

Occasionally, you can find usable structural steel at salvage yards. This is a hit-or-miss affair, and you should know exactly what you're looking for. You will rarely find stock lengths, and some of the beams you find may be bent. They can be straightened, but this is work for experienced steelworkers. Almost everything you uncover will have had the flanges cut back ("coped" ends) or steel angles (clip connections) welded to them. And you usually have to arrange transportation yourself. But if these kinds of problems don't cost you too

much to deal with, the savings can be dramatic.

Almost every piece of steel you use will have to be cut to length. Steel suppliers will do what most lumberyards would do if you walked in and asked for a spruce 2x12, 13 feet long. They either refuse to sell cut lengths or charge so much per cut as to effectively discourage you from asking for that service. And just like the lumberyard, when they do agree to cut the material to length, you pay for the stock length, whether or not you take the "drops" (leftover pieces) with you.

Nevertheless, if you only use steel occasionally and in small quantities, the cheapest, most convenient thing to do is to have the supplier cut the steel to length before delivery. In this case, make sure you price the steel as stock lengths, not cut pieces, and include the cutting fee. If you are going to use steel in quantity on a regular basis, however, you should consider tooling up to cut it yourself (see "Cutting and Welding Steel").

Don't attempt to cut steel with your circular saw. To begin with, it's only practical with thin materials, such as steel studs. Eventually, the very fine particles of the abrasive thrown into the tool's innards will destroy the bearings. A reciprocating saw isn't much of an improvement. It takes forever, and will probably wear out both the operator and the tool, not to mention a lot of expensive blades.

Making Holes

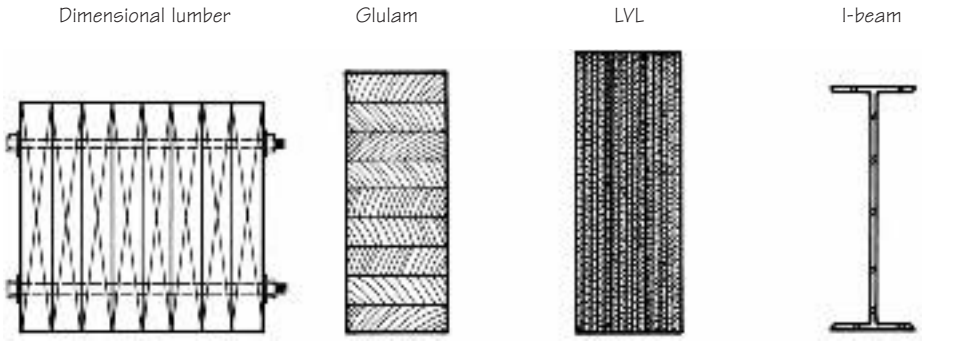
Another common operation performed on steel is cutting holes. If you only use steel occasionally, this is another operation a supplier can perform for you at extra cost. If you want to do the drilling yourself, there are three tools for the job: a torch set, a magnetic-base drill, or a hand drill.

A torch is best for piercing large holes in thick (1 inch or larger) steel. Holes less than 1/2 inch in diameter may have ragged edges, especially when cut by an inexperienced operator, but a small grinder will take care of them.

A magnetic-base drill is a portable version of a drill press. It will drill small (up to 1-inch) holes cleanly and reasonably fast, depending on the thickness of the steel you're working with, and you can use a core bit to drill much larger holes as well. But it's hard to justify investing in this expensive tool when a torch set is more versatile and about the same price. If you have a lot of small holes to drill, consider a rental.

You can drill small holes with a hand-held 1/2-inch drill, but it takes longer and it's hard work. Use high-speed-steel bits for this. Exotic bits, like those with tungsten or carbide cutting edges, will last longer, but

Comparison: Garage Door Headers

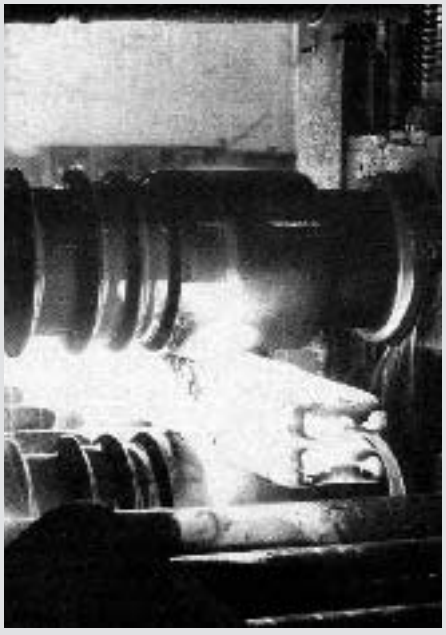


	Dimensional lumber	Glulam	LVL	I-beam
SIZE	8 - 2x12 SPF with pairs of through-bolts 16" o.c.	1 - 5 1/8 x 13 1/2 glulam	3 - 1 3/4 x 14 LVL	1 - W12x14 I-beam
WEIGHT	24 lbs./LF	17 1/2 lbs./LF	21 lbs./LF	14 lbs./LF
COST	$8.80/LF	$15/LF	$14.25/LF	$6.75/LF

