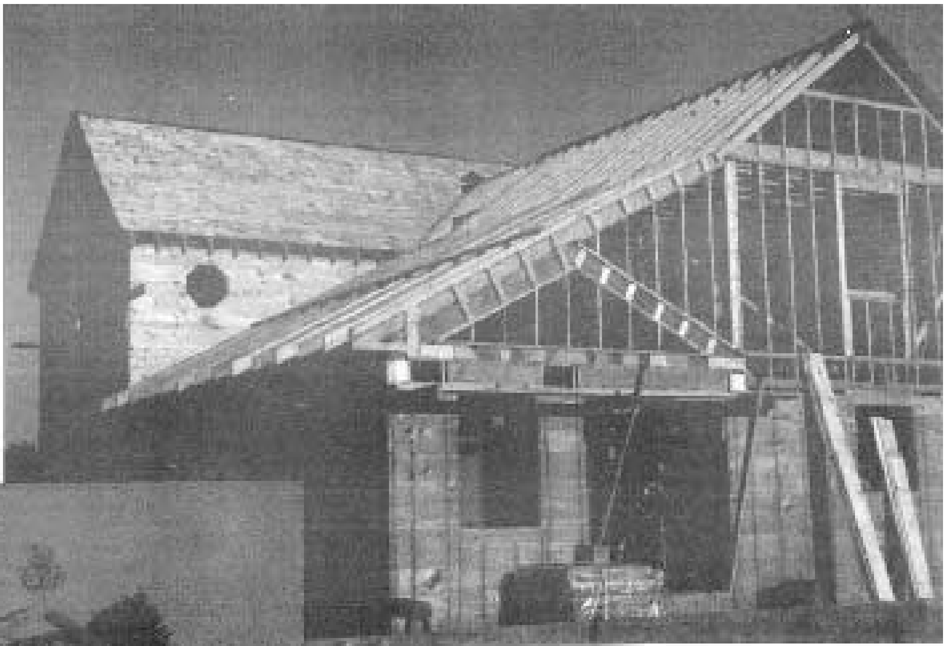
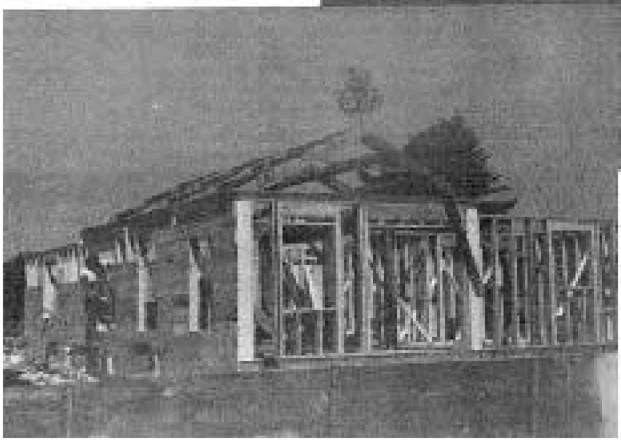
HYBRID TIMBER FRAMES



The timber-framed living room (below) is almost completely enclosed by stick framing (right) when the house is completed. The Builder, David Lindeman, of Gorham, Maine, likes the timber effect, but sees no need to be a "purist" about it.



It's fine to mix timber and stud. But you must understand each structural system to make them work together.

by Steven Chappell

Over the years, I've been approached by many individuals who thought it would be a great idea to have exposed timbers in one or two rooms in their new house. For one reason or another they did not want a complete timber-framed home. Their reasons for wanting a partial or "hybrid" timber frame are usually sensible. But the results I've seen in the field are often less so. Some of the hybrid frames I've seen rely far too much on hocus pocus for my peace of mind. This does not have to be the case. Integrating some of the finer points of timber framing into otherwise conventionally built custom homes can be accomplished very easily and economically if one takes a *whole-system* approach to building. Although we have yet to build a project, I feel there is a place for it in the custom-building market.

Whole Systems

Before analyzing the various forms that a so-called hybrid frame may take, it will be helpful to look at the two building forms that are being combined. By a hybrid frame we mean one in which the general principles and methods of traditional joined-timber frames are combined with conventional platform or stud-frame construction. It is important to keep in mind that the structural principles inherent in each system must be present in the hybrid offspring if the combined frame is to be structurally sound. Just as conventional framing and timber framing are whole systems, so must the hybrid frame be when complete. Magic just doesn't work. To successfully accomplish this, it is essential to have a working knowledge of each system's basic engineering.

