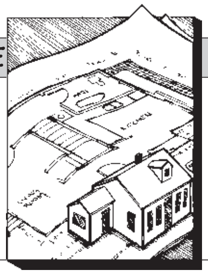


Using Steel in House Construction

by Gordon Tully

Wood-frame construction can be accomplished without the use of steel, but we wouldn't dream of such a thing today. Steel in many guises forms a crucial part of a modem house (see "Steel Parts," page 12).

Characteristics

1. Steel is used because of its special physical properties, and not because of its looks or durability. Because steel rusts so easily, only expensive stainless steel looks good if left exposed without a durable coat of paint. Also, most steel products have irregular finishes.

2. Steel is terrific as a structural material because of its high tensile and compressive strength combined with a high modulus of elasticity (that is, it doesn't move much under stress) and a high yield point (it returns to its original shape even after being severely stressed). Its values are 10 to 25 times those of wood for most of these characteristics.

In particular, steel does not have any grain to speak of, and resists tension and compression more or less equally in all directions. Wood by contrast is very weak in compression along the grain, and almost useless in holding fasteners against pull-out in its end-grain.

3. Steel does not burn in a fire, and it melts at a high enough temperature that it can provide moderate levels of fire protection.

4. Steel is easy to form into useful shapes, such as plates, rolled sections, and pipes. It can be joined easily, though not in comparison to wood. But steel connections excel in transferring large stresses across a joint-something hard to achieve with wood construction.

5. Because it is so heavy and expensive, it is worthwhile to carve away the steel that is not needed to do the job at hand-rolled sections are a good example. Wood by contrast is cheap and light, and useless portions are left in place for convenience and continuity.

6. Thermal expansion: Building materials fall neatly into groups with approximately the same thermal expansion coefficients (divide each number by 1 million to get the actual value):

Wood: 2 to 4, average 3
Steel and concrete: 6.5 (wood x 2)
Copper, stainless steel, and plaster: 10 (wood x 3)
Aluminum: 13 (wood x 4)
Glass: 5
Lead and Zinc: 16 to 18

It is hard to believe that steel does not expand much more than wood, because it seems to move around a lot when it gets cold or hot. To understand this, you must take into account steel's ease in conducting heat (next item).

7. Thermal resistance: The ability of a material to transmit heat depends upon its coefficient of thermal conductivity, expressed by the familiar R (resistance) factor. Here is how steel compares with other materials:

Materials	R-Value/Inch (resistance)	Comparison (Steel = 1)
Insulation	3.0 to 5.0	1,000 to 1,667
Wood	0.9 to 1.3	300 to 433
Gypsum Board	0.9	300
Brick	0.1 to 0.2	33 to 66
Concrete	0.1	33
Stainless	0.006	2
Steel	0.003	1
Aluminum	0.0007	0.2
Copper	0.0004	0.1

This helps explain some of the complications of using steel where it can change temperature. While its thermal expansion is only twice that of wood, it conducts heat 300 to 400 times more easily, and therefore can get much colder much faster than wood. The combination can cause serious problems.

Floating Steel

The list of steel items in the home is a long one, but every item shares one important characteristic: Metal items, including steel, "float" in a matrix of wood.

If you were to take an X-Ray of a house, it would look disassembled, because few of the metal items touch one another. With the exception of piping and electrical conduit, no steel ems even form a sub-system.

This is a good thing, for the following reason: Wood moves a lot under changes in relative humidity, while steel does not move at all. If there were two frames, one of wood and one of steel, they would compete with each other, and the joints in the wood would open up as the wood shrank up against the immovable steel.

An analogous situation arises in a masonry structure. Since a masonry structure inside the heated envelope will not move, it is essential that plaster or wood panelling placed over masonry be allowed to "float," just as the steel in a house floats relative to wood.

Whenever a metal system is not allowed to float, trouble arises. For example, piping and ductwork which carries hot water or air must be allowed to float free of the surrounding walls to avoid noise when the heat is turned on, as everyone knows. (If everyone knows this, why is there a squeaky pipe in my house and a noisy duct in my brand new office?)

Steel Cantilevers

On occasion, it is desirable to create cantilevers by extending a beam from inside to outside, for example to hold up a porch or long overhang. Here steel is in its element, but secondary complications often make a wood beam the better choice.