Figure 1. *The beams shown here in section represent four ways to span a 16-foot door opening on the eaves end of a 24-foot-square garage. (Beam supports 780 lbs./LF.) Not only is the steel beam less expensive than the others, it is also the lightest.*

Recipes For Steel

The word "steel" covers a large group of materials with many different characteristics. The basic recipe for steel consists of iron combined with varying amounts of carbon, which directly affects malleability and hardness. Steel with 1.5% carbon is extremely hard and brittle, as in cast iron. Carbon content of between .75% and 1% is considered "high" carbon steel, which is the material commonly used for cutting tools. "Medium" carbon steel has less than 0.5% carbon and accounts for most structural steel, which is hard but also flexibile and malleable. This oversimplified description doesn't account for a variety of trace elements added to structural steel to give it specific characteristics. Adding nickel, for example, produces stainless steel, and adding manganese increases resistance to wear.



The steel shapes you are most likely to use in residential construction are made by a process called "hot rolling." An I-beam, for example, is produced by passing a red-hot steel ingot repeatedly through a series of rollers. Hot-rolled steel varies slightly in dimension, but not enough to matter for most uses. It also results in a "mill finish" — a dirty, flaking scale that must be removed before finishing.

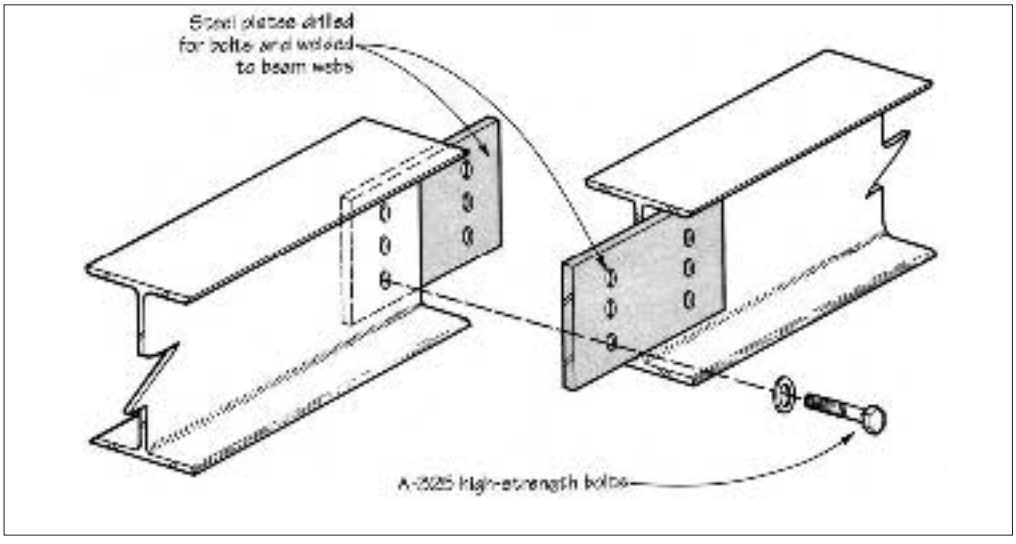
Another method creates common structural steel shapes from hot-rolled coil stock. In this case, an I-beam is constructed from three flat pieces — two flanges and one web. The joints are welded together simultaneously in a process called "electro-resistance welding." This is a common method today among "mini-mills," which fabricate steel shapes, but do not actually manufacture the raw material.

When hot-rolled steel is put through another set of rollers after it has cooled somewhat, it is called "cold rolling." This process is used to size steel tubing and flat bars for precision machining. Consequently, cold-rolled steel has crisper edges and its dimensions are very accurate. Also, the scale is removed in a "pickling" bath and the steel is either sprayed with an oil preservative ("pickled and oiled") or galvanized. Because of the additional steps required in its manufacture, cold-rolled steel costs about twice as much as hot-rolled steel.

should only be used in a stationary tool. These bits are so hard that even slight misalignment, such as you are likely to get with a hand-held drill, will cause them to chip. You can increase the life of your high-speed-steel bits by using a liquid or a stick lubricant, such as Accu-Lube (Lubricating Systems, 22261 68th Avenue S., P.O. Box 805, Kent, WA 98035; 800/999-5823) or Fisk Darl Cutting Oil #2 (Fisk Bros. Refining Co., 129 Lockwood St., Newark, N.J. 07105; 201/589-9150), while drilling.

Don't waste time drilling more holes than you need to bolt on lumber nailers. Most nailers need no more than one fastener every 24 to 36 inches, staggered from side to side along the length of the board. You can also fasten wood nailers to steel with a powder-actuated fastening tool. For a good connection, use a knurled shank pin, and a charge strong enough to drive the point fully through the steel. (Before using powder-actuated fasteners, consult the Powder Actuated Fastener Tool Manufacturers' Institute, 1000 Fairgrounds, Suite 200, St. Charles, MO 63301; 314/947-6610, for proper procedures.)

