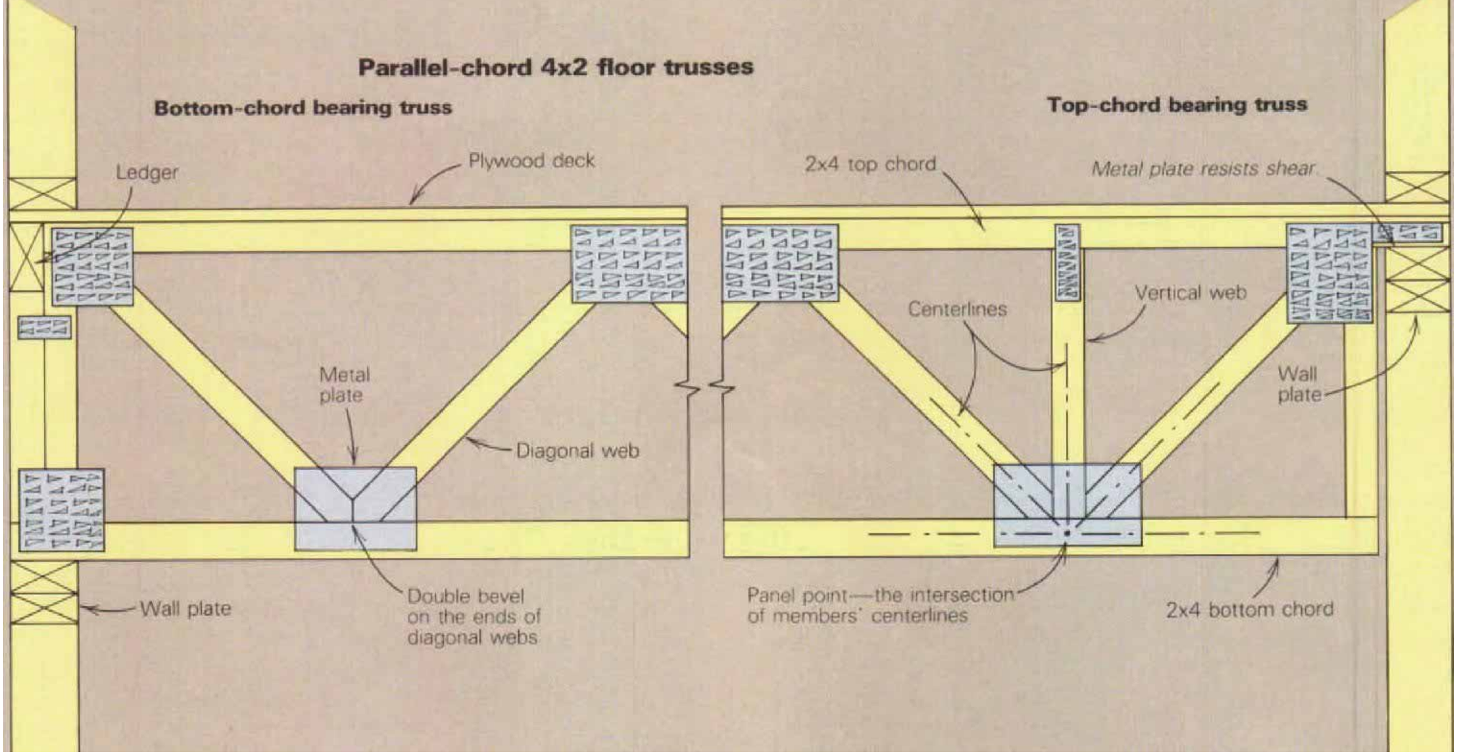
Parallel-Chord Floor Trusses

Strong and efficient, floor trusses may someday replace wood joists as the builder's favorite floor frame

by E. Kurt Albaugh



Once associated more with commercial construction, structural trusses are becoming increasingly popular among home builders. Though most builders are familiar with roof trusses, fewer builders realize that floor trusses can be used quite effectively in residential construction, too. They offer a number of structural and economic advantages, and can easily be incorporated into the design of a home without significantly changing the way a builder builds.

