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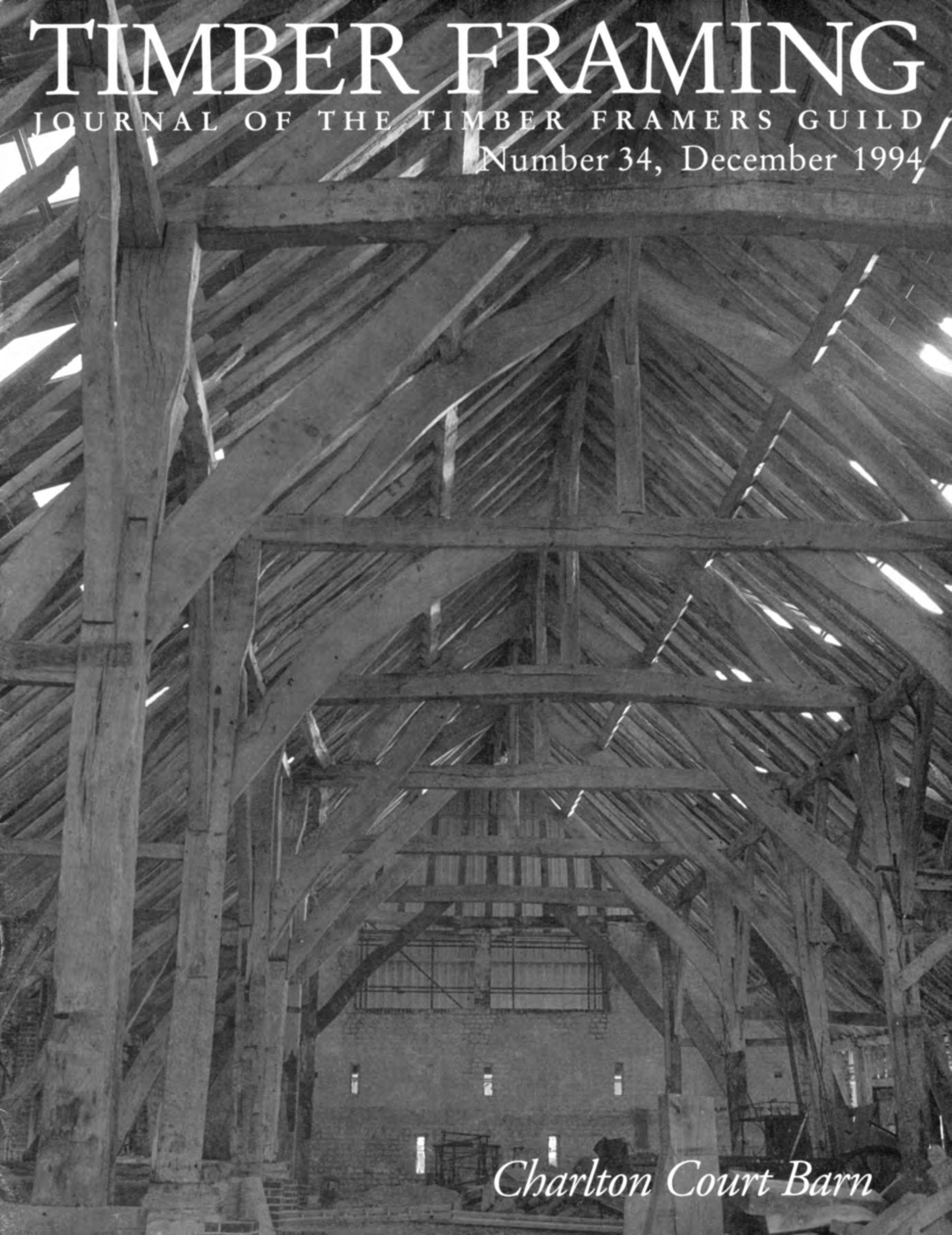

Charlton Court Barn

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TOPICS

On Longevity

AMORY LOVINS, co-founder of the Rocky Mountain Institute, an energy conservation think-tank, proved that utility companies could actually earn a profit from managing and conserving energy rather than promoting energy use and thereby having to build the required production capacity. His concept was dubbed "negawatts" and is now widely accepted. Conservation, not consumption, has become the common-sense operating philosophy of our utility companies.

