TIMBER FRAMING

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Raising the Frame

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On the cover, hand raising with pike poles at Malabar Farm, Malabar Farm State Park, Mansfield, Ohio, 1994. The heavy strapping fastened across the bent will act as jibs for tackle used later to raise the purlin and wall plates. Haul-back line, presumably assigned but unmanned for the moment, can be seen at the left. Yellow strap from gin pole, guyed outside the picture frame, acts as safety. Photo by Will Beemer. Raising and rigging articles begin on page 4.

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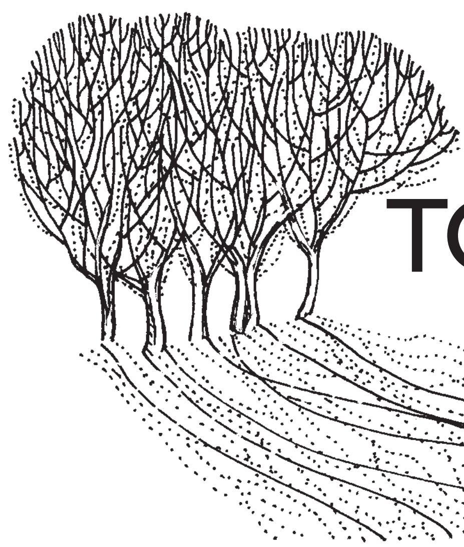
1985



TOPICS

In Appreciation of History

AS was the case with many of my school subjects, I thought that history had no relevance to my life. Then, when I began to make my way through the world on my own, the connections and influences of the past on my life became apparent.

My introduction to timber frames came at an early age in the family dairy barn that was a playhouse and fort long before becoming the focus of so much dreaded *work*. That work was one of the natural cycles, repeated yearly—fill the barn, the silos and the granary with the harvest, then gradually feed it in one end of the animals and take it away from the other. As a teenager, it was difficult for me to appreciate the steadying connection to the past that came with the lifestyle and that was embodied in the timelessness of the old barn.

When I began to hear of the revival of timber framing in the 1980s, it immediately aroused my interest as an extension of the woodworking I had come to love. After several years of attending conferences and workshops and occasional work helping a nearby shop through its busiest times, I opened my own shop. Cutting house frames for rich people was my bread and butter, but the occasional involvement in historic projects lit a fire I couldn't put out. The house frames began to feel sterile compared to the richness of subject matter surrounding every project that came from a previous time.

Over the years, I have been involved in a broad array of historic timber frame projects. When working with Rudy Christian on lock gates for a canal reconstruction in Ohio, the history of that era seemed much more immediate. It was natural to explore beyond wickets and swing arms to the lives of the people who were part of that time.

When helping to reconstruct a 1626 French Jesuit missionary settlement near Syracuse, N.Y., at the museum of Saint Marie Among the Iroquois, I learned the laboriousness of French Scribe timber framing as well as the beauty of irregular hewn surfaces meeting perfectly. I also learned how the Jesuits found the first petroleum in America at Oil Spring in Cuba, N.Y., five miles from my home. After a couple of years, the Jesuits hurriedly left the area when their Iroquois hosts became restless.

While the technical lessons learned building the boat shop in St. Petersburg, Russia, may not have been great, the trip was a life- and perception-altering experience, and its effects will always remain. The Russian people were so warm and so curious about our lives, such unlikely enemies, possessing an odd juxtaposition of naïveté and cynicism.

The conversion of a logging railroad grade to a recreational trail in Pennsylvania brought lessons in historic timber railroad bridges, as well as in the logging era that clear-cut the mountains, and the Carnegies and Mellons who financed the operations from their grand estates in the valley. My children had a lesson of their own in natural history when, sitting on the cabin porch on a peaceful evening, I heard, "Daddy, there's a bear!" Our host taught a class in gourmet cooking (and eating) when he showed up with elk steaks, native brook trout, morels from a nearby wood and a salad of wild greens. How sweet it was!

A project at a 19th-century water-powered grist mill, again in Pennsylvania, taught mill mechanics, history and terminology, as well as how the village of "Burnt Cabins" earned its name in 1750, shortly before the existing mill's predecessor was built. A young surveyor named George Washington had followed Generals Braddock and Forbes through the nearby hills and, if the outcome of action between British Fort Ligonier and French Fort Duquesne (Pittsburgh) had differed, you and I would likely converse in French.

I'd always been interested in covered bridges, but I took a crash course in their construction and history with the stabilization of one on the verge of collapse in Somerset County, Pennsylvania. King's Covered Bridge was built early in the 19th century with multiple king-post trusses. In 1906, a major rebuild added arches to the trusses. Bottom chord failures (both sides, luckily at opposite ends) had likely prompted the addition of arches, but deterioration had continued to the point that I think it was only force of habit holding the bridge up. The construction of an adjacent steel bridge removed traffic and saved the unusual lattice-joist floor system, which otherwise might have been replaced by steel beams, a common remedy to modernize similar bridges. The retired bridge was then used for years as a very long, narrow sheep barn.

The engineer's stabilization remedy was to stack several thousand 4-ft. 6x7s in neat piles to a level elevation right across the river bottom (slippery, and cold at Thanksgiving, ask me how I know) on which we wove two temporary bow-string trusses into the bridge. It's a thing of beauty. Word is that the money for permanent repairs is slowly working its way through the pipeline.

When I worked with Jim Kricker and a bunch of other merry adventurers on the Guild's replication of the 1656 Richardson Windmill in Indiana, I thought, "It'll be hard to top this one." The picture of Jim balanced on the great central post, lifting himself and the 5000-lb. post by himself, may never leave me, nor will the memory of Al Anderson off to one side scratching his head, then coming up with elegant solutions to the rigging and handlifting problems of multi-thousand-pound assemblies. Lift the other side? Don't move the lifting apparatus, just turn the frame around.

The hay barracks project at the 2000 International Preservation Trades Workshop proved that you can indeed timber frame a hip roof without cutting any compound angles. I had to see it to understand how. You've got to center a principal rafter on a plate, to make a sort of upside-down T, miter the jack rafters into that assembly, then join four such structures at the corners and peak.

Think the windmill's hard to top? Leave it to Kricker to try. In 2001, he put together a team to build a reproduction of an 1854 water-powered up-and-down "muley" sawmill in Wisconsin. This time the job required the fabrication of a dizzying conglomeration of idler and cone pulleys, wide leather belts and belt lacing, gears, flywheels, shafts and countershafts, levers, stops, log carriages and tracks, advance and return mechanisms, ropes with handles, water-flow-control linkages, guides, counterweights, log dogs, headstock and tailstock pins, pitman arms and rocker arms. Oh, and a water turbine to power it all, and a snapping turtle in the millpond observing the process. Did I forget to say that every square inch of the surfaces of six semi-trailer loads of white oak timbers had to have a hand-hewn surface, and the power-planer ripples on every door and window frame and every trim board had to give way to hand plane tool marks? The carpenters from the local general contractor, speaking in their Wisconsin-Swedish accent, gazed at the shavings coming off the planes. The next day several rusty relics just happened to be left lying around, waiting for the plane-tuning gods to resurrect them.

Complying with regulations of Wisconsin's Department of Natural Resources (this was a state historic site) dragged things out to about 10 years, start to finish. First, the state archeologists were called in. They found remarkably well-preserved mud-sills from the original mill buried in the mud, so they cut a section out of the center of a pristine 40-footer to take back to the office. Then the State Environmental Protection boys showed up and found an endangered species of mussel (a half-inch long) in the river. "Shut 'er down, let's move these mussels [and mud] to a new home," they said. Then, "You can't dam the river, the millpond might raise the water temperature and lower oxygen levels too much. Instead, you'll have to move the river over, then create a separate millpond. It's only a few hundred thousand cubic yards of soil. Oh, and let's install a few miles of wires, a computer, and some instruments to monitor conditions in the water." So, the 1854-2001 mill has a computer room.

I NOW have the opportunity to develop a trade-based program in Historic Preservation at SUNY's Alfred State College of Technology in Wellsville, N.Y. To date, preservation education in the US has been primarily for architects and planners. They've been instrumental in raising public awareness of the benefits of saving our historic architectural heritage. Now the problem has become finding craftsmen with the proper combination of skills and understanding to restore our structures in a manner respectful of the craftsmanship that originally went into them.

I suppose you might understand my feeling a certain amount of reluctance when I considered leaving all the fun and games behind. What did I have to gain, other than a steady paycheck, a retirement fund that should mature shortly after I'm 70, and paid vacations? (My idea of a vacation had been going on an out-of-town job.) And what's this, health insurance?

Well, maybe I won't have to leave it *all* behind. Last year, I was allowed to come out and play with the other kids to help build the Norwell Crane (see TF 64), a replica of an 18th-century treadwheel-powered construction crane. And as a real kid, 4-year-old Silas Russell, learned to his great delight, it can be used to lift your father 50 ft. in the air, all by yourself. I hope footage of that lift survives to become part of the film documentary.

Now, remember the old family barn where this all started, the one I thought was timeless? Well, I'm afraid time has caught up with it. I've extended the lives of a few barns, but this is one I won't be able to save. When its working days ended and its upkeep was no longer necessary to the economy of the farm, it sat neglected, a relic. When I drove by a couple of months ago, the silos were gone, boards were missing from the walls, and the roof was starting to cave in. It won't be long now.

It's all part of the cycle. But you know, the cows' contributions made the soil pretty good there, and after the old barn becomes part of it, it may grow some really fine trees. Maybe some of them will have the honor of becoming part of something useful to us, appreciated by generations to come. It's pretty cool to think that by picking up a piece of a tree, turning it around and looking at it, taking away a little here and there and fitting it together with other bits and pieces, we can turn it into something much more than it was. We can make it gain our appreciation as something unique, and in the process maybe even deny our own mortality a little.

—Leon Buckwalter

TIMBER FRAMING FOR BEGINNERS

V. Raising the Frame

TIMBER framing differs from light (or stick) framing in many ways, perhaps none so dramatic as in the manner in which the frame is erected. That just a few people using lightweight members could quickly construct a balloon or platform frame with studded walls contributed to the popularity of this new method as Americans migrated West in the 19th century, and it led to the diminution of timber framing as an economical building method. Today, with the availability of mobile cranes, it is possible for a small crew to build with heavy timber, but the skills and equipment required are still very different from light framing's, and more akin to steel erection. Raising by hand with a large group of people and specialized rigging equipment is a viable option that adds economic, spiritual and photogenic benefits, but it's potentially more dangerous as well. Sometimes both methods can and should be used at the same raising. Either method requires care and foresight.

Because of the endless variety of timber frame designs and site conditions, every raising has its own peculiarities and requirements, but some general principles apply. I highly recommend that you seek out nearby timber framers to let you observe a number of raisings, or participate in a Guild rendezvous or workshop, to get the basic experience and understanding of the principles.

As explained in the second article of this series ("Ten Factors in Timber Frame Design," TF 62), the raising method is one of the 10 factors. At the very start of planning, you have to visualize how you are going to assemble the frame and get it up. It's possible and sometimes necessary to stand up one post at a time and stitch the frame together piecemeal, but this is very arduous and doesn't take advantage of the ability to pre-assemble much of the frame on the ground. Most timber frames can be broken down into either *bent raisings* or *wall raisings*. Bents are transverse assemblies that usually run across the width of the building, parallel to the rafters. Walls for raising purposes usually run the length of the building, parallel to the ridge, and provide rafter plates on top of the posts. Some joinery, such as the English tying joint, requires a wall raising because the tie beam that keeps the walls from spreading from the rafter load must be placed on top of the rafter plates. *Full-bent* systems that include principal rafters and use common purlins and wall girts to connect the bents require extensive rigging and scaffolding, in part because of the higher center of gravity in the bent. Rafterless bents (*H-frames*), with the tie beam below the plate, as well as wall assemblies, are easier to hand raise and require less rigging.