Structural advantages of trusses—Traditionally, the size of rooms in a home has been based largely on the span limitations of standard wood joists. Floor trusses with the same depth as joists can be used over longer spans, and this means that rooms can be larger, with less space obstructed by columns or unnecessary partitions. Trusses have a much greater variety of depths than wood joists do, and therefore a much wider range of spans and strength.

Trusses rarely warp. With a joist floor, natural warpage in the members can lead to an uneven floor deck. This problem can be reduced somewhat by culling out the warped joists before installation, but that increases wood waste.

Another advantage of floor trusses is that they permit ducting, plumbing and electrical service to be run easily between the open webs. With a joist floor system, holes must often be cut through each joist in order to run electrical and plumbing lines.

Since floor trusses are sized by the fabricator, they're delivered to the job site in lengths that meet the specific requirements of the project. With joists, the material must often be cut on site to fit, which wastes wood and increases the handling of material. Installation of *a* truss is relatively easy, because the truss edge is 3½ in. wide. This makes it more stable while it rests on the wall plates, and easier to nail to.

A floor-truss system is engineered, while a joist system usually isn't. This means that greater floor loads can usually be carried, and deflections are better controlled. Engineering also makes for a more efficient use of material (strength vs. weight), resulting in a lower per-square-foot cost.

Cost advantages of trusses—The builders I've worked with who use floor trusses believe that a floor-truss system is cost effective. But exactly how much so is difficult to determine since labor and material costs vary greatly throughout the United States. As a general rule for the Houston area, material costs are about $.90 per sq. ft. of floor (with trusses 24 in. o. c.). If the job is a long way from the manufacturer, shipping can increase the costs significantly. A joist floor system, on the other hand, costs about $.85 per sq. ft. of floor. This means that material costs for a truss floor are about 6% higher than for a joist floor system. But when the time saved for installing a truss floor (as much as 40%) is taken into account, the truss floor turns out to be about 10% less expensive overall.

What are the time savings? Quicker framing means a faster construction schedule, with attendant savings on construction financing. And because plumbers can route the pipes through the open webs of the trusses, no time is wasted by having to bore holes through joists. The electrician and HVAC (heating, ventilating and air conditioning) installers save time as well. Exactly how much time each tradesperson saves is hard to determine, but it can add up over the course of a job.

On the production side, most wood-truss fabricators find that there is little difference in production costs between 12-in., 14-in. and 16-in. deep trusses, so these tend to be comparable in cost to the builder. But when trusses get deeper than 16 in., material costs increase significantly because web material other than #3 shorts must be bought (now you know where mill ends go).

After pricing a lot of wood-chord trusses here in the Houston area, I quickly found out that the size of a builder's truss order is the greatest single factor affecting the cost of trusses. If there are several truss fabricators in your area, each one may have a different business approach. One supplier will probably favor small-quantity, custom truss orders while another will specialize in mass production and large orders. Shopping around for the best price often means shopping for the fabricator whose business most fits yours.

Truss anatomy—A floor truss has only three components—chords, webs and connector plates. Each one is critical to the function of the truss. The wood chords, or outer members, are held rigidly apart by wood or metal webs. The strength-to-weight ratio of floor trusses is higher than that of solid-wood joists because the structural configuration of the truss converts the bending moments and shear forces (produced by loading) into compressive and tensile forces. These forces are directed through the individual truss members and transferred to walls.

Chords. The type of floor truss used most frequently in residential floor systems is called the parallel-chord 4x2 truss. As shown in the drawings on the facing page, the chords are evenly spaced from each other, and the designation "4x2" identifies them as 2x4 lumber with the wide surfaces facing each other. This configuration increases the structural efficiency of shallow trusses, and provides them with a larger bearing area on wall plates. It also gives trusses additional lateral rigidity to resist damage during transport and installation.

In residential construction, a floor truss will most often bear on the underside of its bottom chord (drawing, facing page, left), just as a joist bears on its bottom edge. But because of the structural versatility of a truss, it can also be designed to bear on the underside of its top chord. In this case, the bottom chord is shortened and the truss hangs between walls, instead of resting on top of them (drawing, facing page, right). This can be a useful feature when the overall height of a building is restricted. But since height isn't usually a problem in residential construction, top-chord bearing trusses are seen more frequently in commercial work.