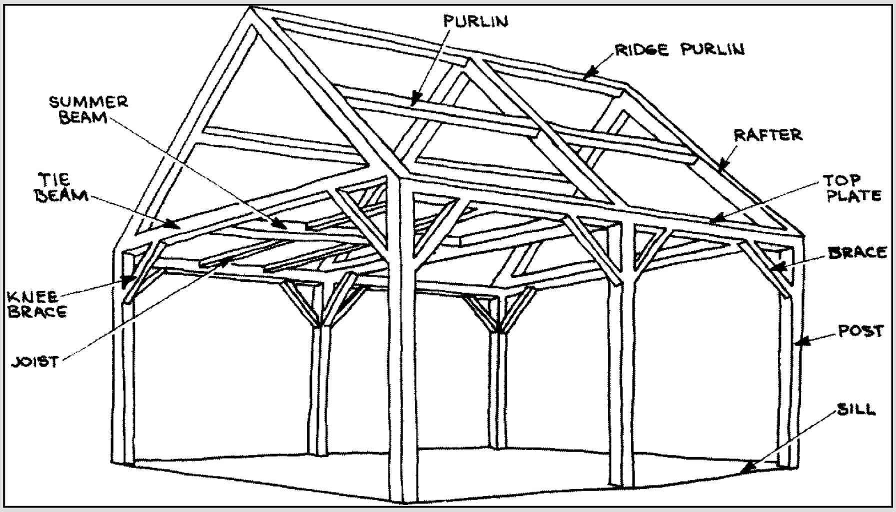
The Structural Frame

Once they left their caves, it became clear very quickly to our ancient ancestors that a rigid structural frame was the essential ingredient of a sturdy shelter. The frame, therefore, is a necessary evil that we must have in order to hang and support the sheathing, roofing, floors, walls, and windows. It must support all of its own weight, as well as the additional weight that will be loaded upon and in it, both now and in the future.

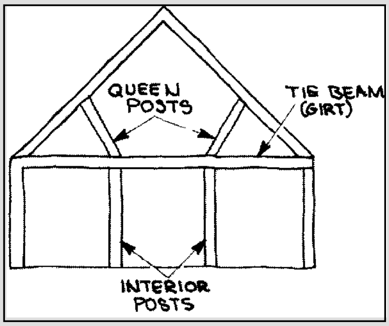
If this sounds a little too simplistic, let me say that the most horrendous cases of bad building I have ever seen were the result of misunderstanding the simplest concepts of structure. It's fairly common for non-timber builders to expect more out of timbers than is physically possible. Perhaps after building with 2x4s all day, a stick builder views a section of 6x8 as a much greater timber than it really is.

Despite obvious differences in appearance, both stud frames and joined-timber frames serve one and the same function. Each is a skeleton over which the enclosure materials are attached. The differences lie in the ways the imposed loads and external forces are distributed throughout the frame. Whether the fastening method in a frame is nails or pegs does have an effect. However, for practical purposes

Parts of the Frame



BENT

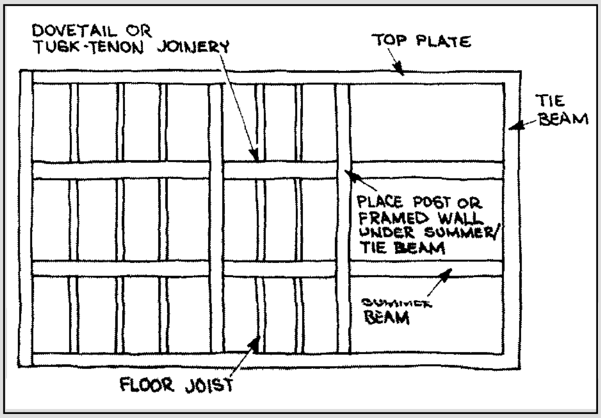


The traditional frame shown in the photo is called a "four-bent principle-rafter-and-purlin frame."

Why the name? Simply because the frame uses four *bents,* and the roof system is comprised of *principle rafters* (each part of a bent) and connecting pieces called *purlins.* Most frames are built from pre-assembled bents, which are essentially timber trusses that extend from sill to ridge. Bents come in many shapes and sizes. The one shown in detail (center, right) uses angled *queen posts* to help support the rafters, and interior posts to support the additional load on the tie beams (girts).