A raising script, in which you imagine and write out each step in the raising process, will help you plan for the big day and anticipate any difficulties in assembly (see Grigg Mullen's accompanying article for an example). It is very possible to cut a frame that cannot be assembled as designed, and this often results in a few "modifications" on site, such as cutting off tenons. A script helps you foresee these problems before the crane arrives.

Another early consideration will be accessibility. Can delivery trucks and a crane reach the site? (Don't forget to check for road restrictions, heights of underpasses and load limits on bridges, especially in rural areas.) If not, a hand raising may be in order, and hence you'll likely want lighter timber sizes and smaller assemblies.

Ken Rower

Frame above was raised walls first, then braced tie beams were laid across the plates; on this safe box, collared rafter pairs were set and joined by tenoned purlins (last collar omitted in favor of window).

Will Beemer

Full-bent raising. First bent has been strapped off. Second bent, reinforced with heavy strapping and comealongs, coming in. Workers on staging will insert braced connecting girts to make the box.

Site considerations include the storage and preassembly area and the foundation and deck design. Many timber frames are built in hilly and wooded regions where frequent deliveries of small loads of light framing lumber from a local supplier would be an easier prospect. For a precut (and often prefinished) frame, there must be an area where a large straight truck or even a tractor-trailer can park for offloading, as well as room for a forklift or crane or lots of bodies to maneuver, handle and store the timbers safely and cleanly. These piles of timbers should be arrayed for easy and orderly

Ken Rower

H-bent raising in progress. Box is complete and roof assembly of decorative faux trusses has been preassembled with ridge and ridge braces, ready for flying in to join wallpost and queenpost tenons. Last principal rafters will be fitted singly while crane holds ridge up slightly.

access as needed during the assembly and raising. If it can be arranged for, a generous, fairly flat area surrounding the foundation of the new building can be helpful. Backfilling around the foundation should have been completed before the timbers arrive.

If a crane is used, it has to be set up on a reasonably level area and close enough to the deck and storage area so it can comfortably reach both. The ground must be firm enough to support the outriggers and pads, which level and stabilize the crane. Usually the crane company will send someone to do a site visit to help you plan for these contingencies. Remember that the farther the crane has to reach, the smaller the load it can lift (more on this later). Keep in mind that if the foundation you're raising on is much higher than the storage area of the timbers, you may need a crane just to get the timbers onto the deck, never mind raising the bents. If you're moving and raising by hand, try to get the timbers delivered uphill from the deck and use gravity to help wheel the timbers onto the floor with your timber cart. Remember, too, that you're paying by the hour for a crane, so try to prepare and preassemble as much as you can by hand before it arrives.

Most timber frames today are raised on conventionally built light-frame decks, since it's a rare person who appreciates seeing the timber frame from the basement. Such a deck can be built in advance by local contractors at lesser cost and provides a level, clean surface on which the timber frame can be assembled. But, since posts in a timber frame impose significant point loads, the construction details must provide for them. This is another departure from the standard practices associated with the distributed loads of stud-framed bearing walls. It's most efficient to have the posts bearing directly on the foundation, which is usually masonry. Since the end grain of the posts can readily absorb moisture and rot can be induced by the moisture-wicking action of the masonry, a barrier is required. This is most often a treated sill, a plastic stand-off base (new high-strength ones are made by Simpson) or a rubber membrane. Since loads on the posts can often exceed 10,000 pounds over less than 100 sq. in., the underlying structure must be kept from crushing. If you are building on a 4-in.-thick concrete slab, this means increasing the depth under the post to 12 in., making a footing. In the case of poured concrete walls, which may be increased in thickness to 10 or 12 in., vertical reinforcing is often added. Concrete masonry units (blocks) cannot take point loads well, so their cores are often filled with concrete and reinforcing is added under posts and pilasters. If the posts sit directly on the joist- and-plywood deck system and don't penetrate through the floor to the foundation, then solid blocking should be added to bear the weight through the floor. Avoid nailing the plywood and blocking where a mortise will be cut out later. Under interior posts, this blocking may bear on concrete-filled tubular steel posts (*Lally columns*); keep in mind that, for timber frames, the little square stamped plates that come with these columns to spread the load at top and bottom should be replaced with larger ¼-in. thick plates. On the perimeter of the building, hold-down straps are often cast right into the foundation wall, especially in seismically active regions, to counter uplift of the posts.

All of these provisions should be detailed in the plans (see the Resources list on page 9 for more information), but there is always some on-site prep that has to be done. At a minimum, the overall dimensions of the deck or slab must be checked for square and to see how close they are to the timber frame's—rarely do they match perfectly, and adjustments are sometimes necessary—and the locations of the post feet must be found and marked. If tenons have been cut in the post feet, appropriate mortises must be cut in the deck or, if they are already blocked in, the mortises must be checked for size and depth. In hand-raised frames that rest on a plywood-sheathed deck, these tenons can be short (1 to 2 in.) and used simply to locate the posts but not to prevent uplift; the latter can be countered with straps down to the rim joists of the deck or the foundation. If desired, a full-length tenon can also be admitted to a blocked-in mortise below the deck covering, and pinned in the conventional way. As described above, some framers prefer to have the whole post penetrate through the floor framing and rest directly on the foundation. This approach makes a crane raising the more suitable choice, as the posts can drop gently and vertically through the floor. During a hand raising, it's difficult to guide the post feet through a hole in the plywood and most disconcerting to have the bent drop 12 in. as it reaches vertical.

LIFTING EQUIPMENT. Whether transporting or lifting timbers, it's heavy work. Therefore you'll want to know both the weight of individual pieces and assemblies and their centers of gravity (see page 10). Once the weights of the objects to be lifted have been determined, the rigging and equipment to do the lifts can be arranged based on the rated capacity required.

A complete examination of the variety and combinations of rigging and hoisting equipment is beyond the scope of this article. Courses and textbooks are available that adequately cover the topic for most situations a timber framer will encounter (see Resources). We can, however, give an overview of the terminology and types of gear available.

A *crane* is a piece of equipment designed to lift, transport and place a load. Some timber framing shops use electric overhead traveling cranes, sometimes called rolling bridge cranes, to move timbers from and to any point in a rectangular space below. On site, the vast majority of raisings are done with mobile cranes, which can move around the site under their own power, most often on rubber tires, though some are on crawler treads. They may have lattice booms but are more likely these days to have hydraulic telescoping booms. Typically, mobile cranes can rotate through 360 degrees, extend or retract and raise or lower their booms as well as lift or descend their load lines—with all four of these motions independently controlled. *Truck cranes*, the lightest class of mobile crane, mount their cranes directly on the truck bed or on a special sub-chassis. They are commonly available for ordinary timber frame raisings.

When planning where to set up the crane, keep in mind that the lifting capacity will often change depending on the rotation and orientation of the crane. Truck cranes can usually not pick off the front (over the truck cab) at all, and have the greatest capacity when pointed straight back. This has much to do with the location and arrangement of the counterweight used to offset the load.

Crane stability is based on the leverage of the load balanced by the leverage of the counterweight (sometimes the crane body) over a fulcrum (the tipping axis). When ordering a crane, specify the greatest distance the crane must reach, the expected weight of the loads at that distance and the height the crane will have to lift the assembly or pieces. Go through your raising script to anticipate if the crane will need to lift a bunch of weighty purlins over a ridge beam that's 50 ft. in the air, for example.

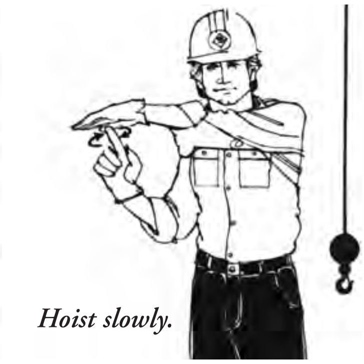
Cranes are rated by the maximum load capacity that can be lifted at *minimum* reach of the boom. For timber frame raisings, typical cranes might be rated as small as 14-ton or as big as 40-ton. They can cost anywhere from $80 to $160 an hour, including travel time portal to portal. Try to get recommendations for a company that has done timber frames before. A crane operator who is familiar with the rhythm of a timber frame raising (often slower and more varied than commercial work), and who enjoys participating, can be a great help. Ask if they provide all the lifting straps required. While the crane company can provide a rigger to attach the loads to the crane, generally this is the timber framer's responsibility. Often the crane operator can provide advice, but it's not efficient for the operator to leave the cab frequently. Sometimes the operator may be out of sight of the lift (try to avoid this), and the noise of the crane often makes communication difficult. Two-way radios are used by some companies, but be prepared to use the essential hand signals described at right. Have one person (and one person only) clearly designated and in plain sight of the crane operator to direct the lift.

Less-common hoisting apparatus can be used during hand raisings (drawings, facing page). *Derricks* have masts supported at the head by guys or braces, and differ from cranes in that the hoisting mechanism is attached separately, not part of the machine. This mechanism is most often block and tackle or a winch. *Boom derricks* have hoisting systems independent of the position of the boom, which itself can luff up or down to change the pick position. Boom derricks can be designed to swivel through 360 degrees and are useful if one is lifting from the center of the site. The *gin pole* is versatile and handy and requires just a single vertical mast but at least three guy lines. It's easy to rig, can be leaned at various angles and turned to lift from all sides. It's suitable for lifting medium loads to heights of 10 to 50 ft. An *A-frame* (or *shear legs*) derrick uses one fewer guy but one more mast.

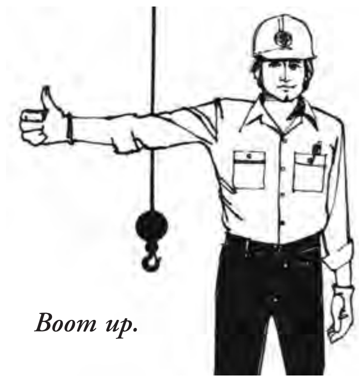
ASSEMBLY METHODS. Before raising day, it's prudent to have as much of the frame as possible preassembled and ready to lift. Usually this is done by stacking the bents (or walls) on top of one another or end-to-end on the deck. Mobile cranes make possible the contemporary practice of assembling completed bents including rafters and then connecting them with common purlins (see the example in the accompanying article). The crane can quickly raise these heavy assemblies with their high centers of gravity while the raising crew inserts connectors in the longitudinal walls. The purlins are then installed from "trees" held aloft by the crane (photo page 8). The bents must be spread slightly to insert the purlins, but that can be done with the help of the crane and a series of ratchet pullers (comealongs) and straps.

To assemble the bents on the deck, start with the last one to be raised so that the first one to go up will be on the top of the even-

Swing to there.



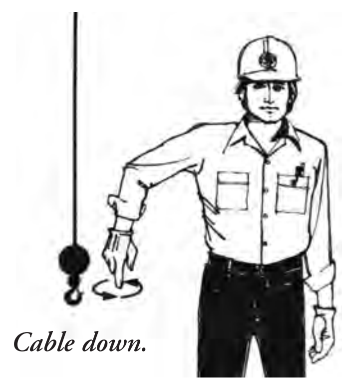
Hoist slowly.



Boom up.

Boom down.

Cable up.