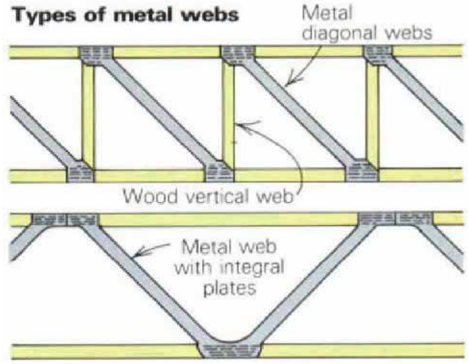
Chords can be made of spliced lumber as long as a metal connector plate is used to join the pieces. Chords are kiln-dried, and in the southern United States, they're generally made from No. 1 KD southern yellow pine. Truss fabricators commonly use either machine stress-rated lumber or visually graded lumber for truss chords, depending on the cost and availability of the lumber grade. During its early years, the wood-truss industry used only visually graded lumber, and trusses were designed conservatively to compensate for substantial variations in the strength and stiffness properties of the wood. Some time ago, engineers at Purdue University developed a technique to test and grade lumber by machine. Lumber graded by this process is called machine stress-rated (MSR) lumber, and truss fabricators are using it with increasing frequency for chord stock. Because every piece of MSR lumber is mechanically tested for stiffness and given a categorical strength rating, trusses can be designed to maximize the use of the wood's strength.

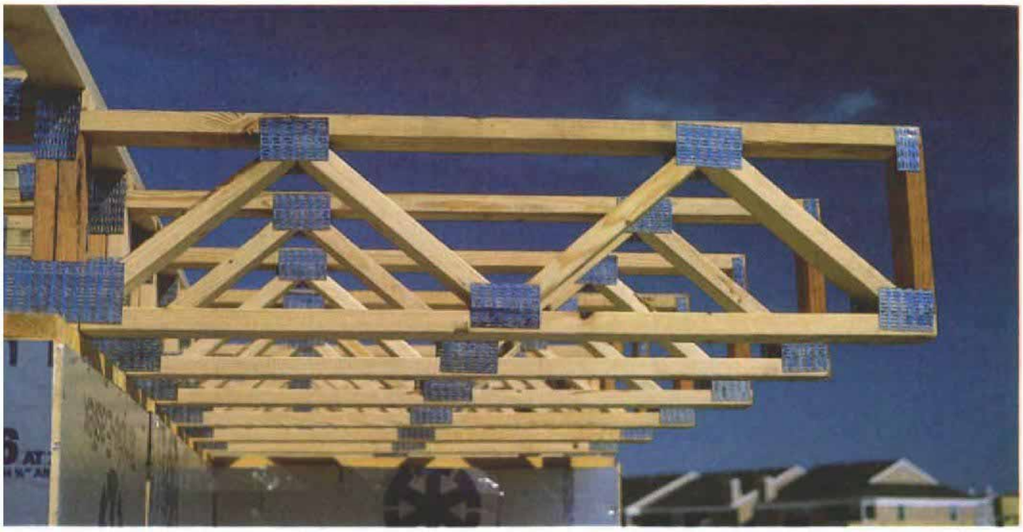
Webs. The members that connect the chords are called webs. Diagonal webs primarily resist the shear forces in the truss, and they are usually positioned at 45° to the chords. Vertical webs, which are placed perpendicular to the chords, are used at critical load-transfer points where additional strength is required. They also are used to reduce the loads going through the diagonal members.

Since the strength of the webs is not as critical as is the strength of the chords, a lower-quality wood can be used, such as #3 KD southern pine. Wood is the material used most frequently for webs, but metal webs are also used. Metal webs are stamped from 16-ga., 18-ga. or 20-ga. galvanized steel. Several truss manufacturers have designed the metal web to incorporate a connecting plate, thus reducing the number of pieces required to assemble the truss, as shown in the drawing below. Metal-web trusses provide greater clear spans for any given truss depth than wood-web trusses. The opening between the webs is larger, too, which allows more room for HVAC ducting. And they're lighter, so they are easier to install. But a major disadvantage of metal-web trusses is that a wide range of truss depths isn't always available. Also, metal webs are more susceptible to damage during transport and installation.