Similar thinking is required in the forest products industries, including housing, for until demand on forest resources is lessened, no management plan can hope to stem the loss and over-harvesting of forest ecosystems. Today's residential building technologies, which employ large amounts of wood products in new structures with short life spans, are an important part of the problem. Replacing wood with other materials such as steel or structural plastic, which consume large amounts of energy in the raw material and manufacturing stages, is not the answer. Trees are indeed a valuable and, if properly and frugally managed, a renewable resource. Our goal should be their better utilization.

There are various ways to accomplish conservation of timber resources in the construction of housing. Some would incorporate more efficient framing or structural techniques. Others would substitute for wood members other products and approaches. We will not review these substitution methods here, for they lie out of the scope of this discussion. Rather, we will discuss the amount of timber used relative to the life span of a home. If we were to add 50% to the life of new houses, replacement would not be required for that much longer, and we would need that many fewer trees over the longer time period; homes that lasted twice as long would require half the trees, and so on.

TIMBER FRAMING, Journal of the Timber Framers Guild of North America, reports on the work of the Guild and its members, and appears quarterly, in March, June, September and December. To assure publication, Calendar notices must be received six weeks before the date of issue. TIMBER FRAMING is written by its readers and welcomes interesting articles by experienced and novice writers alike. Contributions are paid for upon publication at the rate of $125 per published page.

The housing industry in America is a massive economic force, with revenues greater than many, if not most, countries in the world. In its busiest years in the 1980s, the National Association of Homebuilders reported, over 2,000,000 new homes were built. Its impact is felt in every aspect of life, and the results of its work last well beyond the years of its workers. As such a major economic force, with the resulting demands on natural resources and land use, the housing industry must continually be on the search for the most effective use of those resources. One of the ways it can do this is by re-examining the usable life-span of its buildings.

Light framing refers to the use of 2x4, 2x6 and other dimension lumber and plywood to work together as studs, trusses, and sheathing in the platform framing of the structure. The entire length of walls and the total area of roof, using plywood or other panel sheathing as the outside membrane, work as units to spread environmental and functional loads more or less evenly and limit racking. This method allows the use of many smaller structural members fastened with great quantities of nails and plates to achieve what was once thought to require large and heavy timber members.

Platform framing techniques allowed more homes to be built in shorter amounts of time with less skilled help. An early version of the system was seen in the re-building of Chicago after the great fire in the 1880s, and called "balloon" framing because it seemed too light and airy.

Heavy timber framing concentrates the loads on a structure to a few large, well-joined and secured members that do most of the work: it is a point-loaded, rather than a platform-loaded, building technique. An economic advantage of light framing over timber framing as seen above is its capacities in mass production. An economic advantage of timber framing is in its longer life-spans.

There is a great deal of literature to support the suggestion that timber-framed buildings last a long time. Many examples exist, particularly in the pre-20th-century houses and barns in the eastern states. But to really appreciate the long view of timber-framed buildings, one must go back further than our own country's settlement by European immigrants, to Europe itself, where houses built after 1776 are often the new kids on the block.

Extremely old structures should be considered only to emphasize timber framing's potential for longevity. If, however, the assertion rested just on the basis of a few buildings still in use from a particular era, then it could be credited to exception, and therefore have limited value. Of greater value is the review of timber-framed structures built between 1700 and 1850 on this continent, and easily seen today in the thousands of old barns that dot the country side. One can clearly see all the structural members of these buildings by simply walking inside and looking around. The huge timbers connected with traditional mortise-and-tenon joinery and held in place with wood pegs are not only interesting but extremely functional.