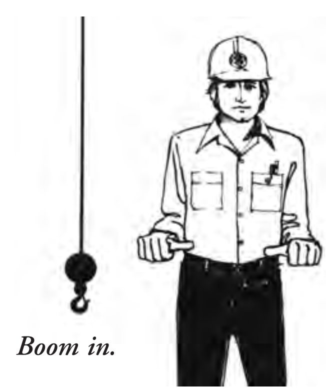


Cable down.

Boom up, cable down (flex fingers).

Boom down, cable up (flex fingers).

Boom out.

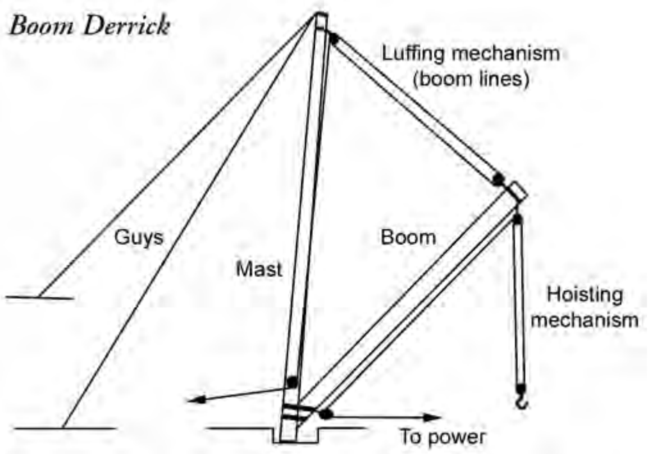


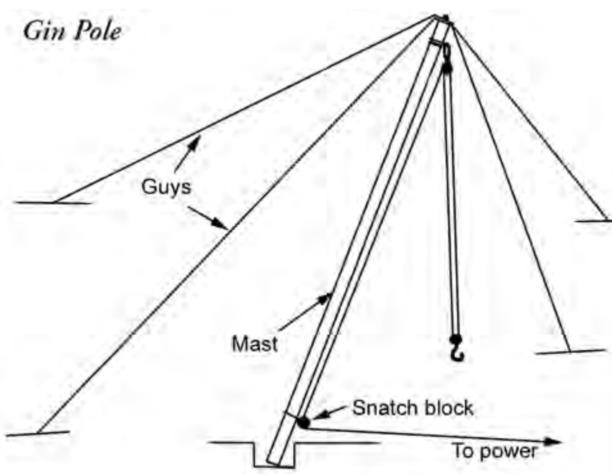
Boom in.

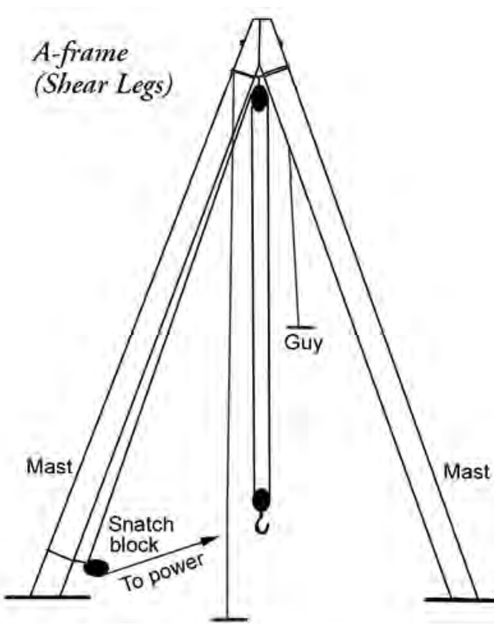
Some of the hand signals for controlling crane operation (with thanks to the Construction Safety Association of Ontario, the source of the illustrations). Any operation can be indicated to be done slowly by combining a motionless hand with the one signaling the operation, as shown in "Hoist slowly," top right. The combination signals "Boom up, cable down" and "Boom down, cable up" can relocate a load laterally without changing its height.

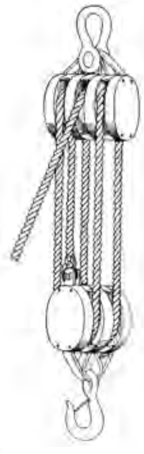
Stop. Palm down, move hand laterally.

Dog everything.









tual pile, and orient the bents correctly. With a crane raising, this is not critical (bents can be swung in midair), but the less you have to move the bent and rotate the crane the better. Make sure that you will have enough clearance to raise the later bents after the earlier ones go up; sometimes this requires that the last bent or two be hanging off the deck.

In a hand raising, the bents are unlikely to include any roof framing, but you'll want to stagger them so that the feet of the posts are close to their final locations and can drop right into their mortises.

Before beginning to work on the deck, make sure all safety precautions are considered. Install guard rails where serious falls could occur, and cover openings in the deck stoutly enough so people can walk and work over them. When assembling the first bent, you will want to block it up off the deck at numerous points to allow straps, clamps and hands to get underneath. The pieces are assembled with the help of a commander (or beetle), a large wooden mallet used to pound on a face of the timber that won't be visible (use a pad to protect show faces of a timber). To help draw the joints up tight and rack an assembly slightly to bring it into square, straps and comealongs or ratchet straps (also good for securing shipments on trailers) might be used and may stay on the bents during the raising. Be sure to protect the edges of timbers, especially softwoods, with heavy cardboard or plastic corners, lest the straps bite and crush the fibers.

Pegging technique varies considerably among timber framers. Some workers tightly draw together their bents with the peg holes predrilled only in the mortised pieces, then mark the tenons for center through the peg holes and take the bent apart to drill the hole through the tenon, recentered slightly offset (usually about an eighth) toward the shoulders of the joint. When eventually pegged with a tapered pin, this drawbore will cause the reassembled joint to draw up tight and remain so to some degree as the timbers shrink. (See article on the history of drawboring, page 22.)

Other workers leave the bent assembled and clamped and, after inserting the drill in the hole in the mortised piece (from each side when possible), tilt the drill toward the shoulder of the joint to drill through the tenon. This practice is said by its practitioners to accomplish the same purpose as drawboring but with less effort.

Still other framers, working by measure alone, predrill for the drawbore in both the mortise and the tenon before assembling. Drawboring pulls the joinery up tight, and with a lot of people supporting an assembly during a hand raising, all but eliminates the need for straps and comealongs to hold a bent together as it's being lifted. But beware of racking or twisting loads that joints cannot well resist, and never rely on a peg alone to hold a joint together during the lift; if gravity or people are not keeping an assembly in plane, apply a ratchet strap or comealong.

Assuming the joints all fit well and have been predrilled for drawboring, the bent can be pegged off. If you're raising the frame for a client, it's a nice touch to offer the first pegs to be driven by family and friends. If more bents are to be assembled on top of this one, block them up as well to allow pins to be driven through without damaging the assembly below and, of course, to allow access for straps. For more tips on preparing the bents for raising, see Grigg Mullen's raising an rigging article on page 10.

At top left, a boom derrick with two guys, used to lift a load and change its lateral position. At middle left, a gin pole with four guys (minimum three) and a two-part lift tackle. If a gin pole or a derrick is not fastened to an immovable object, but is out in the open as shown, it should be set in a shallow hole (somewhat exaggerated here). At left, shear legs with two guys (must run perpendicular to the plane of the legs), best for lifting straight up. At near left, four-part block and falls (or tackle), standing block above, traveling block below.

Spike Baker

Jim Buck (all)

Above, a purlin tree is flown in using a spreader bar; crew on staging will remove and drop in the purlins one by one. Above middle, a complete first-floor deck is rigged to avoid hinging on sill joints, and flown in to sit on the foundation and the basement posts and braces. Note tag line at lower right corner, to control the load in rotation. Above right, deck in place, the first bent (likewise tension-rigged to prevent hinging at its vulnerable joints) is flown in to drop into sill mortises. At right, box has been completed and pinned off, post and collar assemblies have been installed and half the roof frame, prefabbed on the ground and again carefully rigged to stay in plane, is being flown in to land on the post tops and collar tenons.

ASSEMBLY EQUIPMENT. Rope is essential at any raising. Tag lines are frequently attached to any bent or piece being lifted by the crane, to keep the object from swinging or rotating and to help guide it into place. Rope is also *reeved* through blocks (pulleys in a frame, shown on previous page) to produce tackle for lifting or pulling with mechanical advantage. Most rope used for timber frame raisings is of natural or synthetic fiber (not wire), and a good knowledge of splicing, tying knots, bends and hitches, and assembling tackle is advantageous, especially at hand raisings. See Resources for good books on rope work.

The most ubiquitous type of strap at a raising is the polyester round endless sling. These are attached to the hooks of comealongs to draw assemblies up tight. They are color coded as to their lifting capacity, with purple, green and yellow being the most commonly used and also the lowest rated (the higher rated straps are rarely needed in timber framing). The stronger ones may also be used for lifting assemblies, but this is equally often done with heavy-duty flat nylon web straps up to 3 in. wide. Ratings are given in the catalogs. Various lengths are available, but an assortment of 4-footers and 6-footers ought to handle all your needs. They can be choked together to form longer slings.

Ratings also vary according to the hitches used to secure the load. The basket hitch has twice the capacity of the vertical hitch, but simple loads are free to slide. The choker hitch has the least capacity, but is also the most widely used since it can roll a timber needing a different face up, and it keeps a timber from rolling once the lift is in the air. It resists slipping along a beam and it also can hold irregular or unbalanced loads securely.

Comealongs, hand-operated winches with 6- to 10-ft. cables (sometimes longer) and hooks on each end, are generically known as wire rope ratchet pullers or hoists, and some timber frame companies use dozens at each raising. You should get versions fitted with a pulley on the cable so you can secure the hook back to the body and get a double mechanical advantage (but with only half the length). Comealongs range widely in quality and materials, and it's well, if you can, to examine the ones you plan to buy. An assortment of shackles is also desirable for securing straps to hooks and each other.

Other equipment needed for the raising includes a supply of dimension lumber for strongbacks, blocking, temporary bracing and other purposes, and 16d or 20d duplex (double-headed) nails for fastening the temporary members.

SAFETY EQUIPMENT. Raising doesn't need any additional drama to add to its appeal, but it's arguably the most dangerous part of timber framing. The similarities to steel erection become most evident when the raising crew scrambles around the roof members as the frame nears completion. Rafterless bent and wall systems that allow you to install the floor joists early in the raising sequence will be safer and more convenient, especially for the beginner who doesn't have a lot of raising experience or rigging equipment.

Stationary or rolling scaffolding can be of some help, but often the work is not in one place long enough to make its use practical. For complex jobs with a lot of work up high, it may be a worthwhile investment. Ladders are the tool of choice for getting up and down the frame and providing quick, movable access. Scaffold-grade planking is good for providing a working surface on upper floor joists. Scissors-lifts and extendable boom lifts can be used as long as one remembers not to hang onto a moving timber as it swings by (equally true when one is standing on a ladder). I've been to many raisings where budget or other considerations prevented hiring a crane or scaffolding, but local contractors or the facility itself had this other gear.

The US Occupational Health and Safety Administration requires fall protection if one is working only a short distance off the ground—fall arrest devices such as body harnesses and lanyards clipped to structural members or lifelines, but these could also include safety nets. In practice, our trade is aligned with the steel industry where mobility is required. Climbing around unprotected is acceptable to OSHA if there is a written company policy to that effect, a restricted access zone identified and enforced by an appointed safety officer, and if the crew is made aware of acceptable procedures and policies and participates in an established company safety training program. Fall protection is a developing area in timber framing, and the Guild is committed to increasing awareness of the issues involved. (See the Guild newsletter *Scantlings* 92, August-September 2002, for more information.)