Other parts of the timber frame are identified in the large illustration above. Note that it is a complete system in which loads are concentrated and transferred vertically to sturdy posts. Problems arise when stick framing is mixed in, since it distributes loads evenly across beams (top plates, summer beams, etc.) which sag or twist if not supported.

Also note that the second-floor framing, shown in derail at right, is not designed to resist the outward thrust of the rafters, except at tie-beams. This can be a problem if standard roof rafters are used on 16- or 24-inch centers.



SECOND-FLOOR FRAMING

we can assume for now that all connections are fixed and solid.

The primary forces acting upon any frame (see Figure A) are:

- Dead load—the weight of the structure itself.
- Live load—the forces acting on the frame as a result of its intended use, that is, occupants and furnishings.
- Snow load—based on the maximum accumulated snow that can be expected to fall and remain on the roof.
- Wind load—the forces exerted on walls and roof by the wind (either a positive pushing force or a negative lifting).
- Resultant or combined load—due to combined wind and snow loads.

As these loads are imposed on the frame, each member is subjected to a number of forces. Primarily each member is subjected to one of two distinct loading stresses—compression or tension. Often, as in the case of a horizontal carrying beam, a timber is in both compression and tension simultaneously. In the example of the carrying beam, the wood fibers on the top half of the timber are under compression loading, while the fibers on the bottom are subjected to tension loading.

Of course, not every member nor every connection has to be dissected and analyzed in every frame that you build. A good example for this is a conventional stud frame. Most experienced framers learn quickly to recognize proper construction methods. There are standards used throughout the industry that remain pretty much the same from coast to coast (ask your local building inspector for a copy of your local code and suggestions as to other reference materials). It is likely that many stick framers go through their careers without ever having to acknowledge the thrust of a rafter or the compression on a stud. However a prerequisite to timber framing is to gain a general working knowledge of these facts. In some ways, it becomes even more important when working on hybrid frames.

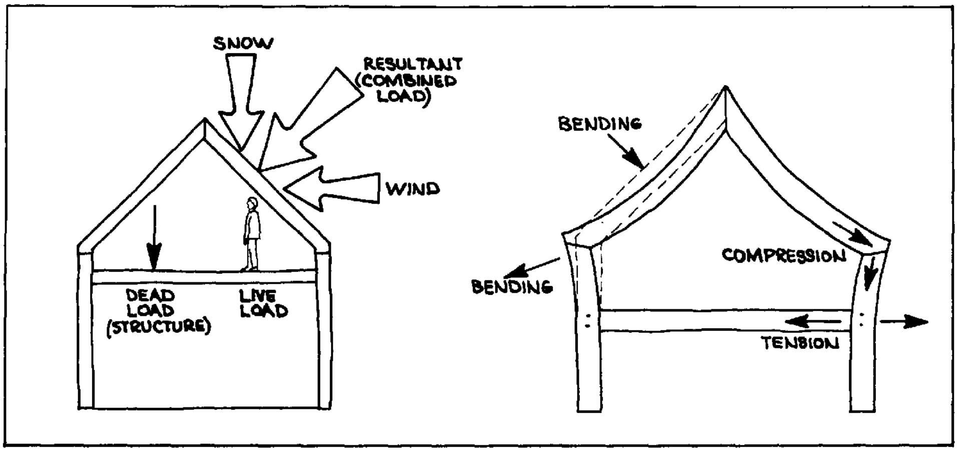


Figure A. In timber frames, the primary loads (left), are concentrated on a few key members (right). The great demands on each timber and joint leave small margins for error compared with conventional framing.

Distribution of Loading

In a conventional frame, the primary goal is to distribute the imposed loads so evenly throughout the frame that each member ends up carrying only a minute portion of the total load. The demands on each member and each connection are so dramatically reduced that removal or destruction of one member or connection has little or no effect on the stability of the frame as a whole. In contrast, a timber frame is designed to concentrate loads on a few primary members, significantly increasing the demand on each member. What this means for timber framing is that the margins for error commonly accepted in conventional framing cannot be used. Fewer structural members and greater forces call for much stricter tolerances in workmanship. Dead loads also become a bigger issue. Whereas the actual dead weight of each common rafter in a conventional roof is insignificant, the weight of the wood becomes an important factor when building with timbers.