Among other factors, of which proper maintenance is paramount, the use of heavy timber construction is largely responsible for these long life spans; had these structures been light framed they would not still be of value. Heavy timber framing should be re-examined as a viable building technique in light of today's demands on our forests and our need to limit that demand.

No one can point to a specific study or experiment to prove that light framing can not last as long as timber framing. Small dimension lumber has not been used long enough for a full review of its potential. Both for its speed and economy, light framing technique has some clear advantages over its more labor intensive counterparts. If two buildings, identical except that one be light framed and the other timber framed, were built side by side, we would be able to compare their structural wear over a great many years. It could be assumed that if moisture and ultra-violet light, the two greatest weather-related maintenance issues, were kept carefully in abeyance, and that if natural disasters and Acts of God were absent from these plots, both structures would last exceptionally long, and that the final difference in years might be small. Controlled, fully-maintained environments for housing are rarely the case, however. These two structural systems should be reviewed with an average wear and tear schedule, the possibility of natural calamity and the likelihood of premature demolition due to outside causes or obsolescence.

Given identical use, wear and tear and environmental conditions, I suggest that houses built with a heavy timber structural method will outlast a light-framed house by a factor of two or more. Specifically, if the usable life of a stud-framed home is 100 years, the usable life of a timber-framed house is 200 years, and so on. (Note that the 100-year figure is used by the insurance industry for depreciating the framing component of light-framed houses.) This conclusion is reached with a variety of inputs. Discussions with firemen, insurance adjustors, historical architects and contemporary timber engineers have been pieced together to paint a picture that can support an intuitive understanding.

A heavy-timber-framed home is more likely to survive a natural disaster than a light-framed home. More than one fireman has told this author that in case of fire he would rather be on the roof of a heavy-timbered structure than any other. This seems to be due to both the ability of a timber to char over on the outside and insulate itself and the difficulty for a fire to spread via a large timber compared with the "kindling" qualities of smaller wood members. It is good practice for the timber posts of not only houses but also industrial buildings to have their corners chamfered to deprive a future fire of using the more exposed fibers on the corner as tinder. If steel is employed as a framing material, its propensity to anneal, or fold over, at the high temperatures often seen in structure fires is a frightening disadvantage.

NORMAL wear and tear, and the general ravages of aging, can also be addressed. In a perfect world, both light-framed and timber-framed buildings rest on strong foundations and have fully-maintained roofs, as well as complete control of interior and exterior moisture relationships. In that same world, all homes would be built by precise, committed craftspeople using the highest quality materials available and installing them not only to the building code specification, but beyond. Because that is not the case, timber framing holds some practical advantages. These include an exposed structural system for closer monitoring, and, in traditional timber framing, a minimal use of ferrous fasteners. (In small diameters particularly, ferrous fasteners like nails can become corroded and even loose under certain conditions of high humidity or electrolytic reactions between metal and wood.)

With the structural system exposed and the work requiring a high degree of craftsmanship, it might be hoped that more consistent attention to detail would result. One of the lessons of Hurricane Andrew and Homestead, Florida, goes beyond questions of whether the construction system was sufficient. It was obvious from the damage that even minimum standards of workmanship were ignored in too many cases. Pride of craft and pride of ownership go hand in hand to ensure that a product is up to its own standard.

The building of high quality, heavy-timber-framed houses will ultimately lower the demand on forest resources by requiring fewer replacements of required housing stock. The benefit to the forest products industries will be felt as longer-rotation harvesting cycles create a better grade of log, thereby yielding higher value timber and grade boards.

It has been professionally argued that 180-year rotations of western forest harvests could yield greater profit than 60- or 90-year rotations. While this work has not been extrapolated to eastern forests, it flies in the face of ruling West Coast business practices, and may well apply elsewhere.