In a truss with wood webs, the ends of the diagonal webs are double-beveled wherever they meet a vertical web and the chord. There is an important structural reason for this cut. The objective in the design of any truss is for the centerlines of the chord and adjoining pairs of webs to intersect at one point. This is called the panel point. When centerlines don't intersect at

Types of metal webs





Floor trusses can be cantilevered over longer distances than wood joists. These trusses will support a balcony. Pressure-treated wood was used for the end web as a precaution against rot caused by possible water infiltration. The double vertical web member at the wall provides additional support for the deck loads on the cantilever.

a panel point, additional and undesirable stresses are introduced at the joint.

There are several different types of parallel-chord floor trusses, and what makes each one different is the arrangement of its webs. Depending on their arrangement, the webs will be either in compression or tension, and this dictates how loads are transferred from the truss to the structure supporting it. Pratt, Howe and Warren trusses were named after their respective developers. Howe and Pratt designed their trusses for railroad bridges. Two giant timber-framed trusses could span, a river or a canyon, and trains would run over tracks that stretched alongside the bottom chords.

Connector plates. In 1952, A. Carol Sanford invented the toothed metal connector plate, which eliminated the need for nailing and gluing truss plates. Metal connector plates substantially reduced the cost of trusses by allowing them to be mass produced.

Variations of the toothed connector plate are now commonly used to assemble trusses. They are made from 16-ga., 18-ga. or 20-ga. hot-dipped galvanized steel, which is punched to form numerous metal prongs, or "teeth," that extend outward from one side of the plate. When embedded in the wood of the truss (usually by a hydraulic press), these teeth give the plate its holding power. Specifications for designing trusses using metal connector plates are available from the Truss Plate Institute, Inc. (583 D'Onofrio Drive, Suite 200, Madison, Wis. 53719), which also distributes test and research data.

If you've had a chance to examine connector plates, you may have noticed that they are not always the same size. As they increase in size, they provide more embedded teeth, and therefore more holding power. Larger plates are used in joints with higher stresses.

Deflection—The design of a truss is usually governed more by bending limitations than by anything else. Too much bending, or *deflection,* can make a floor noticeably springy and result in cracks in the finished ceiling below. The American Institute of Timber Construction (333 W. Hampden Ave., Suite 712, Englewood, Colo. 80110) recommends deflection limitations for trusses of L/360 for the live-load portion of the total load and L/240 for the total load, where L is the span in inches. Live loads are calculated only if they are expected to be unusual—for example, placing a pair of pianos on the second floor. Generally, though, the total load calculation is used. Total load includes the weight of everything attached to or bearing on the top and bottom chords. It includes the dead weight of floor and ceiling materials, as well as the live loads of people, pianos and furniture.

To see how deflection limitations are used, suppose a floor truss must be selected to span 22 ft. between two walls. The maximum allowable total load deflection is calculated by converting the span distance to inches (22 x 12 = 264) and dividing this by 240. So a truss must be selected that will deflect no more than 1.1 inch at mid-span. In other words, if the truss is subjected to all the loads anticipated, the most it may deflect downward is 1.1 in. Remember that this is total deflection, including that caused by dead weight; it doesn't mean that every footstep will cause the truss to deflect 1.1 in.

Deflection limitations provide design parameters for the engineer in selecting an appropriate truss. Knowing the maximum deflection allowable over a particular span, the engineer can determine a truss depth that will deflect less than the maximum allowable distance. This can be done by mathematical calculation or by consulting data from truss-plate manufacturers concerning their products.

A floor system consists of the deck material and supporting network of trusses, and both components function together to transfer floor loads to the walls and foundation. But when trusses are engineered for a particular application, the effect of the deck material on truss stiffness is not taken into account. The floor-system strength is based solely on the stiffness of the truss itself. Because of this, the deflection calculations are on the conservative side.