Timber-Framed Walls and Ceiling

A common form of hybrid frame is one in which only the first-floor walls and ceiling are timber-framed. On top of this platform, trusses are placed or a site-built roof is framed, which will allow second-floor living space. In both cases, the rafters are placed conventionally at 16 or 24 inches on-center. In this design the posts are all too often 6x6s spaced at 4 to 12 feet on-center with a 6x6 top plate. It seems common in this design for the builders to overlook two very important concerns: (1) the outward thrust of the rafters and (2) the distribution of loading on the top plate by the roof rafters.

As previously mentioned, joined-timber frames are a whole system. The design of the *bent* is nothing more than a very heavy truss. The same principles used to design conventional 2x4 trusses are employed. The tie or bottom chord prevents outward thrust of the rafters. The queen posts and struts prevent rafter sag and simultaneously stiffen the tie beam. If one or more elements of the truss were to be left out, there would be cause for great concern.

In a traditional four-bent principle-rafter-and-purlin frame (see sidebar, "Parts of a Frame"), the bents are commonly spaced 8 to 16 feet apart. Because purlins span between bents, the roof places outward thrust on the top plate. The roof load is transferred across the purlins, in equal proportion, to each bent. In turn, the sum of this load is transferred down along each rafter. If not secured at their feet, the rafters would give way to the accumulated thrust (horizontal outward force) and collapse. Understanding this possibility beforehand, the timber framer can easily design the bent to resist the load comfortably. In this type of traditional design all of the outward thrust remains within the bent. All of the roof load is directed vertically onto the posts.

Let's imagine that our four-bent frame was 28x36-feet with the bents spaced at 12 feet on-center. Let's also assume that the maximum total roof load for this house is 45,000 pounds. Now let's see what happens if we project these figures into our hybrid design.

If we were to cut off the top portion of the frame leaving only the tie beams and posts, and then build a conventional rafter roof on top, what will we see happening? Two very important changes have occurred. First we have completely altered the way in which the forces are distributed to the first-floor wall framing. Instead of concentrated loading on the few posts, there is now an evenly distributed load along the length of the top plate of approximately 625 pounds per foot or 6,250 pounds along each 10-foot span between posts (see Figure B).

Instead of concentrated loads on few posts, there is now an evenly distributed load. No matter how comforting this sounds, it is not a desired condition for timber frames.

Second, the outward thrust of the rafters is now an evenly distributed force along the top plate. No matter how comforting the term "evenly distributed" sounds, this is not a desired condition for timber frames. We must find a way to counteract the outward thrust and support the mid span of the top plate to prevent sagging.

The sagging top plate may easily be remedied by placing intermediate posts or by infilling between posts with 2x4 or 2x6 wall framing. The outward thrust, however, can be a little more difficult to restrain.

Two things are happening to the top plate because of the outward push of the rafters. First, the plate will tend to bow out, placing a twisting force on the post and second, the top plate will want to roll out at the top. If living area is desired on the second floor, the easy option of using trusses will not do. And collar ties will not work either. They will not alleviate the thrust adequately-unless they are placed so low you would hit your head on them.

A very direct way to reduce the thrust imposed on the top plate is to redistribute the load with two stud walls (kneewalls) framed the entire length of the building (see Figure C). These will pick up the roof load and transfer most of it to the tie beams, which must then be supported by posts or stud walls on the first floor.

But what will support these second-floor stud walls between the points here they rest on the primary tie beams, which may be 12 feet on-center? Often a summer beam is placed directly under the wall, as shown in Figure C, and is strong enough to carry the load. If the tie beams are placed more than 12 feet apart, however, pay very close attention to this detail to determine accurate loading information and to assure safety.

Timber-Framed Second Floor and Roof

Another common approach to *hybrid framing* is having the first-floor walls conventionally framed and the roof and second floor timber framed. Although this may require more timber-framing talent, it is really a more complete system. In this way the first-floor wall framing is nothing more than a foundation for the roof framing and the roof framing is nothing more than a timber frame with no posts. The major structural forces, such as the thrust of the rafters, that usually dictate the design criteria can be completely handled within the roof framing system. Therefore, if the roof frame is properly designed, the first-floor walls will only be subjected to vertical loading (see Figure D).