You can cut holes in steel structural members to allow pipes or wiring to pass through them, but avoid guesswork. Try to anticipate this ahead of time and have an engineer review the size and location of the holes you need. Large holes may require plates welded in place to reinforce the web or flanges.



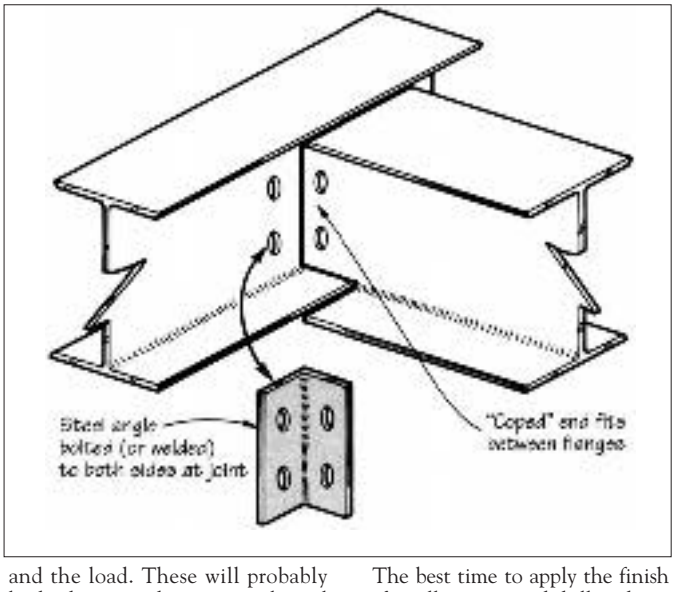


Figure 2. *In an in-line beam splice (above), the ends of the beams butt together with welded plates on each side. In both cases, high-strength (A-325) bolts placed in predrilled holes complete the connection on site. Steel angles or "clips" are used to bolt beams together at right angles (left). Note that the flanges have been cut back ("coped") from the web at the butt end of one beam so that it fits the profile of the other beam. The fit does not have to to be perfect because the bolts handle the load.*

Making Connections

Most steel connections are either bolted or welded together. Welding is useful when the surface area to be joined is small, such as the edge of a steel column. It produces a strong joint that is almost invisible in the finished product. But welding is by far the most difficult and specialized skill used by steelworkers. If you plan to do a lot of steelwork, it's a skill worth learning, but in most cases you'll be better off hiring an experienced welder to do this work.

Bolted connections, on the other hand, don't require special skills. The most common bolted connections are in-line splices and beam-to-beam connections at right angles (Figure 2), and where column plates join footings and beam flanges (Figure 3). Make plywood templates for the bolt hole locations, and use these to lay out the steel for drilling or to locate anchor bolts in concrete. If your steel is being fabricated by a steelworker in the shop, templates are the best way to ensure that everything fits when it's time to put it together on site.

An engineer should specify the diameter and length of the bolts needed for the type of connection and the load. These will probably be high-strength, structural steel (A-325) bolts, which are available from steel supply houses or steelwork shops. Most bolts can be tightened with an ordinary box-end or open-end wrench. If you have a large number of connections, you may want to use an impact wrench. A torque wrench is almost never needed unless the engineer specifies it.

Don't count on concrete to hold embedded steel in place. The concrete will shrink away over time, so you should attach the steel to anchor bolts. Or you can attach hooks to a portion of the steel that will be surrounded by concrete. These will "grab" and prevent movement of the steel once the concrete has shrunk.

Finishing Structural Steel

Most hot-rolled structural steel is covered with a smooth, hard, black scale of iron oxide that forms as the hot material comes off the rolling line and reacts with airborne oxygen. Left untreated, this "mill finish" steel will rust immediately if exposed directly to the weather.

The best time to apply the finish is after all cutting and drilling have been done, but before you lift the steel into place. If you need to weld the steel after it's in place, you can either mask the weld area before applying the finish, or grind the finish off before welding. In either case, be sure to go back and finish these spots later.

For the simplest finish, remove the loose scale with a wire brush, and spray or brush-coat the steel with a coat of red or gray metal primer. This is sufficient for most situations where the steel will be protected from the weather, and will delay the inevitable growth of rust by a year or two, longer if the steel is buried in framing.

But even when steel isn't exposed directly to the weather, it can deteriorate from condensation. In cold climates, steel used as headers in exterior walls, for example, gets cold faster than the surrounding materials. This increases conduction heat loss through the wall and causes moisture to condense on the steel. Eventually, this moisture can damage interior finish materials and exterior siding and trim, as well as the beam itself. To prevent this, provide a thermal break between the steel and exterior surfaces (rigid or expanding foam works well), and apply a good finish to the steel. An inside vapor barrier also helps protect the steel from interior moisture migration.