Whenever steel penetrates the heated and air-sealed envelope of a house, condensation is likely to form on the inside, because of the excellent conductivity of steel. Insulating around the beam merely moves the point of condensation.

Rust can form and accumulate, weakening the beam and creating growing lumps of rust which force themselves into and under the surrounding materials with irresistible force. Even without rust problems, condensation can be a permanent nuisance, as the water drips into hidden construction or behind plaster.

Whether wood or steel, the beam will be loaded and unloaded periodically by people, snow and wind loads. Its inside portion must be tied down properly to avoid cracks which open and close with the beam's flexing.

Differential Vertical Shrinkage

As I have mentioned numerous times in this column, it is important to avoid large differences in vertical shrinkage at various points in the house, especially as the moisture content of our construction wood continues to rise.

A good way to understand the problem is to add up the thickness of wood in cross-grain below various parts of a floor (if it is a second floor, add in 1/20th the dimension of wood standing lengthwise). To find the shrinkage of moderately wet wood at that point, divide by 25.

Suppose for example that there is a large beam running under the first-floor joists. If this beam were made of 2x10s, there would be an additional 3/8-inch shrinkage at the beam. If this beam were made of steel, however, the shrinkage would be the same throughout the floor. This is an excellent reason for using steel for your basement beams.

In some cases, however, this differential shrinking doesn't matter. One state agency we work for only worries about this problem if there is a door perpendicular to and near an outside wall, because such a door invariably will bind up when the building settles in the middle.

Fastening to Steel Beams and Columns

Steel is often used to pick up substantial loads, which cannot be handled by a wood beam. If this load is to be transferred from the steel to wood, be careful not to overload the wood and crush it in its weak cross-grain direction (about 245 psi for most softwoods).

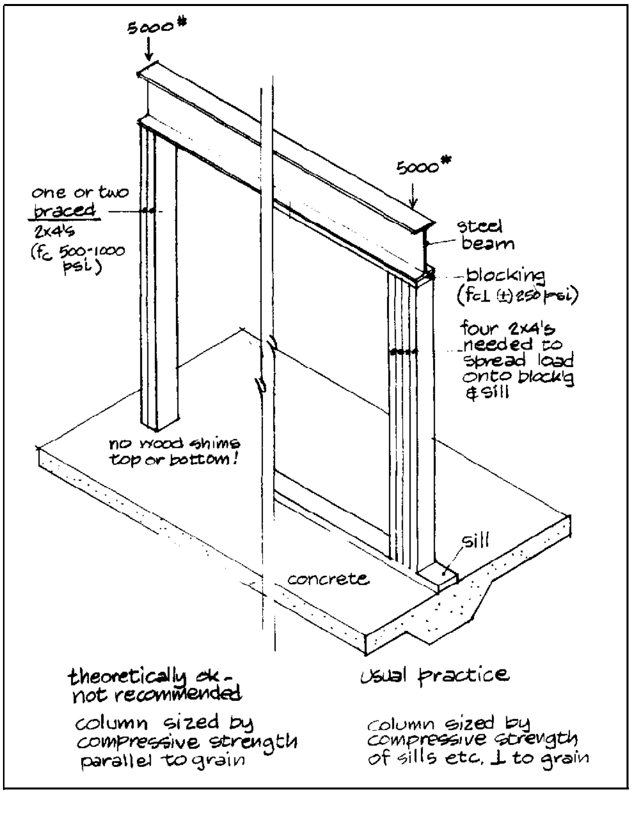
In theory, vertical stresses can be taken directly from the steel beam to the foundation without using any cross-grain wood. But someone always seems to slip a wood shim into the system. To avoid problems, posts (whether steel or wood) that carry steel beams should always be sized with the assumption that they will bear on cross-grain wood. That is, the cross-section of the post should be large enough that it will not crush a board on its side.

You cannot simply slide a steel column under a heavily loaded beam: You need a steel plate at each end of the column to transfer the load. Nine times out of ten, these plates are undersized. Remember that a thin plate is useless, because it bends out of the way and leaves the column to punch through on its own.

Use at least 1/2-inch column caps and bases, and if they have to be bigger than 4x6 inches, go to 5/8 or 3/4-inch plates. Make sure these plates are welded to the columns, not simply set in place. They should be bolted to the beams and held into the foundation with embedded anchor bolts or secure expansion anchors.