Racking of the walls due to wind loading can be prevented by letting in corner bracing or solid plywood sheathing (I do not recommend oriented-strand board). If the roof frame is a principle rafter system with purlins, you must also consider the concentrated loading on the walls where the rafters bear on the top plate. Under each rafter end, use solid studding the width of the rafter as shown in Figure D. This will be sufficient to support the load if the wall is built with 2x6s or greater. I would not recommend building 2x4 walls in this system.

Since the roof system is the major structural element in this type of hybrid frame, the quality of the joinery and the type of timber-framing system are extremely important. Although the specifics of the joinery and framing system are beyond the scope of this article, some mention of timber-framing concepts is in order.

Joinery

We have assumed up to this point that all the joinery and connections have been adequately strong. Perhaps the hardest thing to decide when building a hybrid frame would be where to stop the timber joinery and begin the nailing. Steel plates and straps work wonders, but they do detract from the appearance of the timbers. They also do not work well at resisting twisting forces, which are important when working with timbers. Outside of glulam, there is no such thing as a dry timber. Mortice-and-tenon joinery then, is still the best approach of connecting timbers. Since several articles would be necessary to do that topic justice, I'll just offer a few suggestions.

Tension. Tension is the force that tries to pull things apart. With any timbers joined under tension, it is best to use full *through-mortice-and-tenon* joints. In a typical timber frame this

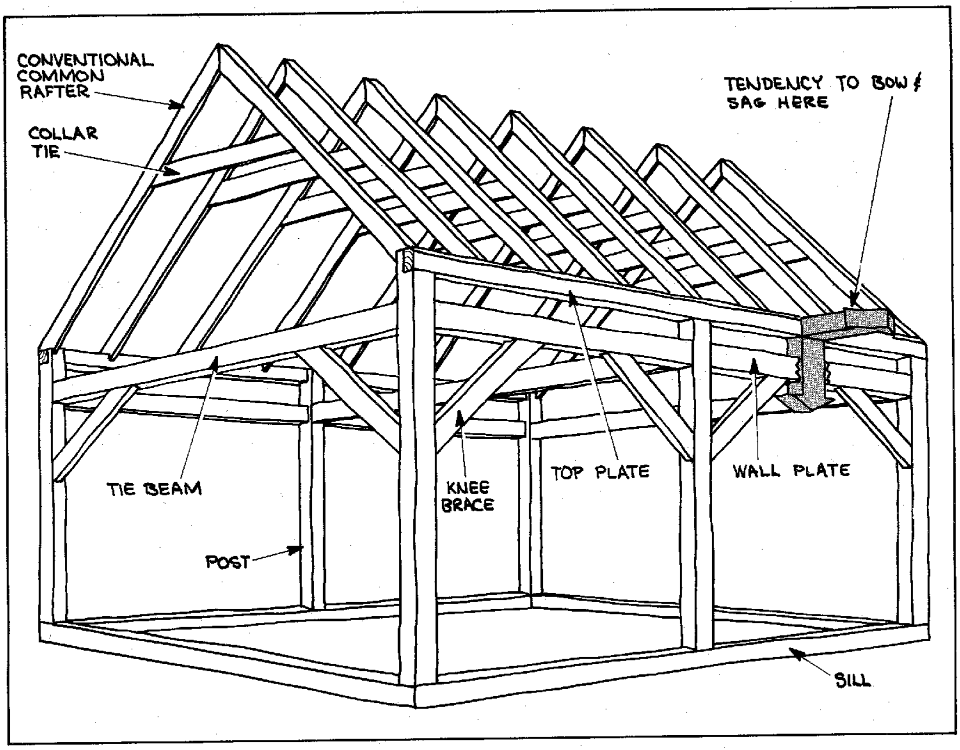


Figure B. ***Conventional roof with timber-frame walls and ceiling.*** *A common-rafter roof imposes evenly distributed loads downward and outward along the top plate (shown by arrows). The timber frame, however, is designed to carry concentrated loads, not distributed loads.*