Choosing a truss—Figuring the total loading on a floor system involves some calculation, but you don't necessarily have to hire an engineer or an architect to size trusses for your project. Engineering is provided either by the truss fabricator or by the plate manufacturer whose plates are purchased by the truss fabricator. These people work together to ensure that the combinations of plates, webs and chords are structurally sound.

To size a truss, the fabricator will first review your plans and look for any unusual circumstances that could affect the truss design. If nothing unusual is found, the truss design and depth will be chosen from reference manuals supplied by the plate manufacturer. These manuals list the standard truss designs and include span tables for each. The span tables simplify all the engineering variables into a very usable form, and are based on design formulas that come from actual laboratory tests of trusses. Spans are listed for four commonly used truss spacings: 12 in, 16 in., 19.2 in. and 24 in. The most common spacing for residential construction is 24 in., but trusses can be placed at any spacing that will allow the floor system to carry the loads specified in the building codes. All the spans listed in the tables assume the deflection limitations of L/360 or L/240.

Since truss-plate size is a critical factor in truss design, the plate manufacturer will often supply pre-certified engineering for the trusses, stating the limitations with in which they will meet certain performance standards, such as the deflection limitations.

If a standard design can be found to meet your needs, the truss fabricator will provide you with a certified drawing of it. Proof of this certification is the engineer's stamp on each page of the drawing.

If the design of your structure is unusual, with particularly long spans, heavy loads or unusual support conditions, it may call for a floor truss that has to be engineered specifically for your project. In this case you'll need to arrange for an outside engineer to do the calculations.

Typically, parallel-chord floor trusses with wood webs are available in depths ranging from 12 in. to 24 in., in 1-in. increments. The most common depths are 14 in. and 16 in. One plate manufacturer has designed a metal-web truss with the same actual depth dimensions as 2x8, 2x10 and 2x12 solid-wood joists. These smaller sizes are interchangeable with an ordinary joist-floor system.

The amount of space between webs is another thing to consider when you choose a truss. When ducts will be routed under the floor, the depth of the truss may be dictated by the size of the ducts. Usually this isn't a problem, since most fabricators have a standard truss design that includes a chase opening. To create a chase opening, one web in mid-span is removed to provide space for large ducts. The truss doesn't collapse on account of the missing web because shear forces are minimal at mid-span.

One last note about choosing trusses. Before you leave the fabricator's office, make sure that your order is complete. If you run short of joists, you can dash off to the lumberyard. But since trusses are precisely fabricated to your specifications, you will probably have to re-order the ones that you forgot. This can be expensive, and time-consuming as well.

Truss bearing details–A critical aspect of floor-truss design and installation is the amount and location of bearing surfaces, since the accumulated loads of the truss are concentrated here. Bearing details vary, depending on how and where the truss is being used.

For the simple-beam condition (drawing A, right), the truss is supported at each end, and rests on its lower chord, in joist fashion. It can also rest on its upper chord, and will carry the same amount of weight as an otherwise identical bottom-chord bearing truss.

A floor truss designed as a continuous beam will be supported on each end, as well as at one or more points in between. To ensure proper load transfer at the intermediate support points (a column or partition, perhaps), a vertical web member should be located directly over the bearing area (drawing B). Some truss fabricators will identify the intermediate load-bearing points on a continuous-span truss by stapling a green or red warning note to the area. These warnings are particularly helpful when you install the truss, since they help position the truss and keep you from accidentally installing it upside down.