Outdoors, steel needs a much more durable finish, for example, on pipe handrails for exterior porches or stairs. Prefabricated pieces should be sandblasted and immediately coated with a steel primer. After installation, follow up with at least one top coat of enamel paint formulated for metal. This finish should last four to six years in direct weather before signs of rust appear.

Masonry lintels and other items that are to be embedded in concrete should have a hot-dipped galvanized finish, but this must be done by the supplier and is often too expensive for small builders. The alternative is to sandblast the raw steel and then use a special zinc-rich epoxy paint, such as that made by TNEMEC (123 W. 6800 Corporate Dr., North Kansas City, MO 64120; 816/483-3400), on the surfaces that will be in contact with concrete.

For steel that has rusted but doesn't warrant a costly sandblast treatment, I have found a finish that seems to work. First, use a wire brush to remove the loose rust. Then brush, dip, or spray on several coats of Watco Danish Oil Finish (Minwax Co., 15 Mercedes Dr., Montvale, NJ 07645; 800/526-0495) or Penetrol (The Flood Co., P.O. Box 399, Hudson, OH 44236; 800/321-3444). The surface will be gummy unless the finish cures completely, which means you should apply this finish at temperatures over 70°F. The result is a coating that encapsulates the rust and holds it to the steel. An additional advantage is that paint adheres well to this base finish. It is far from permanent, but is a good, quick alternative to more labor-intensive methods.

Lifting Steel Into Place

You can install many common steel components as easily as their wood counterparts because the major obstacles are the same for both materials: site access, length and weight of the pieces, and their height off the ground. The method you use depends on the conditions you face.

Preparation. Do as much as you can while the beam is still at ground level. If you ordered a stock length, first cut the piece to length. Even though steel beams are supposed to be very straight, check for a crown or bow in the steel by blocking it at each end and sighting along the edge of the flanges. As with wood beams, you will usually install steel with the crown up.

Then attach the wood nailers you need to the beam flanges and web. Prepare beam pockets or jack studs just as you would for wood framing (Figure 4). Theoretically, steel doesn't require a larger bearing area than wood. But because of the greater loads it often carries, it's a good idea to increase the bearing area to avoid crushing the ends of wood columns. Always support steel on the end grain of wood posts, since wood resists crushing much better in this direction than across the grain. Where large point loads are concentrated, you may also need to add welded stiffeners to the web to keep the beam from deforming. This should be clearly called out in the engineer's specification.

Using a crane. A crane is sometimes the only practical way to lift steel into place. It is most useful when overland access to the building is poor (a steep slope, for example) or when the steel needs to be placed in the second story or higher, as with a ridge beam. Since a crane with operator can be expensive — about $60 to $90 per hour, including travel time to and from the site — make sure everything is ready before the crane arrives. If