Finally, make sure that a good first-aid kit is on hand at the site and that people know where it's kept. Find out where the nearest hospital is and how to get there. Have a phone on site if possible, and keep the crew well fed, hydrated and protected from the sun.

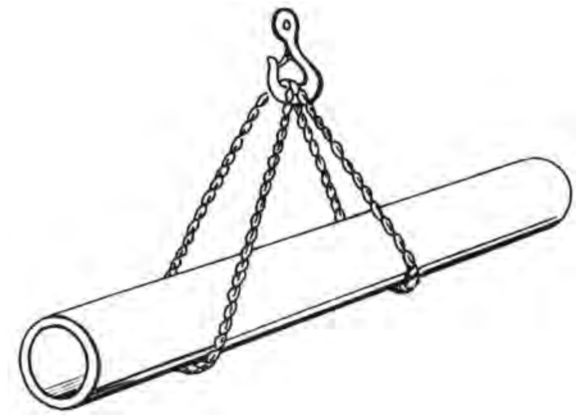
THE last piece of material to go on the frame is the wetting bush, in this country usually a small sprig or branch of an evergreen, or perhaps of the species from which the frame is made. The wetting bush is nailed to the highest point of the roof when the frame is complete. (See upper photo, page 4.) The origins of this tradition are murky—some say the wetting is a libation owed to the workers by the client—but today it signifies the roots of the frame, its stability and endurance. It might also commemorate the contribution of trees to the lives that will flourish within the house. For the timber framer, it's a way to give thanks for a safe and successful raising. —WILL BEEMER

Resources:

Grainger & Co.: 888-361-8649, www.grainger.com
MSC Industrial Supply: 800-645-7270, www.mscdirect.com
McMaster-Carr: 732-329-3200, www.mcmaster.com
These national companies stock material-handling tools and equipment, including slings, ratchet pullers, straps, rope and shackles. Local industrial hardware houses may also offer such equipment where you can see it. For examples of comealongs, go to www.irhoist.com and go to www.spanset-usa.com for examples of slings.

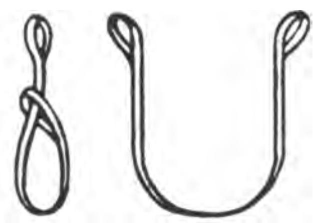
Books:

Timber Frame Houses, Taunton Press, Newtown, Ct., 1992. See "Solo Timber-Raising" and "Raising Heavy Timber."
D. E. Vickie, *Rigging Manual,* Construction Safety Association of Ontario, Toronto, Ontario, 1975. Great book on rope, slings, rigging and reeving.
W. E. Restage, Lindley R. Higgins and Joseph A. MacDonald, *Handbook of Rigging for Construction and Industrial Operations,* McGraw-Hill, New York, 1988. Rigging machinery, accessories, safety, scaffolding and rigging engineering.
Resource Systems International, *Rigging for Commercial Construction,* Reston Publishing, Reston, Va., 1983. Rigging, cranes, derricks and a good glossary of terms.
Ronald G. Garb, *IPT's Crane and Rigging Training Manual,* IPT Training and Publishing, Edmonton, Alberta, Canada, 1991 (www.iptbooks.com). Manual for riggers and crane operators.
Tedd Benson, *The Timber-Frame Home,* Taunton Press, Newtown, Ct., 1988. Details on foundation design, deck preparation, enclosure systems.



Double basket hitch with two endless rope slings.

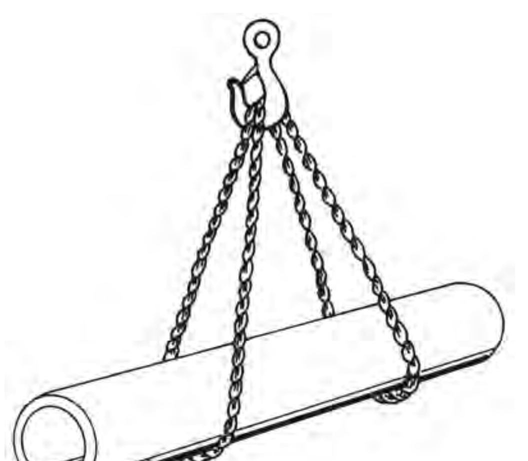
Vertical hitch, rope sling and shackle.



At left, eye-and-eye web straps shown in choker hitch (far left) and basket hitch.

Dozier Equipment Co.

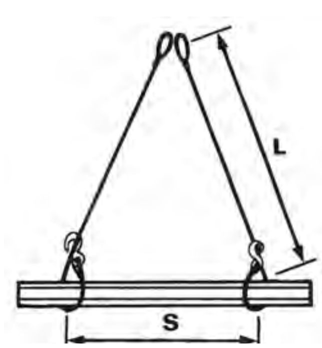
Above, endless web strap. Below, eye-and-eye web strap.



Double basket hitch with one endless rope sling.

Choker hitch with endless rope sling.

Construction Safety Association of Ontario



Most lifts at a raising use two slings, and the safest hitch is the choker (shown above right and at left, with rope slings). To avoid excessive load in the slings, the angle between them should not exceed 90 degrees. Put another way, the sling length L should be greater than the distance S between the hitch points.

Raising Calculations and Prep

CALCULATION OF FRAME WEIGHT. As simple as it sounds, the total weight of a frame assembly is the sum of the weights of the individual pieces in that assembly. So it's possible to estimate the weight of a bent by estimating the weight of each timber in that bent and then adding up all the weights. Further, the weight of a timber is directly related to its volume. A timber's weight can be estimated by calculating its volume and then multiplying that volume by the appropriate unit weight for the wood species at a certain moisture content:

$$\text{Length} \times \text{Width} \times \text{Depth} = \text{Volume}$$
$$\text{Volume} \times \text{Unit Weight} = \text{Weight}$$

The one trick is to be sure the measurements are all in the same units. Lengths should all be in either inches or feet, unit weights in pounds per cubic inch (lb/in^3) or pounds per cubic foot (lb/ft^3). As long as the units are consistent, the answers will be accurate.

To start the process, let's calculate the weight of the girt in the model bent (Fig. 1). The girt is an 8x8 timber connecting two 8x8 posts spaced 12 ft. outside to outside. The length of the girt should be taken as the length from shoulder to shoulder along the centerline of the timber. (The weight of the tenons will be included in their receiving members, the posts.)

Converting to inches for consistency, the length of the girt is then 144in − 8in − 8in, or 128in. The volume of the timber, Length×Width×Depth, is then 128in × 8in × 8in, or 8192in^3. As most unit weights are given in lb/ft^3, it will now be easier if the timber volume is converted into cubic feet (ft^3). One cu. ft. is the volume of a box 1 ft. to a side: (1ft)(1ft)(1ft) or (12in)(12in)(12in). So 1ft^3 = 1728in^3. The volume of the timber in cu. ft. is then 8192in^3 × 1 ft^3 ÷ 1728in^3, or 4.74ft^3.

From Dr. Bruce Hoadley's book, *Identifying Wood* (Taunton Press, 1990), we find that white oak has a unit weight when wet of approximately 55 lb/ft^3. The weight of the bent girt (Volume × Unit Weight) is then (4.74ft^3)(55lb ÷ ft^3), or 260 lb.

These calculations can be set up easily in a spreadsheet. Table 1 shows the calculation of the total weight of the bent. The completed spreadsheet gives the weight of each individual timber and the total weight of the bent. In this case, the bent weighs approximately 1638 lb. Note that accuracy to a single pound is a snare and delusion. This is an estimate.

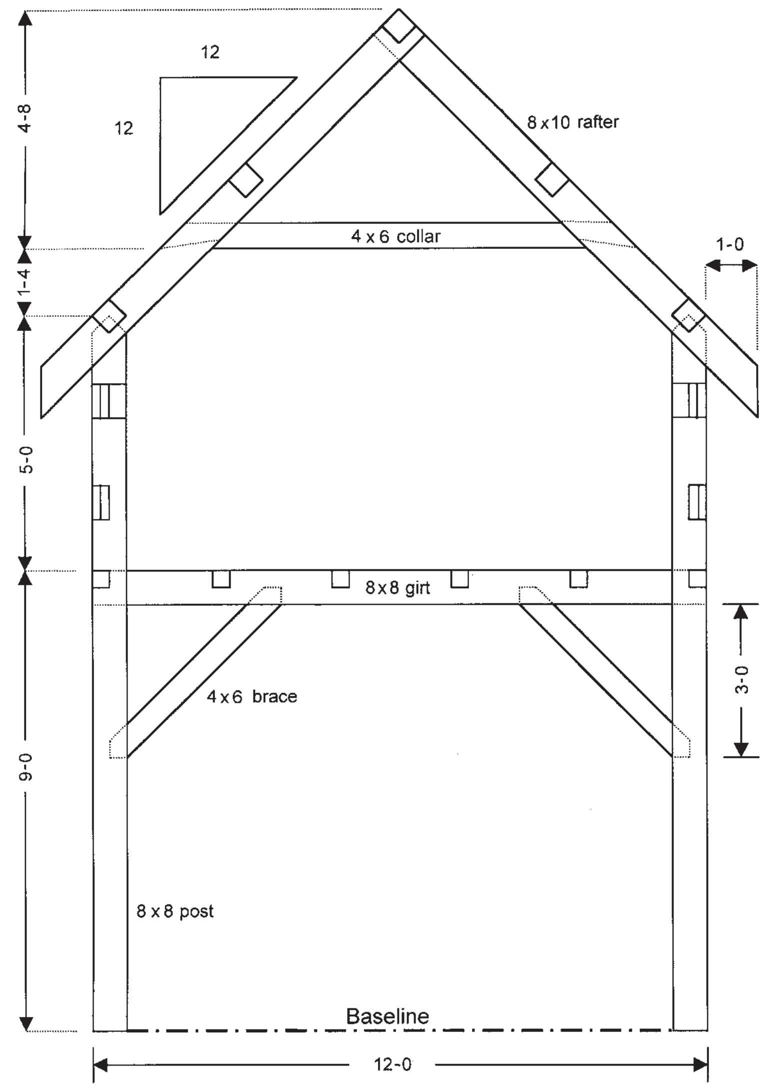


FIG. 1. MODEL BENT FOR WEIGHT, CENTER OF GRAVITY AND LIFTING CALCULATIONS. WOOD SPECIES IS UNSEASONED WHITE OAK. TIMBERS SIZED TO FULL DIMENSION.

Timber	pcs	Lgth (in)	Width (in)	Depth (in)	Vol (cu in)	Vol (cu ft)	Unit Wt of wood (lb/cu ft)	Wt of 1 pc (lb)	Wt of all pcs (lb)
girt	1	128	8	8	8195	4.74	55	261	261
post	2	158	8	8	10112	5.85	55	322	644
rafter	2	119	8	10	9520	5.51	55	303	606
brace	2	45	4	6	1080	0.63	55	34	68
collar	1	78	4	6	1872	1.08	55	59	59
								Total weight of bent in lbs =	1,638

TABLE 1. SPREADSHEET OF MEMBER WEIGHTS.

CALCULATION OF FRAME CENTER OF GRAVITY. The center of gravity (CG) of an object is the imaginary point through which the total weight of the object would act. Our bent girt just described is a timber of constant section. If you were to put a roller under this timber, it would balance at its middle, since the CG within the timber would be just over the center of the roller (Fig. 2). Let's take the idea a little further and stand an imaginary 10-ft. 8x8 next to an imaginary 14-ft. 8x8 (Fig. 4). Common sense would indicate that the vertical center of gravity of the two timbers combined would be somewhere between the centers of gravity of the two individual timbers.