Each house requires natural resources not only to be built, but also to be maintained and operated. Few people think that there are unlimited resources to be used without foresight. The longer life spans result in less replacement material over the life of the structure. Higher initial costs per square foot often result in a somewhat smaller houses, necessarily using fewer materials for completion. The generally high insulation and low infiltration rates found in these houses translate to lower costs in heating and cooling.

But beyond the benefit of reducing forest resource demands, there is a compelling rationale to re-examine our attitudes towards house-building. The housing stock of the country represents enormous collective investment. We all hold a stake in these buildings because their construction affects us so dramatically. Thus construction of each house represents jobs and the socio-economic sustenance that jobs create. The increased labor intensiveness and greater skill requirements typical of timber frame construction should be celebrated. In a time when class after class of lawyers and stock brokers graduate into swollen ranks, the crafting of high-quality buildings offers an exciting manufacturing alternative for our young people. Finally, it should be remembered that each house adds to or detracts from the quality of life for its inhabitants and the neighborhood in which it stands.

—Jonathan Orpin

CALENDAR

Conferences

Timber Framers Guild
Traditional Timber Framers
Research and Advisory Group
February 24-26, 1995
Plimouth Plantation
Plymouth, Massachusetts
Timber Framers Guild
Box 1075, Bellingham, WA 98227
206-733-4001

ERRATUM

In the article "Ethical Design and Construction," which appeared on page 11 of the September issue, Sinclair Lewis was incorrectly identified as the author of *The Jungle.* The correct author is Upton Sinclair.

Charlton Court Barn, A Medieval Frame and its Conservation

Charlton Court barn, 45x120 ft., before restoration.

SOME 590 years ago, around 1405, English oaks were felled, hewn, cut and raised to form the eight-bay aisled barn at Charlton Court, Steyning, West Sussex. After housing so many harvests, this unusual frame with early king-post roof framing still clearly displays the innovative high quality of medieval English carpentry. We found the main structure remarkably intact although one end wall had been rebuilt in stone and the aisles much repaired. Subsidence had occurred under the main arcade posts inducing very large deflections and racking, fracturing some of the main timbers under the load of the heavy stone roof. Frame repairs were completed last winter by Carpenter Oak and Woodland Co. and subcontractor Woodwrights, to survey and repair drawings by the architects, The Conservation Practice.

Charlton Court is near the town of Steyning, a few miles inland from the south east coast of England. It lies in farmland beneath the scarp slope of the South Downs chalk hills and is overlooked by the Iron Age hill fort of Chanctonbury Ring. For over 200 years from the Norman conquest and on into the 14th century the Manor of Steyning belonged to the French Fecamp Abbey. War with France and the expulsion of French monasteries brought the manor into the hands of the crown in 1369. Then in 1399 Henry IV came to power having deposed his cousin Richard II who was soon murdered, such was the nature of politics at the time. Henry had to fight hard to keep the throne and needed money and support. As a result the lands around Steyning were given to one John Cornwall (later to fight at the Battle of Agincourt), who had married the King's sister, Elizabeth of Lancaster. It seems likely that the prestigious barn at Charlton Court was ordered built by Cornwall although a thorough search of the records has yet to be made.