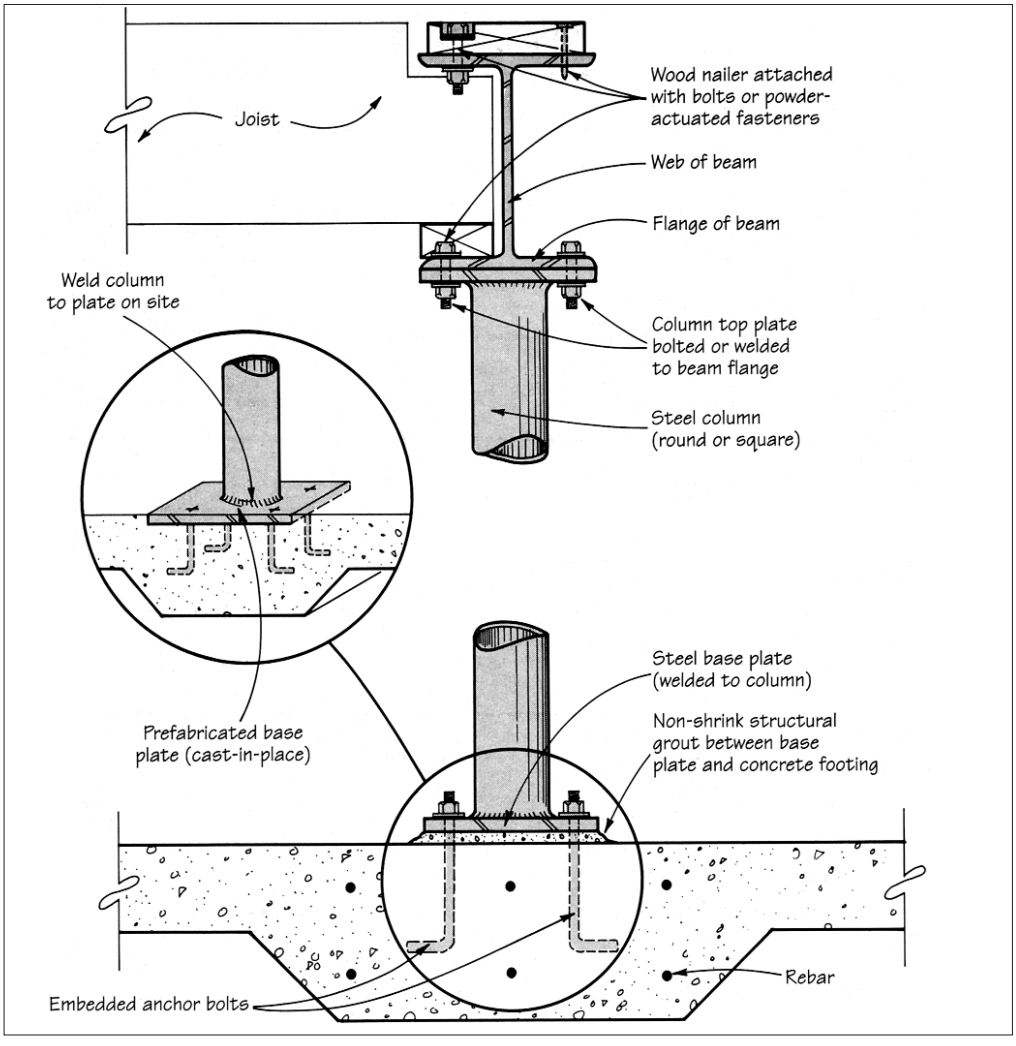


Figure 3. *In most cases, workers on site can use ordinary wrenches to bolt columns to overhead beams and foundation anchor bolts. An alternative is to weld column plates to beam flanges, and weld the column bases to steel plates cast into the slab or footings (inset).*

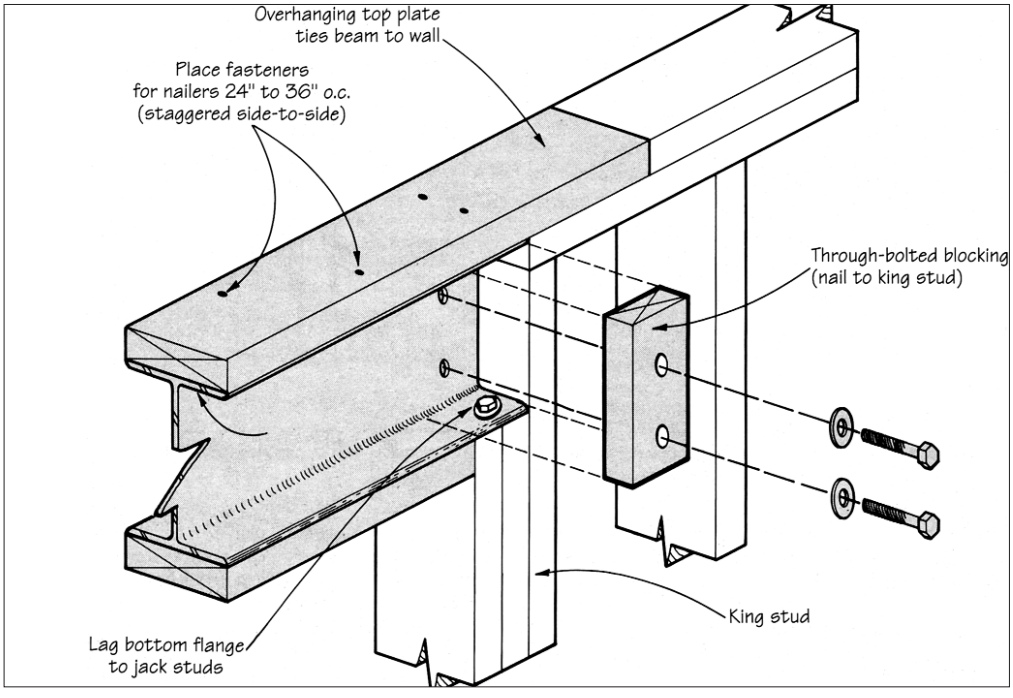


Figure 4. *Attach wood nailers to the top and bottom flanges of a steel beam with small-diameter bolts or powder-actuated fasteners, spaced 24 to 36 inches on-center and staggered side-to-side. The overhanging nailer on top splices into the top plate of the adjacent stud wall. Lag bolt the bottom flange down into the jack studs, and toenail through the king stud into vertical wood blocking bolted to the web.*