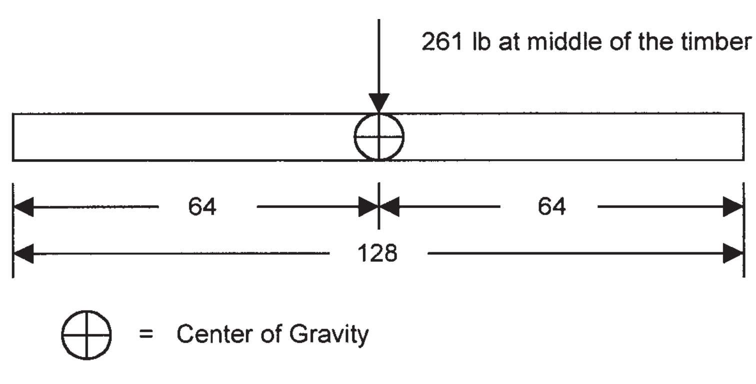


FIG. 2. CENTER OF GRAVITY OF BEAM OF UNIFORM SECTION.

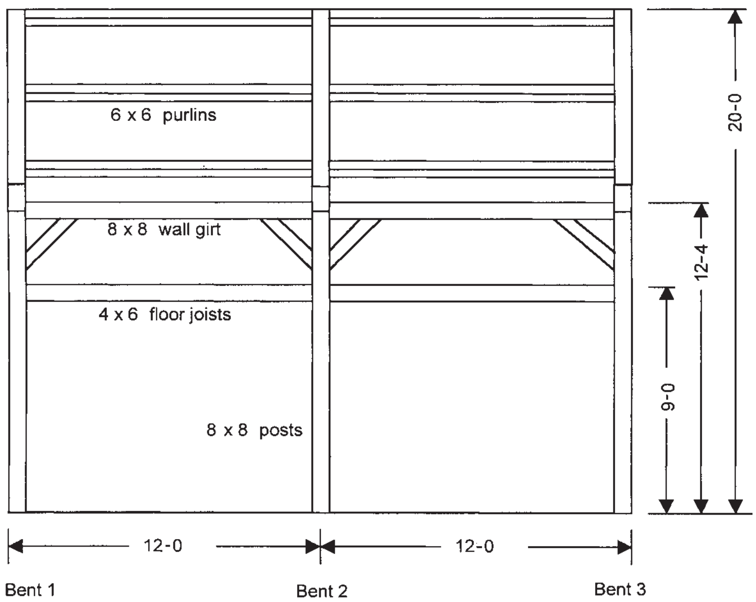


FIG. 3. ELEVATION OF A THREE-BENT MODEL FRAME.

Mathematically, the vertical center of gravity of the two timbers can be found by multiplying the weight of each timber by the height of its CG above the baseline, adding up the answers and then dividing by the combined weight of both timbers.

Our 10-ft. timber weighs 245 lb. and its CG is at half the height or 60 in. above the baseline:

$$W \times H = (245\text{lb})(60\text{in}) = 14{,}700\text{in-lb}$$

Our 14-ft. timber weighs 343 lb. and its CG is at 84 in. above the baseline:

$$W \times H = (343\text{lb})(84\text{in}) = 28{,}812\text{in-lb}$$

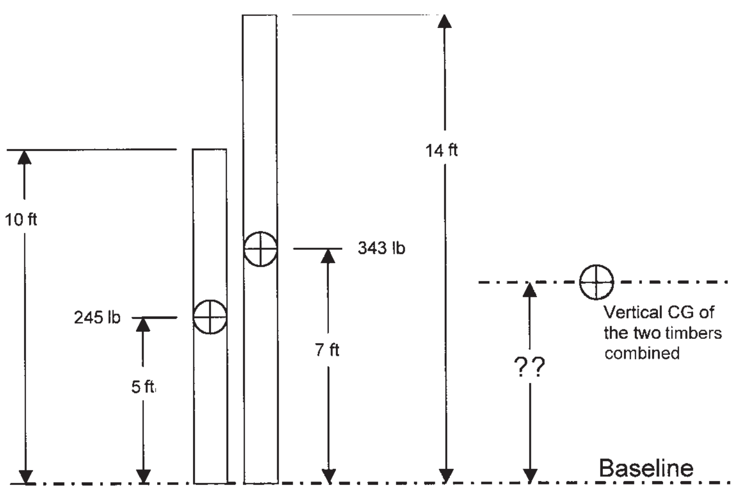


FIG. 4. COMBINED CENTERS OF GRAVITY FOR TWO TIMBERS.

The sum of Weight × Height for the two timbers is then 43,512 in-lb. The sum of Weight for the two timbers is 588 lb.

43,512in-lb ÷ 588lb. = 74in. (6 ft. 2 in.) above baseline

The process is the same for an entire bent. There are just more timbers involved, including horizontal and diagonal members. But since it is of uniform section, each timber in the bent can be treated as if its weight acted through its midpoint. The timber weight is multiplied by the height of the midpoint of that timber above the baseline. Then all the answers of Weight × Height are added up and divided by the total weight of the bent. The individual timber weights in our model bent have already been calculated. Likewise, the total weight of the bent is already known. All that is needed is the height of the center of gravity of each timber above the baseline. A spreadsheet again facilitates the calculation:

Timber	pcs	Weight of one pc (lb)	Weight of all pcs (lb)	Height of center above Baseline (in)	Weight x Height
girt	1	261	261	104	27,144
post	2	322	644	79	50,876
rafter	2	303	606	191	115,746
brace	2	34	68	84	5712
collar	1	59	59	187	11,033
				Total of Weight x Height (in-lb) =	210,511
				Total Weight (lb) =	1638

TABLE 2. SPREADSHEET OF CENTERS OF GRAVITY OF MEMBERS.

Bent CG is then 210,511in-lb ÷ 1638lb = 128.5in

The center of gravity of the bent is about 128½ in. above the baseline. That means that the total weight of the bent, about 1638 lb., is acting at a point 10 ft. 8½in. above the post bases, or about midway between the girt line and the top of the wall.

CALCULATION OF LOADS IN THE LIFTING TACKLE. If a crane line or block and tackle were attached to the bent at its center of gravity, a vertical lifting force equal to the weight of the bent would be required to lift it off the ground. With a crane, a vertical lifting force is easily applied: position the end of the boom directly above the center of gravity, drop the cable, hook to the bent and lift. As long as the bent weight is below the safe working capacity of the crane, the lift is safe and the load in the cable is equal to the weight of the bent.

But if the lift point is not at the CG (and usually it isn't), the calculation of load is a bit more involved. In a hand raising, for example, the tackle is usually attached to a gin pole or another bent in the frame and can be far from the center of gravity of the bent. Indirect pull significantly increases the load in the lifting tackle.

The first problem is to calculate the vertical load required at the collar to lift the bent. Since the collar is above the center of gravity of the bent, the vertical load required should be less than the total bent weight. The problem (Fig. 5) is much like the force needed to lift a wheelbarrow, where the post bases are the wheel, the bent weight at the CG is the load in the wheelbarrow pan and the vertical lifting load is the lift on the handles.

When the bent just starts to lift, the product of the bent weight times the distance from the post bases to the CG is equal to the vertical lifting force times the distance of the attachment point above the post bases. In engineering terms, the sum of the moments around the post bases is zero. Moment is the product of a force

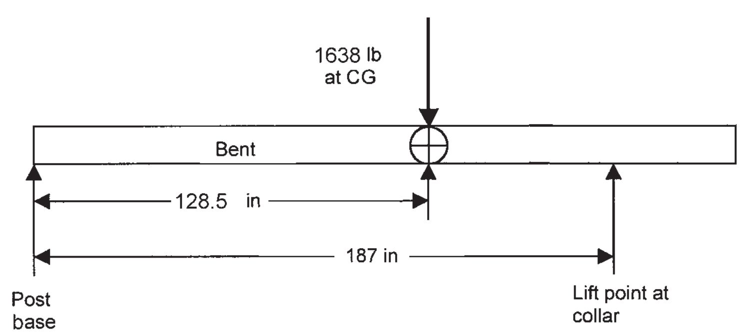


FIG. 5. DISTANCES FROM FULCRUM OF LIFT POINT AND BENT CG.

(bent weight) times its distance (height to CG) from a point (post base). When the bent starts to lift, the moment due to the weight just counteracts the moment due to the lifting force at the collar. The two moments are of equal magnitude. From Fig. 5:

(1638lb)(128.5in) = (vertical lifting force)(187in)
Vertical lifting force = (1638lb)(128.5in) ÷ 187in
Vertical lifting force = 1125lb

Let's now do calculations for a hand raising using a 15-ft. gin pole set vertically 5 ft. back from the post bases and a single set of block and tackle to raise the model bent (Fig. 6). The problem now becomes to calculate the loads that the 1125-lb. vertical load at the lifting point produces in the rest of the lifting system.

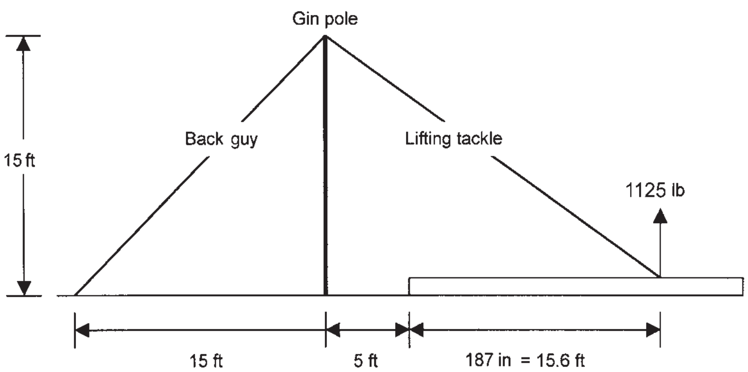


FIG. 6. GIN POLE LIFT DIAGRAM FOR CALCULATING LOADS.

To solve for the load in the tackle, it's possible to use similar triangles (Fig. 7). A triangle representing the vertical gin pole, the horizontal distance to the lift point and the inclined tackle has the same proportions as a triangle of the vertical lift load, the horizontal load along the bent and the inclined load in the tackle

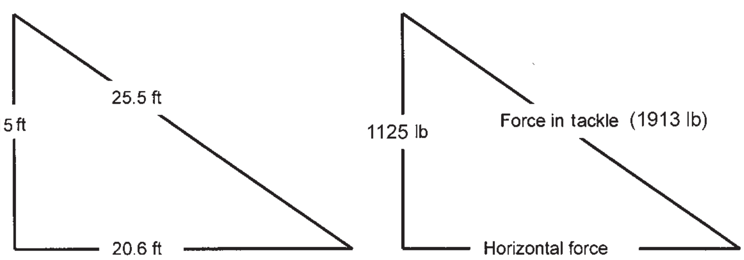


FIG. 7. CALCULATION BY METHOD OF SIMILAR TRIANGLES.