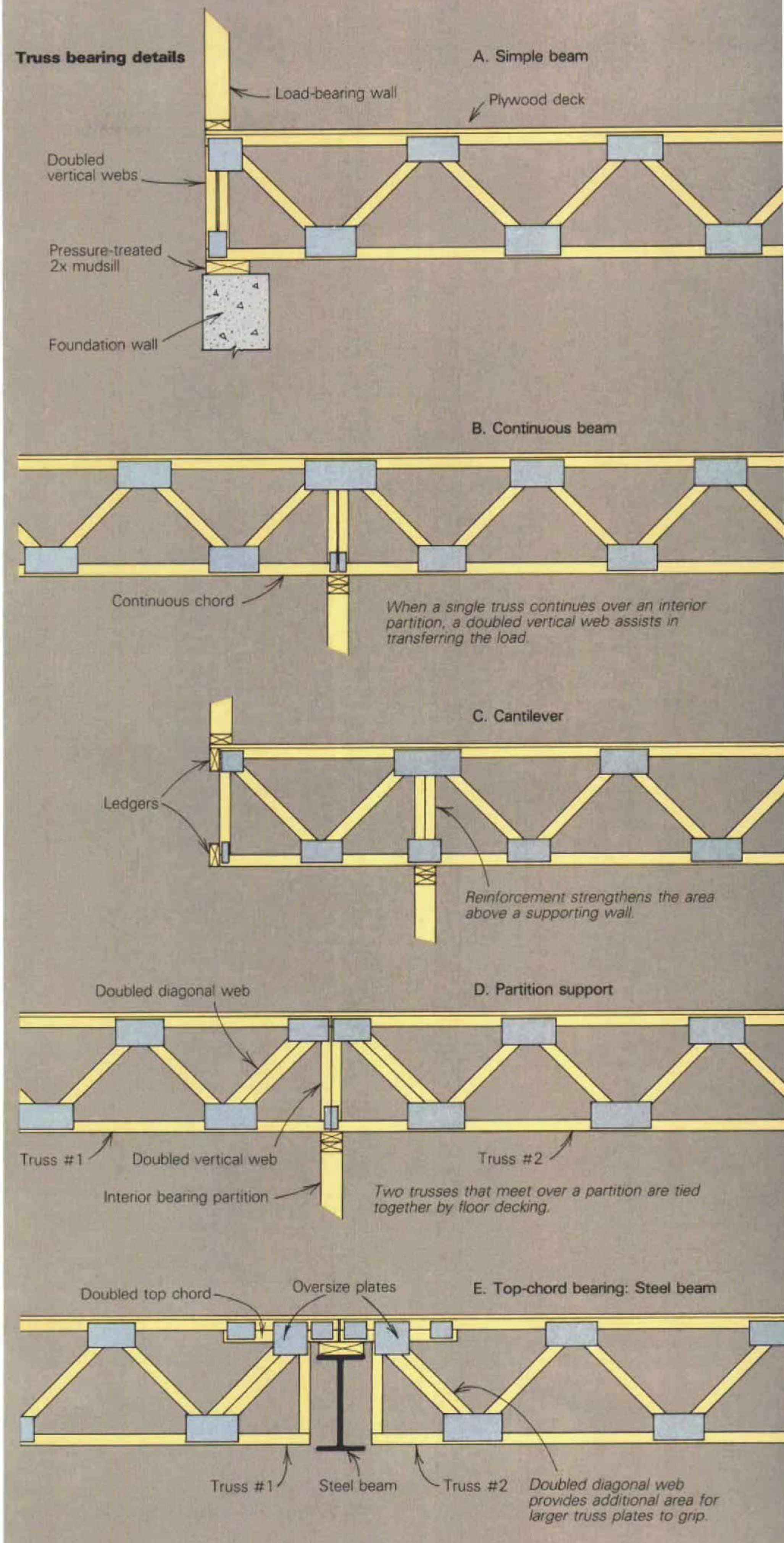
When floor trusses are to be cantilevered (drawing C)to support a balcony, for example, it is particularly important that provisions be made for extra support at the bearing points (photo facing page). The truss should always be designed so that a panel point rests over the bearing point. This transfers the load from the truss directly to the supporting element. To strengthen the area even more, the bottom and top chords can be doubled near the support point of the cantilever.

Trusses can also be used in multiples. In drawing D, two of them meet over an interior partition, while in drawing E, a steel beam provides the intermediate support.

Strengthening trusses–When floor systems are designed, the usual approach is to specify a single truss depth that will work for the entire system, regardless of the various span distances. This simplifies material orders and eliminates the possibility of mix-ups at the job site. Situations do arise, however, when it isn't practical or cost-effective to increase the depth of all the trusses in order to beef up just a few, and in these cases the truss fabricator can increase the stiffness of individual trusses.