Steel Types and Sizes

	SHAPE & TYPE		SYMBOL	SIZE SPECS	STOCK LENGTHS	FINISH	USES
I-BEAMS	I	Junior *	M	Height in inches x pounds/LF (Ex: W8x24)	20, 40, 50, and 60 feet	Hot-rolled, mill finish	Carrying beams, headers, ridge beams, cantilevered beams
		Standard	S				
		Wide Flange	W or WF				
CHANNELS	[	Stringer *	MC	Height in inches x pounds/LF (Ex: C5x9)	20 and 40 feet	Hot-rolled, mill finish	Carrying beams, flitchplates, headers, ridge beams, columns
		Standard	C				
		Ship & Car **	MC				
TEES	T	Tee †	T	Height in inches x width in inches (Ex: T6x8)	20 feet	Hot-rolled, mill finish	Lintels, ledgers, light-load columns
ANGLE	L	Equal Legs Unequal Legs	Angle in degrees or L	Leg x leg x thickness (Ex: 3x6x1/4")	20 and 40 feet	Hot-rolled, mill finish	Lintels, ledgers, web and flange reinforcements, joint clips
BAR	—	Flats	N/A	Thickness x width (Ex: 1/2x8)	20 feet	Hot-rolled, mill finish	Column plates, splice plates, machinist parts, tools
	●	Rounds		Diameter (Ex: 2")	12 feet and random	Cold-rolled, pickled and oiled	
	■	Squares		Width of one side (Ex: 1")			
PIPE	○	Sch. 10 *	BPPE (black pipe plain end) or BPTC (black pipe threaded coupling)	Inside diameter x schedule weight (3" Sch. 40 BPPE)	21 to 24 feet	Hot-rolled, mill finish, painted, hot galv.	Columns
		Sch. 40					
		Sch. 80 **					
TUBING	○	Round	ERW (elec.-res. welded) DOM (drawn over mandrel)	Outside dim. or diameter x wall thickness (Ex: 2x1/8" round; 2x4x1/4" rectangle)	20 and 40 feet	Hot- or cold-rolled, pickled and oiled	Handrails, balusters, specialties
	□	Square					
	▭	Rectangular					

* Also called "Lightweight" ** Also called "Heavyweight" † Made by splitting I-beams in half

Note: *Each grade of structural steel has a specific quality as described by the American Society for Testing & Materials (ASTM) standards. ASTM A-326 is the predominant grade in the structural steel market. It has a carbon content of .26%, which gives it relatively high strength (60,000 psi tensile), yet it is easy to weld and fabricate. It is produced in several different shapes, each of which has its own descriptive nomenclature, typical finishes, and stock lengths.*

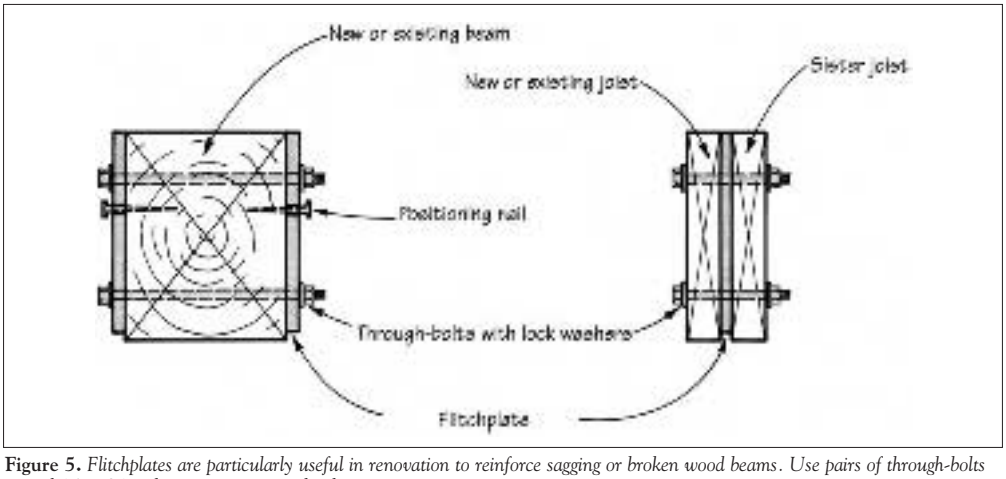


Figure 5. *Flitchplates are particularly useful in renovation to reinforce sagging or broken wood beams. Use pairs of through-bolts spaced 16 to 24 inches on-center to make the connection.*

you can, make good use of the crane for other work, such as setting trusses or stress-skin panels.

Brute strength. If access to the site is good, however, steel can often be placed by hand. One extremely practical use for steel is in flitch-plate beams (see Figure 5). These can be used in renovation to shore up overstressed or broken wood beams, or in new construction to reduce the size of wood beams.

Another common use of steel in residential construction is a garage door header. Two men using brute strength can coax an 18- or 20-foot-long steel beam weighing up to 350 pounds into place without special equipment, as long as they know their lifting limits and have help at hand.

Even smaller carrying beams are heavy, so you should lift them in stages. Build a crib or step scaffold so you'll have a series of "platforms" to lift to. You can also use steel pipe scaffolding. If it doesn't have horizontal rungs at appropriate intervals, use solid planks or small wood beams that you can reset as you go up.