Height of gin pole = 15ft
Horizontal distance = 5ft + 15.6ft = 20.6ft
Length of tackle = $\sqrt{(15ft)^2 + (20.6ft)^2}$ = 25.5ft

By similar triangles:

20.6ft ÷ 15ft = horizontal force ÷ 1125lb
Horizontal force = 1545lb

And:

25.5ft ÷ 15ft = tackle force ÷ 1125lb
Tackle force = 1913lb

The tension in the 45-degree back guy can also be calculated by the same method (Fig. 8 above right). The lift tackle applies a horizontal force of 1973 lb. at the tip of the gin pole. The horizontal force is resisted by the tension in the angled back guy. Thus:

21.2ft ÷ 15ft = guy force ÷ 1545lb
Guy force = 2184lb

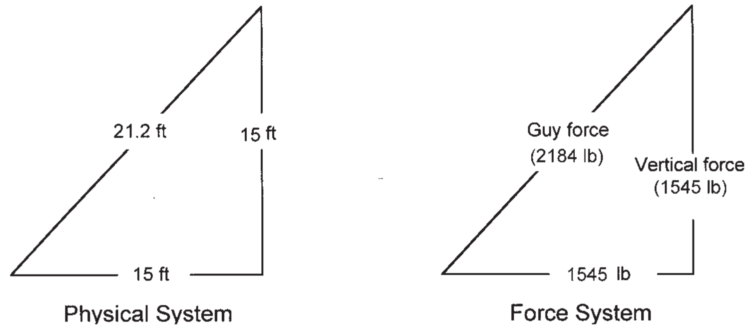


FIG. 8. CALCULATION BY SIMILAR TRIANGLES OF TENSION IN A GUY.

The lift tackle also produces a vertical force on the guy of 1973 lb. So, the overall forces in the lifting system are as follows:

Tension in the lift tackle = 1913lb
Tension in the back guy = 2184lb

And compression in the gin pole is the sum of the vertical forces from the tackle and the back guy (1125lb + 1545lb):

Compression in the gin pole = 2670lb

One more question. Is it possible to safely raise the frame by hand using one set of four-part block and tackle (see illustration at bottom of page 7) as the lifting tackle? The two-sheave blocks sized for 5/8-in. rope available for the lift have a safe working load of 3000 lb. The safe working load is greater than the tackle load of 1913 lb., so the blocks themselves are up to the job.

The nominal load in the rope will be 1913 lb. divided by the four parts (the lines between the blocks), or 478 lb. Braided 5/8-in. nylon rope available for the lift has a breaking strength of 7000 lb. Using a factor of safety of 5:1, the rope has a safe working load of 1400 lb. At 478 lb., the actual load in the rope will be well below the safe working load, so the rope is acceptable for the lift.

Finally, how many people are needed to exert 478 lb. of pull on the raising line? A safe estimate is that one person can comfortably exert 50 lb. of pull on a rope. Using that figure, the number of people required is 9.6 people. Looks like a minimum of 10 people on the pull line. Finding the 0.6 person would be difficult, and the sight would probably prevent the other nine from pulling.

PREPARATION OF THE FRAME FOR RAISING. During the raising, it's highly desirable that the frame fit together well and that the lifting process not destroy it. Once the raising starts, there should be no surprises about the fit of the joinery. Completely prefitting the frame assemblies before the raising eliminates unexpected problems. Assemble the sections on a flat surface and ensure that all the joints fit, the frames are square and the assemblies dimensionally correct. Connecting pieces not accounted for in the major preassemblies for the crane should be individually tested in their joints. Adjusting a thick tenon or a shallow mortise is far easier and safer on the ground than in the air.

During a raising, the joinery will see higher stresses than it ever will in service. Also, the stresses will be in directions that the joinery was not intended to resist. Examine each assembly and determine if additional bracing is needed. For example, the lifting system for the model frame is designed to pull at the level of the collar, which puts extreme stress in the post-to-rafter joint. If the joint is not reinforced, the frame could hinge at that joint and fail. The joint can be reinforced with strongbacks such as 4x6 timbers or built-up sections of dimension lumber (include their added weight in the lift load). The strongbacks run from near the post bottoms across the bent girt and end at the rafter-to-collar joint (Fig. 9).

Heavy-duty ratchet straps work well for attaching the strongbacks to the frame. Wrap the strap several times around the frame member and the strongback, and then tighten it securely. In this example, the strongback should be strapped at its crossing with the bent girt. As the frame tries to hinge at the rafter joint, the ends of the strongback will press against the rafter and the post while the strap causes the strongback to lift the bent at the girt level, keeping the bent in plane. Metal clamps should not be used to attach strongbacks. Clamps can loosen or bend and open up, thereby falling off in the middle of the lift, with undesirable consequences.

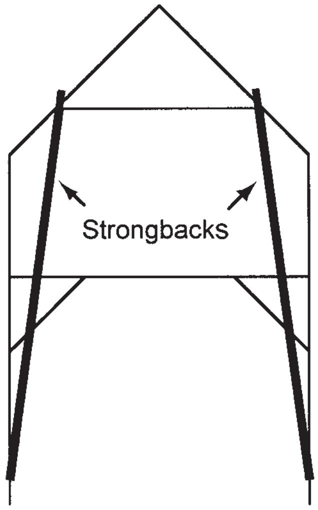


FIG. 9. STRONGBACKS FITTED TO ASSEMBLY TO PREVENT UNWANTED HINGING.

For the rigging to work properly, it must remain in place at its attachment points on the bent. The bent also must be constrained so that it finishes the lift in the proper position. Rope (or rigging) only works in a straight line. If that line is not perpendicular to its attachment point, the tension in the rigging will try to move the attachment point along the timber. Slings will slip along the timber if they are not physically restrained. In our model bent, the sling would try to slip down the rafter as the bent came up, and so it should be choked around the rafter at the middle purlin pocket so that it will be restrained by pulling into the pocket. If such an anchor point is not available, blocks can be nailed to a hidden face of the timber to secure the rigging.

In the calculation of the lifting forces on the bent, we determined a horizontal force of almost 2000 lb. Because of that force, at the start of the lift the bent will try to slide horizontally along the deck. The post feet must be blocked to prevent that movement and to position them so that they drop into their mortises as the bent becomes vertical. For the first bent, these kicker blocks can be braced to stakes in the ground, clamped to the deck or otherwise secured. For interior bents, the kickers can be braced to the posts of the previous bent.

DEVELOPING A RAISING SCRIPT. The easiest way to avoid confusion and errors during a raising is to think through the whole process beforehand. This procedure is important enough that it warrants writing a formal raising script. The people leading the raising should sit down with a set of frame plans, talk through the necessary steps and record them. The idea is to have all the necessary equipment at hand for each step of the raising. That way, no one is frantically searching for something as the crew tries to stabilize the piece of the frame that has just been raised. The general raising sequence for our three-bent frame (Fig. 3), which has drop-in purlins and joists, would be to set the gin pole, raise bent one, add wall girts between bents one and two, raise bent two, add wall girts between bents two and three, then raise bent three; finally, with the bents connected, drop in the purlins and drop in the joists. Following is the model raising script.

1. Raise Bent 1

Set the gin pole
Assemble the bent on the deck with the post feet positioned at their appropriate mortises
Install the kicker blocks for the post feet
Attach the strongbacks to the bent
Attach the rigging between the gin pole and the bent
Attach a safety haul-back line to the top of the bent
Attach 2x4 or 2x6 braces at sides of posts to brace the bent once it is raised. Nail braces for now to outside of bent with one 16d (or 20d) duplex nail so braces can rotate into position as the bent is raised
Set a commander near the post bases for positioning the posts as the bent approaches vertical
Set a level near the post bases
Provide pike poles
Clear the deck of all unnecessary material to avoid tripping
Recheck the rigging
Stop and explain the lift to the crew
Raise the bent
Using the level, plumb one post and nail off the 2x4 brace
Plumb and brace the second post
Add two additional 16d nails at each end of the braces
Remove strongbacks
Remove haul-back rope

2. The wall girts and outer floor joists between bents one and two are fitted in preparation for raising Bent 2 (see Fig. 3)

Place the girts with braces in Bent 1
Using dimension lumber, prop the other ends of the girts at the correct height to mate with Bent 2
Using comealongs, tie the girts safely back to Bent 1
Repeat the procedure for the outer floor joists

3. Raise Bent 2

Reposition gin pole and lifting tackle (or lift off Bent 1 with the installation of appropriate back guys)
Install kicker blocks between Bent 1 and Bent 2 post bases
Position Bent 2 on the deck against the kicker blocks
Attach the strongbacks to the bent
Attach the rigging between the gin pole and the bent
Attach a safety haul-back line to the top of the bent
Position braces for installation as Bent 2 is raised
Hang comealongs from slings near ends of Bent 1 bent girt
Attach matching slings near ends of Bent 2 bent girt
Extend comealong cables so they will easily reach Bent 2
Position a level and pike poles at the ready
Recheck the rigging and explain the lift to the crew
Begin raising Bent 2
As bent approaches vertical, hook up to comealongs
Insert wall girt braces
Bring bent closer to vertical and engage brace and girt tenons
Use comealongs to pull Bent 2 into position
Check for plumb and peg off Bents 1 and 2
Bents 1 and 2 now form a braced, stable assembly

4. Repeat Steps 2 and 3 to Raise Bent 3

5. Install Purlins

Use a rolling stage (safest way) to install purlins
Position stage, feed purlins up to people on the stage and install
Alternatively, set purlins singly using the gin pole

6. Install Floor Joists

Set what floor joists are possible from the stage
Remove stage or decrease its height
Set remaining joists from ladder or lowered stage

7. Last

Fasten the wetting bush
Take picture of entire crew on the frame

—GRIGG MULLEN

Grigg Mullen teaches engineering at the Virginia Military Institute. He has served on the Guild's Board of Directors and been a crew leader on many Guild projects, as well as helping to teach the Guild's Raising and Rigging course. He recently worked on the development of the Guild's Apprenticeship Curriculum.

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A Boring Essay

TO DRAWBORE or not to drawbore? I had been a framing and finish carpenter for over 20 years when I decided to build a timber frame in the Sierra foothills of California where, thanks to a six-year drought, I had a large stand of bug-kill trees. With a Sperber chainsaw mill, I squared the logs into timbers and dimension lumber. I owned a slick and framing chisels from my days back East, and I roughed out the mortises with a right-angle drill. I had two books for technical instruction: Jack Sobon's *Timber Frame Construction*, written with Roger Schroeder (Pownal, Vt., Storey Publications, 1984), and Tedd Benson's *Building the Timber Frame House*, written with James Gruber (New York, Charles Scribner's Sons, 1980). I decided to do my frame traditionally, using continuous top plates; stick framing, the child of timber framing, preserves this principle, and it was familiar to me.

The one thing that seemed intimidating was the business of drawboring. Benson argued that comealongs made drawboring obsolete—it was just a matter of buying more equipment to draw the joints together before pinning. Sobon argued that drawboring would give a tighter fit to the frame. It seemed easier to go the comealong route, but I thought to do so would violate a cardinal rule of construction—that anything done on the ground is more cost effective than if done in the air. I decided to conduct a test—drawbore a brace to a post. When I drove the pin through the post, the brace closed so tightly that it looked grown in place. I was a believer and canceled my order for a truckload of comealongs. A number of years later, I was assembling some 32-ft. queenpost trusses, and I had ⅜-in. gaps between the bottoms of the queen posts and the 8x12 bottom cord. I fastened my one comealong to the center of the straining beam and the center of the bottom cord. It pulled it up 3⁄16 and died. The pinholes were still offset. With 8 in. of relish on the queenpost tenons, I threw caution to the winds. My helper Jason and I simultaneously drove the pins. They sucked the joints up tight and loosened the comealong. Now I was not just a believer, I was a fanatic!

AS FAR as I can determine, the process of drawboring was first described in English by Joseph Moxon in 1678, when he was elected a Fellow of the Royal Society for Improving Natural Knowledge and began publishing how-to pamphlets on smithing, joinery, carpentry, turning and bricklaying; the series was completed in 1680. Drawboring has been cited in dictionaries and described in builders' manuals since Moxon's for over 300 years. Drawboring, then, is a well-established element of timber framing.