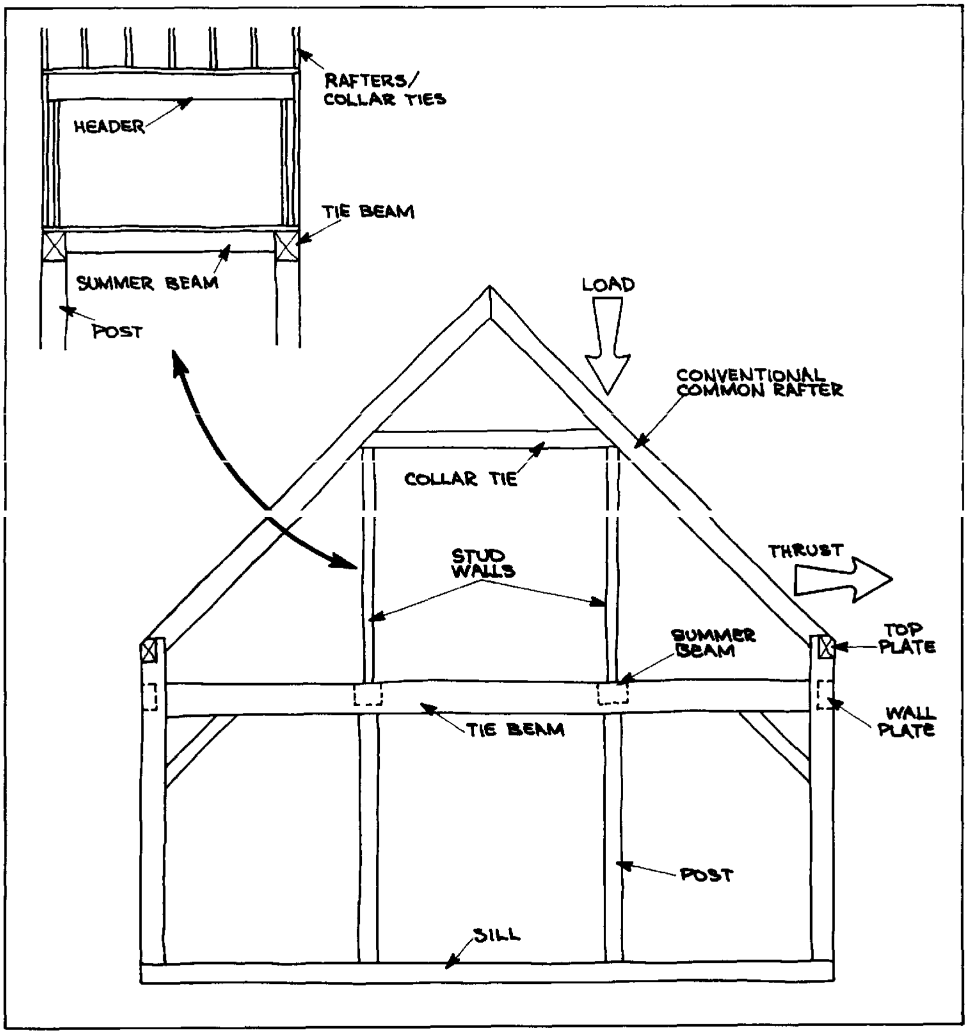


Figure C. *Collar ties are not adequate to reduce rafter thrust. One solution is to add stud walls (kneewalls) the length of the building, as shown. Openings are allowable in the stud walls with appropriate headers (see inset). To support the added walls, first-floor posts are needed as well as hefty summer beams placed under the walls.*

Two of the main factors influencing the strength of a mortice-and-tenon joint are the width of the tenon and the amount of wood behind the peg.

might mean that a 7x12 tie beam would be joined to a 7x9 post with a tenon of 7 inches high by 9 inches long (Figure E). The width of the tenon will vary according to the situation at hand, the average being 1 1/2 to 2 inches. Two of the most important factors influencing the strength of a mortice-and-tenon joint are the width of the tenon and the amount of wood behind the peg resisting in shear (see Figure E). The wider and longer the tenon the greater will be the resistance to shearing and the stronger the joint will be.

Pegs are, of course, an important and required element in most joinery details. It should be the goal, however, to design joinery and framing details that rely less on the pegging for strength and more on proper structural design. If adding another framing member would greatly reduce the load to a given timber, thereby reducing the demands on the joinery holding it together, then it should be added. The desire to have an attractive open span of timbers should not be the justification for doing so. The justification should be calculated and proven structural ability.

Compression. Compression, as opposed to tension, is the force that wants to crush timbers together. The more the surface area in contact under a given load, the stronger the connection. Wood is much stronger in compression than in tension. For this reason it is desirable to use smaller compression members, such as struts and queen posts within a timber bent or truss, to distribute the roof and floor loads in a balanced way. This will reduce much of the stress placed on the key tension joints.