There are many neat details for attaching wood to steel beams. When joists rest on top of a beam it is often useful to bolt a continuous wood member to the top of the beam, toenailing the joists to the member.

If the beam is flush with the joists, remember to keep its top at least 1/4 inch below the floor to account for the wood shrinkage. Set dry wood members into the sides of the rolled



Steel Parts

Here is a partial list of common steel items found in a typical American house:

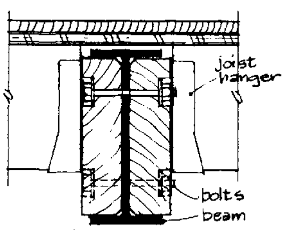
- Columns and beams
- Flitch plates
- Tie rods and hanger rods
- Bearing plates
- Brackers, angles, and lintels
- Wind bracing
- Reinforcing steel
- Masonry reinforcmg, ties, and accessories
- Nails, bolts, screws, and fasteners
- Embedded anchor bolts, expansion bolts
- Timber connectors and joist hangers
- Flashing
- Gutters and leaders
- Fire and bulkhead doors
- Garage door cracks
- Hardware
- Suspended ceiling supports
- Metal lath and gypsum/plaster accessories
- Prefab fireplaces
- Piping, fittings, and accessories
- Electrical equipment and conduit
- Light fixtures
- HVAC equipment and ductwork
- Plumbing fixtures and trim
- Special equipment (elevators, vacuum systems)

section, and bolt them in place through holes in the web of the beam. Joists can then be hung from this blocking with joist hangers.

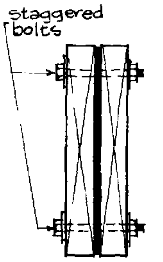
But have your holes punched beforehand. Don't allow holes to be cut in steel beams in the field, with torches. Holes should be punched in he shop, in order not to weaken the beam.

Using Steel and Wood Together

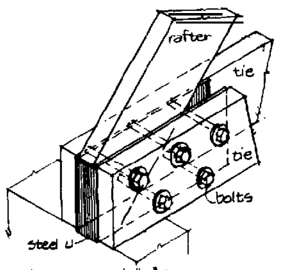
One principal of structures that is poorly understood is that involving two members of unequal strength working together. A good example is the "flitch plate," a plate of steel sandwiched between two wood beams.



steel beam within joist space



1/4" steel flitch plate between 2-2x12's



bent steel "u" to transfer rafter thrust into ceiling ties

The resulting composite can be very helpful where you can't easily fit a full-sized wood beam.

In a flitch plate, the steel must be sized in just the right proportion so that the two materials will work together. If one is too large or small, the stronger member will take most of the load before the weaker one can help, and a connection failure or excess deflection can result.

There are occasions when it is hard to make a strong connection between two pieces of wood meeting at an angle, for example at the joint between a stringer and a landing. Here a steel plate shaped to follow the required bend can be bolted onto each wood member to transfer the stress.

Similarly, steel brackets can help with ceiling ties. If joists are exposed in a cathedral ceiling, it is often desirable to space them out, with one joist for every three or four rafters. Each tie may have to resist more stress than can be transferred to the rafters through its ordinary connection. Use a bent steel plate to catch the end of the rafter. It can be made long enough to distribute the stress into the tie with properly spaced bolts.

Another example I have noted in an earlier column is wooden railings. These seldom meet code. Steel plates judiciously used can sometimes salvage a design which won't figure because there is not enough "meat" in the wood members to transfer the stresses.

Some Thoughts About Steel Studs

Steel-stud construction is routine in office buildings, and we have all gradually grown accustomed to its odd characteristics. In principal, steel studs are radically different from wood ones, because by themselves, steel studs can't resist any loads. The system is a composite, stressed-skin assembly which only works when all the parts are in place.

In my view, steel-stud construction is probably as durable as wood-stud construction: We simply trade off rusting against dry rot and carpenter ants. But I do worry about strength during construction-builders are used to having studs in place to hang stagings and braces from before the skin is on. I also worry about the long-term integrity of the skins that hold the wall together.

Finally, steel studs are not as convenient as attachments for hanging shelves, grab-bars, etc. And it is probably harder to change a steel stud structure when rennovating. ■

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