The citations that follow are by no means exhaustive, but I believe they show drawboring's continuing importance in a timber frame. Under *Draw*, the latest (2001) edition of *The Oxford English Dictionary* lists "draw-bore, a pin-hole through a tenon, so bored that the pin shall draw the parts together; hence draw-bore." The OED cites J. Smith, *Panorama of Science and Art* (1812-16) I, 120, "Draw-bore pins are used in forcing a tenoned piece into its proper place in the mortise" and P. Nicholson, *Practical Building* (1823), 232, "the draw-bore Pin, or Hook-pin [used] for draw-boring." The latter references might be to the alignment tool used to pull an assembly into place before fitting the wooden pin.

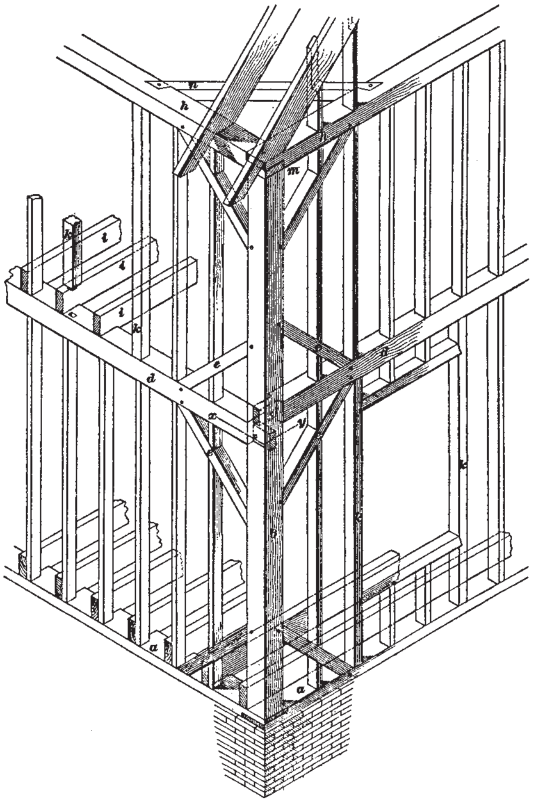
In his *Mechanick Exercises* (Morristown, N.J., The Astragal Press, 1989 reprint of 1703 edition), Moxon describes offsetting the drawbore using piercer (a brace) and pricker (an awl). "Then with the Piercer pierce two holes through the Sides, or Cheeks of the Mortess. . . . Then knock the Tennant stiff into the Mortess, and set it upright, by applying the Angle of the outer Square, . . . and with your Pricker, prick round about the insides of the Pierced holes upon the Tennant. Then take the Tennant out again, and Pierce two holes with the same Bit, about the thickness of a Shilling above the Pricked holes on the Tennant, that is nearer the Shoulder of the Tennant, that the Pins you are to drive in, may draw the Shoulder of the Tennant the closer to the flat side . . . the Mortess is made in. Then with the Paring-chissel make two Pins somewhat Tapering, full big enough, and . . . drive the pins stiff into the Pierced holes" (pp. 87-88).

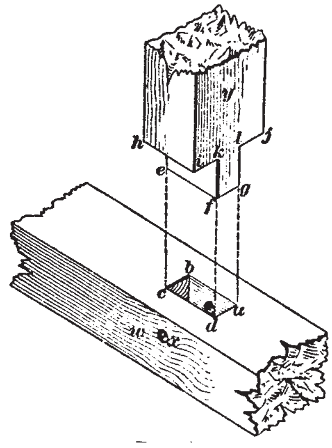
In his introduction to *The British Carpenter* (London, C.&J. Ackers, 1753), Francis Price argues against the practice of drawboring, which we may take to be the normal practice of the day, in the special case of twinned or paired tenons, here called double tenons: "Here also observe, never to make double tenants or tenons for bearing uses, such as binding-joists, common joists or purlins; for, in the first place, it weakens very much what ever you frame into it; and, in the second place, it is a rarity to have a draught in both tenons, that is, to draw your joint close to the pin; for the said pin, by passing through both tenons, (if there is a draught in each) must bend too much."

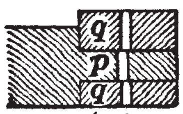
In the glossary of *The Carpenters Assistant* (Glasgow, Blackie & Son, Ltd., 1869), James Newlands defines *draught* thus: "In carpentry and joinery, when a tenon is to be secured in a mortise by a pin passed through both pieces, and the hole in the tenon is made nearer the shoulder than to the cheeks of the mortise, the insertion of the pin draws the shoulder of the tenon close to the cheeks of the mortise, and it is said to have a draught." *Draw-bore* is given as "A hole pierced through a tenon, nearer to the shoulder than the holes through the cheeks [are] from the abutment [with] which the shoulder is to come into contact." Newlands also defines a small form of drift pin, apparently once in use by joiners of doors and furniture: "Draw-bore pin—A joiner's tool, consisting of a solid piece or pin of steel, tapered from the handle, used to enlarge the pinholes which are to secure a mortise and tenon, and to bring the shoulder of the rail close home to the abutment on the edge of the style. When this is effected, the draw-bore pin is removed, and the hole filled up with a wooden peg."

In American manuals, William Bell, in *Carpentry Made Easy* (Philadelphia, H. Challen, 1875), specifies: "The draw bores should be 1 inch in diameter, and 1½ inches from the face of the mortice. The draw bore through the tenon should be 3⁄16 of an inch nearer the shoulder than that through the mortice, in order to draw the work snugly. The proper way to make a draw pin for an inch bore is, first, to make it an inch square; then cut off the corners, making it eight square, then taper it to a point, the taper extending one third the length of the pin. The pin should be about 2 inches longer than the thickness of the timber" (pp. 51-52). In a later passage on barn construction, Bell says, "In the tenons, let the draw bores be 2 inches from each side, and about one fourth of an inch, in large tenons, nearer the shoulder than the draw bores of the mortices. Great care should be observed to have the draw bores perfectly plumb; and workmen should be cautioned against making a *push bore*, as it is called when not plumb" (p. 55).

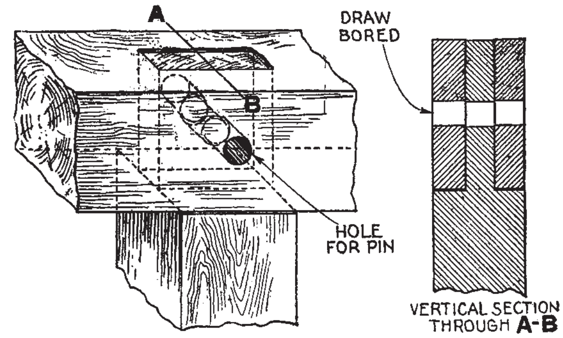
Twenty-five years later, the International Library of Technology (Scranton, Pa., International Textbook Company, 1899), a precursor of the Audel's *Guides*, differs from William Bell in the length of taper specified for the pin and the amount of offset recommended; the author seems to be discussing hardwood framing. "These mortise joints are nearly always secured in place by means of a draw-







(a)



Figs. 1,774 and 1,775.—*Basis of the full frame:* the mortise and tenon joint draw bored.

Illustrations from Audel's **Guide (1923)***, above, and the* **International Library of Technology (1899)***, left, showing drawboring as standard operating procedure even as timber framing declined in use. At far left,* **ILT** *illustration of a composite frame of the day, sometimes called a "braced frame," as distinct from a "full frame" (all heavy members) or a balloon fame (all light members).*

bore pin, which is inserted as follows: After the mortise is cut, and the tenon is accurately fitted to it, a hole is bored in the timber, squarely through both cheeks of the mortise. . . . The position of the hole is accurately marked on the tenon *but [re]located from 1⁄16 inch to 1⁄8 inch nearer the shoulder* than the marks made through the hole of the mortise. When the tenon is now inserted in the mortise. . . . a wooden pin is then driven through these holes, and by forcing them into line it brings the shoulders of the tenon *p* tight up against the cheeks of the mortise *q* [illustration *(a)* above], thus making the joint firm and secure, as well as free from any liability to work itself loose. This wooden pin, usually called a tree-nail or draw-bore pin, should be cut from a piece of straight grained, tough, and durable wood, preferably locust or oak, about 1 inch to 1½ inches square on the ends, and about 2 inches more in length than the mortised timber is in thickness. The corners are planed off, bringing it down to an octagonal shape on the ends, and its sides are then slightly tapered about one-fourth the length, so that the pin will enter the draw bore. If through carelessness, or error in measurement, the hole in the tenon is not slightly nearer the shoulder than the hole in the mortise, the joint will not be tight, and may result in what is called a push bore, which is a term given to this joint when the driving of the pin loosens the pieces instead of tightening them" (pp. 33-34). (Note that a push bore is not cause to discard a tenon; its correction with a glued plug and a rebore creates no additional weakness.)

In Audel's *Carpenters and Builders Guide 3, House and Roof Framing* (New York, Theo. Audel & Co.,1923), a drawboring illustration (above right) opens the chapter on house frames. Timber framing is referred to as full framing, and the draw-bored mortise and tenon joint is called the "basis" of the construction method.

F. W. B. Charles (see TF 66) writes, in his famous work *The Conservation of Timber Buildings* (London, Hutchinson & Co., 1984), "The subject of framing cannot be left without a note on the finer details of framing methods. First, draw-boring is of fundamental importance in obtaining a tight frame. The outer wall of the mortice, after the tenon has been inserted for the first time, is drilled, and the tenon just marked with the bit. It is then withdrawn and the tenon drilled an eighth, perhaps as much as a quarter of an inch nearer to the tenon's shoulder; sometimes the entry into the hole for the peg is eased off, making a slightly spooned-out ellipse. Meanwhile the mortice member is drilled right through, before the tenon is replaced. When the frame is finally erected, the peg is driven in for the first time, tightening the joint as it goes in and biting at the interface of the two components. The pegs are left projecting, to be finally hammered in as the last job. They were never sawn off flush either at the upper or lower side, though the points might be cut back, particularly where they could be dangerous" (p. 73).

In Jack Sobon's *Timber Frame Construction*, drawboring and pin shaping take up almost three pages, including five drawings showing the direction of the offset. The double offset of brace tenons, to draw the brace home against both of its bearing surfaces, is clearly illustrated. On the latter-day technique of clamping and drilling in place, he observes: "This clamping system has some disadvantages. Once the joint is unclamped, it may withdraw slightly or, during the raising, stresses may loosen it, for it does not have the built-in pre-stressing that the drawpinning system has. Another disadvantage is that many clamps and comealongs are needed."

Drawboring is fundamental to timber framing, not only because it gives a tighter fit but also because it's more efficient. It's disheartening that some newer books on timber framing ignore this time-honored technique while perhaps even using the word "traditional" in their titles. In *A Timber Framer's Workshop: Joinery, Construction and Design of Traditional Timber Frames* (Fox Maple Press, 1984), Steve Chappell says of a certain pair of drills, "They're both light enough for one-hand drilling (a must for pegging above the head)" (p. 26). Apart from breaking the cardinal rule earlier cited—any work that can be done on the ground should be—drilling in place for pegs also increases crane time, not to mention the inconvenience and perhaps the danger of crawling through timbers hauling an extension cord and a cumbersome drill.

There is no guesswork involved in drawboring as long as you can read a ruler. And if you cut mortises and tenons accurately, there is no need to prefit the joints in square rule frames.