Chords can be strengthened across the entire length of the truss by reinforcing the top and bottom chords with a second layer of wood, fastened into place with metal plates, nails or glue. Side-by-side floor trusses are often used to carry greater floor loads (bottom photo, next page), in a technique akin to sistering wood joists. Other options include using larger truss plates, stronger wood for the chords, or doubled webs in critical shear areas of the truss.

Sometimes floor trusses have a slight lengthwise curve that's built into them by the manufacturer. This curve is called *camber,* and it helps



Before the decking is nailed down, trusses should be measured at mid-span to make sure they haven't swayed out of alignment (note the tape measure in the photo). A pair of 2x4s can then be nailed to the trusses at the chase opening to ensure that the top and bottom chords stay at the proper spacing. These 2x4s are not strongbacks, however; strongbacks are usually 2x10s or 2x12s.

After the trusses are toenailed to the top plate, a ledger is nailed in place along their top corners. This further stabilizes the floor and provides an additional horizontal nailing surface for siding. To support additional loads, particularly at the edges of floor openings, trusses can be doubled.

to eliminate the visual effects of deflection and to control cracking. But camber does not add strength—it's simply a matter of appearance.

A common way to strengthen a floor system is to install a strongback, usually a 2x10 or 2x12, between the web openings to help distribute loading to adjacent trusses. Sometimes two 2x4s are slipped on edge through the web openings of a series of trusses at mid-span, and then nailed to a vertical web member, as shown in the top photo. This doesn't add much strength, but it helps to maintain truss alignment.

Choosing a truss fabricator—The strength of trusses is affected by the quality of their construction, so purchase your trusses from a reputable fabricator. If you aren't familiar with fabricators in your area, visit their production shops or look at samples of their work at job sites before you buy.

When you examine webs and chords, look at their alignment. Make sure that the centerlines of all the members intersect at a panel point, and that this point is adequately covered by a truss plate. Take a close look at the wood joints, too. They should be closely fitted. Truss-plate teeth should be evenly embedded into the wood for proper load transfer.

Installing floor trusses—A certain amount of care must be taken when installing floor trusses, but otherwise the installation isn't much different from the installation of wood joists. When trusses are delivered to the job site, be sure to check them against the design drawings. Any structural peculiarities, like bearing blocks or doubled chords, should be verified. A bearing block is the extra vertical web that's put in a truss over any support point. Watch for the identification tags on the truss to help you find the bearing blocks.

Metal-web trusses should be inspected carefully to ensure that no webs have been bent. As a general rule, most metal-web trusses are designed to put the webs in tension, so a bent web is not always a problem. But it's best not to take chances. Wood webs should be checked for looseness or damage, as should the plates.

As a rule, the truss fabricator will deliver the trusses to the job site. Make sure you have enough help on site to unload and place the trusses. Be careful when handling them because the edges of a sharp truss plate or metal web can cut. Wear gloves.

Some builders have told me that the reason they don't like to use trusses is because they have to hire a crane to lift large ones into position. I firmly believe that even large trusses can be manhandled up to first-floor wall plates, though the task is a little more difficult when you get to second-floor plates. If you decide to use a crane for the job, you might as well use it to stack the plywood up there, too. Just be sure to nail the trusses securely into place first, and be sure you don't overload them. Bottom-chord-bearing trusses can be further stabilized by temporarily nailing a stringer board to the ends of the trusses.

As the trusses are being set into place, make sure they're right side up. They're sometimes installed upside down by accident, and when this happens, webs and chords that were designed for compression will be in tension. Truss failure is the likely result of this mistake.

Once the trusses have been toenailed to the wall plate (if need be, you can nail through one of the holes in the connector plate) a ledger board (photo below left) is nailed to their top edge to stabilize them and provide a continuous horizontal nailing surface for siding. The ledger fits into a notch created for this purpose by the truss fabricator.

If the top or bottom of the truss system is to be exposed when the structure is complete, it should be permanently tied together somewhere at mid-span. If the top chords are exposed to an unfloored attic, for example, the trusses should be braced with 2x material at least every 3 ft. along their length. If the bottom chords are exposed to an unfinished basement, bracing should not exceed 10-ft. intervals. □

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Photos: E. Kurt Albaugh