Using a backhoe. It may be tempting to use a backhoe to do the lifting. This is certainly possible, and may be convenient if you have a machine on your site, but I don't recommend it. Backhoes are not designed to do this kind of work. They can lift, to be sure, but backhoe controls often produce jerky motions that can be dangerous. If you try this, observe a few simple rules that apply to all situations where you are lifting overhead:

- Always stand to the side — not underneath — when anything is being lifted into place by machinery.
- Use a choker hitch with a chain or a sling at the balance point of the beam. Chains or slings should be in good shape and rated to the required capacity.
- Attach a light rope "tag line" to one end of the beam. This allows someone at ground level to control the swing of the beam in midair.
- Wear a hard hat. Steel is much harder than wood and has sharper edges. You can get a nasty bruise if you bang your head against it.

Mechanical advantage. With a block and tackle, you can do the same job with fewer people and less physical strain. Make sure the equipment is rated for the weight you are trying to lift. A chainfall will do the job, too, but it lifts more slowly. Either method is inexpensive and far safer than lifting by hand.

You can also lift a steel beam using one or two hydraulic "bottle" jacks (available at any auto parts store) and a generous supply of cribbing (see Figure 6, next page). This is often the only practical method of placing steel inside existing structures where a crane or backhoe won't work, and where there isn't much room overhead for a hoist. The cribbing should be as large as possible in section, but easy to move by hand. Roughcut 6x6s are ideal, and 4x4s or sections of smaller dimension lumber are handy for shimming during the last foot of the lift. Keep the base of the crib as wide as possible (3 feet minimum), and narrow it slightly as you go up. If you can't use cribbing, build a step-staging with 2x4s or 2x6s. Use jack studs to support horizontal scaffolding pieces that will carry any weight. Never rely solely on nails to do this; jack studs are safer, and inspire confidence.

Work the beam close to the ends, lifting and blocking first one end, then the other. Don't lift one end too much higher than the other or the beam might start to slide. A long beam, especially one whose section is taller than it is wide, can tip on its side if you're not careful. Plywood gussets screwed to the wood nailers will keep the beam stable. If you go slowly and are sure of your moves, you can lift many thousands of pounds safely into place this way.

Securing the steel. Don't put the jack studs or columns in place until the beam is at its final elevation. Keep some thin plates of steel in 1/8-inch-thick increments for shims. These should have holes cut to

match the bolting pattern of the beam and column plate. If you can't use steel shims, at least use hardwood or plywood, which will compress less than softwood. And make sure the shims spread the load fully over the bearing surface.

Once the beam is in place, use lag bolts to fasten the bottom flange to wood jack studs, or bolt the flange to the top plate of a prefabricated column. You can further secure it by nailing into the adjacent framing through the wood nailers you bolted into place while the beam was still on the ground. Triangulate the assembly with braces, which you can fasten to these nailers as well. If the beam is bowed, string a line on it and straighten it as you frame it in. It won't give as much as wood does, but it's usually straighter to begin with. The overhanging top plate shown in Figure 4 is strong enough to both hold the wall together and keep the beam from rolling.

When to Hire a Sub

Many times the best approach to steelwork is to hire a subcontractor to handle all or most of it. They will have the proper tools for the job, and their experience will ensure a safe, high-quality installation. Another thing to consider is the effect that doing the work yourself will have on your workers compensation rate. Insurance companies classify steelwork as hazardous and will probably raise your premium to extend coverage to your employees. If your employees are not experienced steel workers, limit your involvement to routine installations.

If the job calls for two or three good-sized beams or requires crane work or a lot of fabrication, you ought to consider subbing out the materials and installation as a package. You can price the steel and decide for yourself if the subcontractor's quote is fair. Unless you've had some experience with steelwork, you'll have to guess at the labor costs. But you can assume that most experienced steel fabricators will get the job done faster than you can.

This doesn't mean you can't work together with a subcontractor. In most cases, you can do almost all the prep work at the site and some of the installation. This includes taking dimensions and establishing elevations, preparing templates, and making sketches of joints, bolt locations, and other details. If your information is accurate and complete, the steel subcontractor can fabricate the steel in the shop, and needs to come to the site only to weld the columns to the beams.

You can save more time and money by planning ahead a little. Instead of making templates to locate holes in column plates, you can have your subcontractor fabricate steel-column base plates with anchor bolts welded to the underside. In this case you need to accurately place the base plates in the concrete footing or slab before it cures, as shown in Figure 3. Then the fabricator can bring over-length columns with no base plates, shoot the elevations on the spot, and cut and weld the columns directly to the plates embedded in the slab. ■

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Cutting and Welding Steel

The most versatile tool for cutting steel is an oxy-fuel gas torch. It uses oxygen in combination with one of several gas fuels to produce a high-temperature flame that burns through the steel. Each oxygen-fuel combination has unique characteristics. Oxy-acetylene, for example, can only be used at low pressure, but burns at high temperature, so it is excellent for cutting steel. Any welding supply house can help you decide which fuel to buy.