The problem of accurately drilling the pinhole across the mortised piece can be solved in various ways (see "Timber Framing for Beginners," TF 66). I use a boring machine, and I prefer the Millers Falls model because it's easy to adjust and dead accurate. Shakespeare might have said, had he not been so busy writing plays and instead had been more interested in the building of his theaters, "To be or not to be, that is a question, but to drawbore or not to drawbore, there is no question!" —Paul Oatman

The Close Spacing of Trusses

HEAVY timber trusses were commonly used in the roof systems of North American public buildings from the mid-17th century until about 1920 (Fig. 1). The most common forms were kingpost, queenpost and scissors, all with variations. The majority of these trusses are framed of large scantlings (a 50-ft. 12x14 for a bottom chord is not unusual) and spaced 8 to 16 ft. apart. Lateral stability between the trusses is provided by purlins and braces framed into the sides of the top chords (also called principal rafters in historic sources), which also carry the common rafters between or over the trusses, or by specifically designed girts and braces that join all or some of the posts within the attic space. The actual spacing of the trusses can often be identified from the exterior by the sagging of the roof plane that usually occurs between them, or by differential snow melt patterns (snow tends to stay longer right over the top chords themselves).

We associate close spacing with early English and Continental roof systems using complexly framed rafter couples 3 or 4 ft. apart (Fig. 2), or with modern light-framed trusses held together by glue and gusset plates (Fig. 3). Today's light trusses are true trusses, but they are too flimsy to stand much more than 2 ft. apart. The early rafter couples were similar in intention to trusses, in that their builders wished to produce a rigid frame that would not put outward pressure on the walls. But, in general, their engineering design (the arrangement of tension and compression members) and their joinery are such that, even if the sectional sizes of their members were greatly increased, the assemblies couldn't safely be spaced 12 ft. apart, and would depend upon redundancy or additional principal trusses for sufficient strength in the roof.

However, in recent years another group of trussed roofs has come to my attention in New England. In this group, substantial and traditionally joined timber trusses are spaced 3 to 5 ft. apart along an entire roof. The first examples were shown to me by Arron Sturgis in South Berwick, Maine, in two neighboring churches probably built by the same hand in the 1820s (Fig. 4). The roofs are framed with scissors trusses spanning 42 ft.: the scissor chords, all approximately 4½ x 9, are half-lapped to each other where they cross at a kingpost, and the rafters join the top of the kingpost with tenoned joints; original, hand-wrought iron strapping and bolts reinforce most joints. Unpinned tenons join the scissor chord ends and the undersides of the rafters.

I thought these trusses were archaic in inspiration or an idiosyncratic anomaly. Then, last year, I was called to examine the Strafford United Church (1830) in Strafford, Vermont, where I found kingpost trusses spaced 36 in. on center down the 50-ft. length of the roof. The trusses span 42 ft. and use 6x10 kingposts, 8x9 tie beams and 6x9 principal rafters. The following year, I examined Strafford United's sister, the South Strafford Universalist Society

Wayne Richardson

FIG. 3. SETTING LIGHT TRUSSES, NEWBURY, VT., 2002.

(1833), three miles down the road, where nearly identical trusses are roughly 39 in. on center down the 55-ft. length of the roof (Fig. 5). I was beginning to think I had been missing something.

I can physically visit only a certain number of truss roofs, and of course I can only visit surviving ones, so when investigating an aspect of framing I will often turn to documentary sources for help. I looked at a variety of 18th- and 19th-century builder's guides and found numerous truss designs and a little commentary on spacing, all of which coincided with my former expectations. William Bell's *Carpentry Made Easy* (1891) delineates many truss types and recommends (p. 82) they be spaced "10 to 14 ft. apart." Asher Benjamin, discussing church trusses in *The Practical House Carpenter* (1836), recommended (p. 80) that "the principal rafters should not be more than nine feet from center to center."

I struck gold in my collection of old lumber lists (credit the University of Vermont Special Collections). When John Johnson framed the courthouse in Burlington, Vt., in 1802, he laid two 64-ft. 12x11 long sills and five 40 ft. 12x11 cross sills, giving us the footprint of the building. For the roof system, he acquired 16 10-ft. 12x7 "King Posts in White Pine" and one 10-ft. 12x12 kingpost "in oak or yellow pine," along with proportionally sized tie beams, rafters and braces in the right numbers to make 17 trusses. The larger members probably formed a truss to help support the tower that is also specified in the list. Seventeen trusses produce 16 spaces and, if the gables are not trussed, there may be 18 spaces along 64 ft. of roof. Either way the trusses are on 3- or 4-ft. centers (Fig. 6).

In John Johnson's "Bill of Timber for the Meetinghouse," dated 1811 at Burlington, he specifies two 70-ft. sills and six 55-ft. sills,

Marcus Brandt

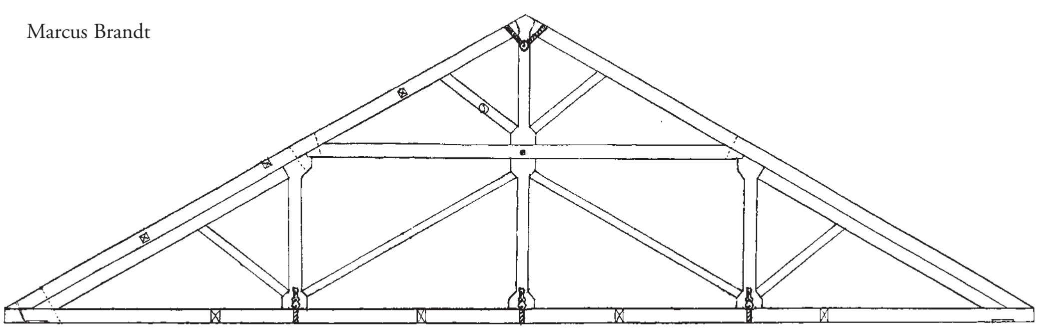


FIG. 1. PRINCIPAL TRUSS, CENTRAL MORAVIAN CHURCH, BETHLEHEM, PA., 1803, SPAN 60 FT.

John Winterbottom

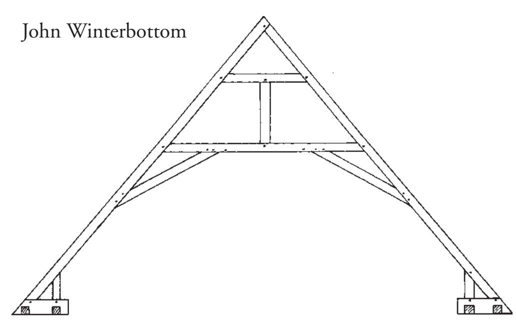


FIG. 2. INTERMEDIATE TRUSS, WINCHESTER CATHEDRAL, CA. 1310, SPAN 30 FT.

Ken Rower

Jan Lewandoski

FIGS. 4 AND 5. FIRST PARISH FEDERATED CHURCH, S. BERWICK, ME., 1825 (LEFT), AND S. STRAFFORD, VT., UNIVERSALIST SOCIETY, 1833.

giving us the footprint. Seventeen 57-ft. tie beams span the roof, including the "End & Tower Beams." Thirteen 16-ft. 16x7 kingposts are specified, with 33-ft. rafters and four pairs of 25-ft. rafters that probably functioned as queenpost main braces in the area of the 16-ft.-square tower, four of them using the four tower posts as queenposts, and the other four probably bearing on tower girts to produce the roof plane. The tower itself rose off sleepers on the tie beams, a pair of 30-ft. 12x12s called "tower sills" by Johnson. This shift at the tower from kingpost trusses to queenposts, with the tower posts as queens, is common in the late 18th and 19th centuries, but not universal. Both the Strafford churches have queens at the tower, but they imply no relationship to Johnson.

An additional survey of historic trusses is found in J. Frederick Kelly's *Early Connecticut Meetinghouses and Churches* (1948). The author and his assistants examined the structure and parish records of 87 pre-1830 churches and prepared a measured drawing of each accessible truss and some commentary on the roof systems. I read all of the entries and found spacing discussed only once: the 1820 contract for construction of the First Congregational Church of Derby specifies, "The roof to be framed of Ten principal Rafters" (p.97). This church is 50 ft. long with a tower, belfry and spire semi-engaged at the front. The trusses are scissors form, of hewn oak, and these probably don't support the tower, so the length is likely divided into 10 or more bays, 5 ft. wide or less. The truss sections are various depths of 7-in. timber, scanty for wide spacing.

Counter-evidence of close spacing is shown throughout Kelly's book. Trusses in most meetinghouses are drawn with connecting purlin sections in the area of 8x9, suggesting substantial spans between the trusses.

WHAT are the advantages and disadvantages of close spacing? When you first enter a church attic where 17 heavy timber trusses are ranked 3 ft. apart, you are impressed and mystified. It's a powerful roof system where a problem in any one truss will have little effect on the whole. But why expend so much timber and skilled labor in construction, and such effort to assemble so much framing in so little space? Part of the answer is that large timber was available and cheap in New England before 1850, and perhaps skilled artisans as well. On the other hand, since these trusses make up a small minority of roof systems, most framers probably agreed that it was easier to put up four or five trusses and connect them somehow.

The advantages of close spacing are numerous. The trusses duplicate each other (with the exception of those at the tower), and they can be built reasonably quickly. The immense quantity of wood involved is balanced by the absence of purlins, purlin braces, common rafters or any lateral bracing system running longitudinally in the attic, a significant savings in timber. The same 1-in. boarding found on any roof can board this one. While each truss requires long timber, it is of somewhat smaller cross-section (for which trees would likely be in greater supply) than the timber used in widely spaced trusses.

An additional advantage in this overall-stronger roof system is its ability to handle the endemic problem of depression of the first interior truss by steeple loading. In South Strafford, the kingpost trusses march from rear to front on 39-in. spacing until reaching the rear of the steeple, where the two tower posts are used as queenposts to form a truss. Two more kingpost trusses sit within the tower, respectively 42 in. and 86 in. forward of the rear queen, until the front posts of the tower seat themselves on the fully framed wall of the portico. There is evidence that the builders at South Strafford were aware of problems at rear steeple trusses. There are original square-section 1-in. wrought iron dogs assisting the joinery at the feet of the principal rafters where they mortise into the bottom chord, and at the shoulder where the principal rafters join the queenposts. In spite of all these precautions, there is a transverse crack in the plaster over the choir loft where that rear truss sags a little more than its neighbors.

In the 1811 Burlington meetinghouse mentioned earlier, the tower, incorporated into queenpost trusses, also sits on 30-ft. 12x12 "tower sills" lodged perpendicular to the trusses. This is a common arrangement but has small virtue when the trusses are far apart; the sill, or sleeper, over the 10- or 14-ft. span between trusses, just bends and loads the closest one. With close truss spacing and sleepers, however, the tower sills are supported by eight or 10 trusses with no room for bending in between. —JAN LEWANDOSKI

Port Orford cedar, Curry County, Oregon

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Joel McCarty (above, below center)

Rudy Christian (above, below, below left)

At top, looking toward the Neckar in the old city of Rottweil (Baden-Württemberg), where deputations of Guild members visited and studied at a German technical school in January and February. Above, integrated frame, infill and doorway of the building at top right. At right, arms of the carpenters' guild depicted in a church window.

At top, newly built timber-framed spruce structure in regional farmhouse style, to be used as residential and commercial space. Notice platform framing and frequent story posts infilled with planking, tin shingles on the roof, foam insulation (not yet stuccoed) on the exposed foundation wall. Above, interior of hip.