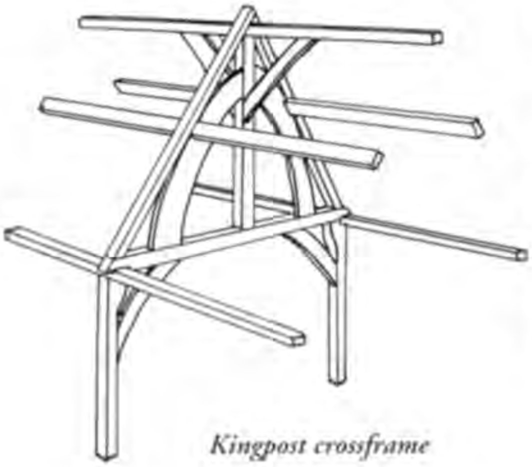
Local materials were used for the framing, walls and roofing. Historic documents and innumerable surviving frames show that oak was used for the huge majority of English medieval timber buildings. It was also the material of choice for staves, roofing battens, tile pegs and later weatherboarding. Greensand blocks and flints dug from the ground nearby, and lime mortar manufactured from the local chalk, were used to construct the plinth walls and the subsequent replacement of the south end wall. The walls were originally infilled with wattle and daub panels. (To make these, oak staves would have been inserted into precut holes in the frame and hazel wattle or oak lathe woven between them. This acted as a base for daub plaster, a mixture of soil, cow manure and fiber such as straw or hair.) At a later date the walls were weatherboarded. Externally the most impressive vernacular material is the Horsham Stone slab roof which weighs over 100 tons. This fissile hard sandstone was quarried near the town of Horsham 15 miles to the North.

After extraction the stone was rough cut and stood on edge for some years to be broken into slabs by frost action. The resulting slabs made an expensive but extremely durable roof covering. The largest slabs, easily 3 ft. across and weighing over 100 pounds each, were used near the eaves. Slab size diminished up to the ridge. Moss was used as "torching" between the courses of uneven slabs to fill gaps and keep out wind-blown rain. Slate and mortar "shading" was used for the same purpose. Typical of Horsham slab roofs, the roof pitch is under 45° compared with up to 50° for thatch roofs.

AISLED barns are common in lowland southern England, representing a continuing tradition dating from at least 1180 (The Barley Barn at Temple Cressing) through to the early 19th century. Often impressive in scale, the tall, open central nave, with a line of arcade posts marching down each side, is flanked by aisles that both increase the storage and serve to buttress these tall buildings. Aisle cross sills on plinth walls divide the aisle bays. Commonly, passing braces rising from these cross sills are framed into the upper outside of the arcade post and halved or pegged (or both) as they cross the aisle tie. Wagon porches over raised doorways on opposite sides of the building project to allow passage in and through for loaded wagons.

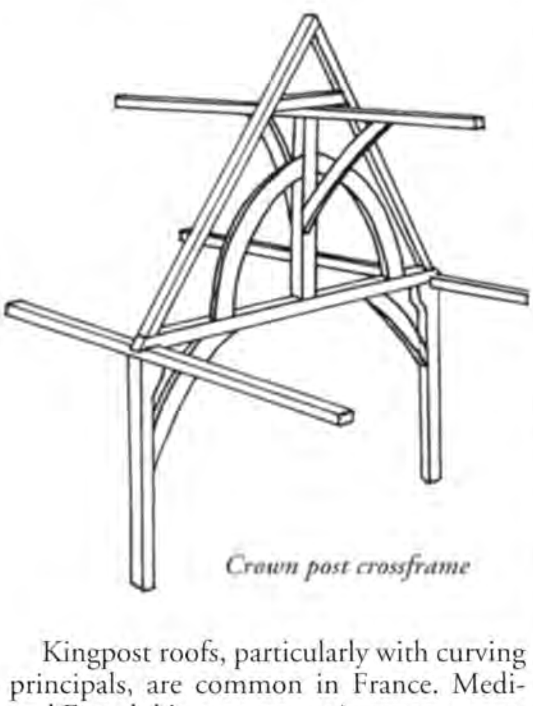
Charlton Court barn, 120 ft. long and 45 ft. wide, follows the pattern, arranged on a north-south axis. The barn can be divided into three sections by the positions of the arcade plate and purlin scarfs. Bays vary in length from 12 to 17 ft. with an average of 14 ft. It is likely that the central three bays were originally conceived as a complete building, the evidence being stave holes found on the undersides of the arcade plates (except in the wagon porches), and top and underside of the tie-beams around this section's "perimeter." Redundant mortises in these original three bays suggest that this frame had long braces rising from low down on the post up to the arcade plates. In each bay the tenons of these braces met in a single long central mortise and pushed against one another. Other empty mortises indicate that each wall had three rails running horizontally around the barn, presumably to support the wall staves. However, there are no stave holes or rafter notches in the tie-beam upper surfaces to indicate a completed gabled or hipped end to the central three bays. The three northern and two southern bays appear from the scarfs to have been added a short time later and are framed in the same manner. Moreover, dendro-chronological dating by comparing tree-ring width sequences with sequences of known age has shown that major timbers throughout the barn were hewn and sawn from oaks felled in the winter of 1404-5. It therefore seems likely that there was a design change during framing and as a result a very much bigger barn was built than had been originally intended.