Contrary to what some believe, timber frames are not capable of spanning long distances on the merits of single timbers. The greatest reasonable span for load-bearing beams is sixteen feet. When spans beyond this are necessary, more elaborate truss designs must be used. Attempting long free spans must be approached wisely and sensibly.

While almost anything may be possible, the goal is to be practical. The decision to combine different building systems in the construction of a frame should be made only after acquiring a thorough understanding of all systems involved, and only if the end result will be a better product. ■

Steve Chappell owns and operates Fox Maple Post and Beam in West Brownfield, Maine, which builds timber-frame homes and conducts workshops on traditional timber joinery. He is also editor and publisher of Joiner's Quarterly.

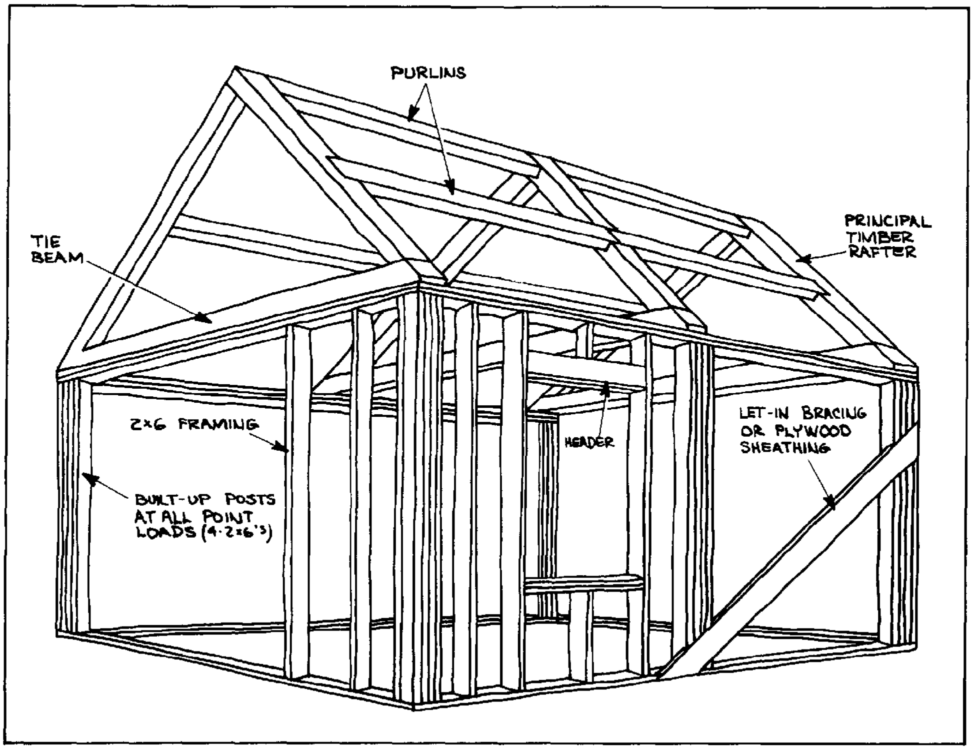


Figure D. Stick-framed walls and timber-framed ceiling and roof. *If the second floor and roof are timber-framed properly, they should subject the first-floor walls to vertical loading only. Use minimum 2x6 stud walls in this type of hybrid, and use multiple studs under rafter ends.*

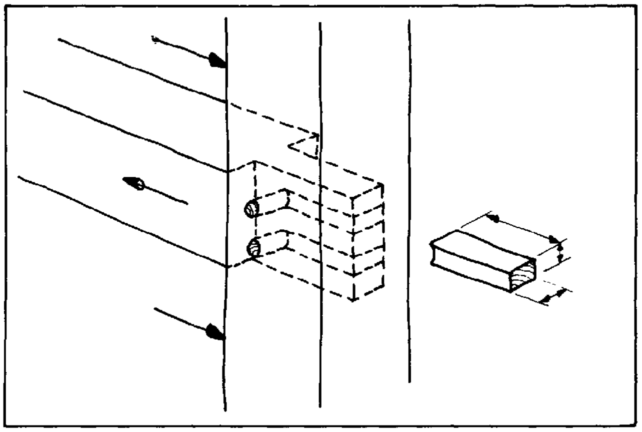


Figure E. *A through mortice-and-tenon is used to join main beams loaded in tension. The strength of the joint is determined largely by the amount of wood behind the peg resisting in shear.*