A medium-duty torch set costs about $300, and extra tips start at about $15 each. You can't buy gas tanks, but you can lease them for about $40 each per year. The cost for fuel will vary depending on the kind and volume. There are also minor costs for related items, such as eye protection and gloves.

A set of torches is a valuable addition to your toolbox. They are portable, require no power source, and, when used properly, can cut through up to 3-inch-thick steel plate with ease. At first your cuts will be rough, so you'll need a small portable grinder to smooth out the bumps. A grinder will also remove welding slag, which intereferes with finishing and detracts from the appearance of the final product.

There are other ways to cut steel, such as a portable band saw or a gas-powered saw with an abrasive cut-off wheel. These will produce clean, square cuts in small-section (up to 3/4-inch) materials, and require little operator experience. But they cost almost as much as a torch set and are far less versatile.

Welding. Welding is one of the most common methods of joining pieces of steel. You can weld with a gas torch, but most welding in residential construction is shielded-metal-arc or "stick" welding. Arc welding uses electricity to fuse steel at a joint with a small-diameter, specially-coated welding rod. With the proper rod and welding technique, an arc weld is as strong as the steel itself.

Welding equipment is fairly expensive. And, like torch work, you need experience to produce good, reliable welds, especially in out-of-position field situations, such as overhead work. Nevertheless, I would encourage anyone interested in steelwork to learn how to weld. Be sure to give yourself plenty of time, and learn from qualified teachers. To do otherwise is to cheat yourself and invite trouble.

Safety precautions. Even if you subcontract all your steelwork, you should understand the potential hazards these tools create. Oxy-fuels are volatile and must be properly stored and transported. And the fumes produced during oxy-fuel cutting or arc welding are extremely toxic. Be sure the work area is well-ventilated and avoid direct exposure to the fumes for extended periods of time.

The shower of sparks generated while using these tools is actually molten steel. It can very quickly cause severe burns, so you should always wear protective clothing (usually leather), including gloves, apron, heavy boots, and a face mask. Protect combustible materials near the work area from the heat and flying sparks. Be sure to check for smoldering materials, like sawdust or insulation, and have a fire extinguisher handy.

Finally, never look directly at the flame of a cutting torch or the burning electrode of an arc welder. The light they generate is so intense it can permanently damage your eyes. Always wear welding goggles (sunglasses won't work), and be sure to have extra eye protection on hand for others working nearby. — *E. B.*

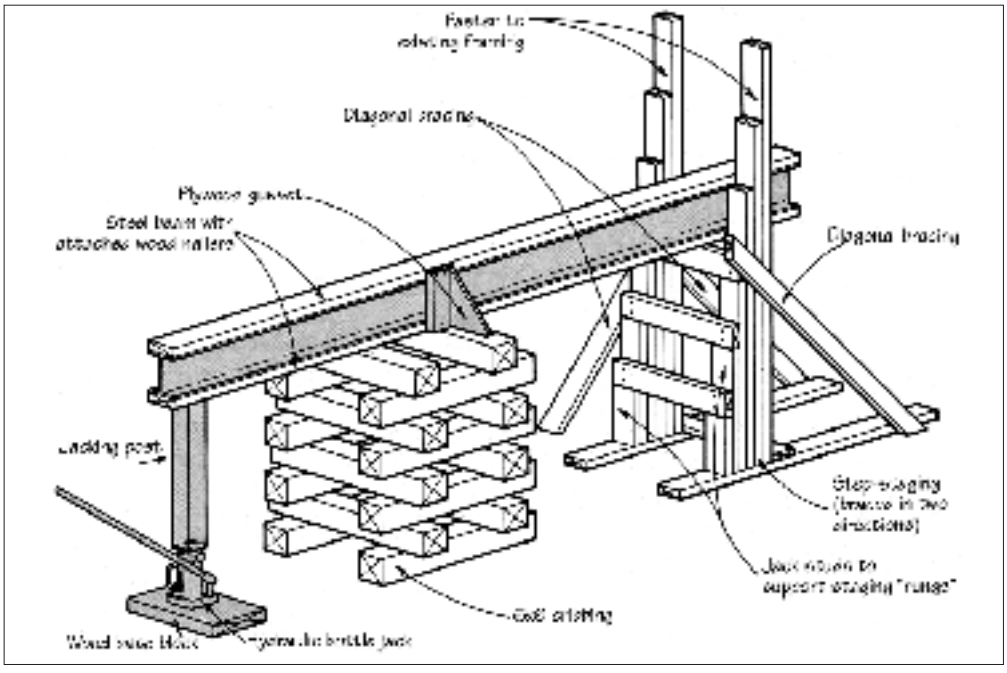

Figure 6. *When a hoist or crane is impractical, you can lift a steel beam into place with one or two hydraulic bottle jacks. Build a crib or step-staging to temporarily support the beam while you reset the jacks. Work the beam from the ends, but don't let one end get too much higher than the other or the beam may slide. Plywood gussets attached to wood nailers will help keep a tall beam from tipping.*