The roof framing arrangement at Charlton Court is unique in southern England. In each crossframe a sturdy kingpost rises to a ridge purlin and is braced to it. Large curving principal braces rising from the tie-beams into the upper kingpost are notched to carry the side purlins that sup-



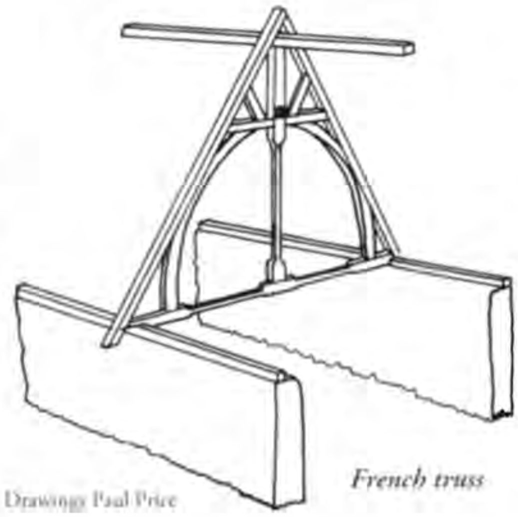
Kingpost crossframe

port the mid-span point of the common rafters. Far more common in medieval southern England was the crown post roof, similar in its bracing and in carrying a longitudinal purlin, the idea being to resist longitudinal racking. But in a crown post roof, a collar purlin runs under collars between each rafter pair. It was once thought that the barn may originally have been framed with a crown post roof and later converted to a king post roof and re-raftered. But no sign of peg holes or cut-off pegs to indicate that it had once been a collar purlin have been found in the ridge purlin, nor has any sign been found of a collar cut in any of the original rafters. Therefore we now believe that the roof, unusual though it may be for its time and place, stands as it was originally framed.



Crown post crossframe

Kingpost roofs, particularly with curving principals, are common in France. Medieval French kingposts or *poinçons* are generally of very small scantling (section) as are the tie-beams, both being clearly and correctly thought of as tension members that act as a truss. In England the tie-beams and crown posts, and the kingpost here, were clearly thought of as supporting the roof structure. The use of side purlins at this date is rare in this area. The way in which they are supported by the curving principals is somewhat similar to those in cruck buildings of the West of England and medieval king posts in the North. However, the roof frame here appears to be a singular development of the crown post roof (itself probably French-derived), retaining the method of bracing but removing the need for collars on each rafter pair, thus saving much time in framing.



Drawings Paul Price

French truss

Rafter holes (peg-sized holes about 6 in. up on one side of the common rafters from the plate notch) are seen on the original rafters. These holes are commonly seen in crown post roofs and probably fitted over pins in an adjustable jig to ensure that the rafter framing reflected variations in the collar purlin (in this case ridge purlin) height and plate spacing. The tie-beams, some cambered or yoke shaped, spanning just under 24 ft., are cogged over the arcade plate. Otherwise the interlocking tying joint is typical of English frames, with a teazle tenon from the post jowl into the tie-beam and a plate tenon from the post into the arcade plate. From the evidence of a wide rafter notch in the end of the possibly original tie-beam atop the flint southern wall, it seems possible that the original roof was hipped, in common with most other medieval buildings. In these buildings the upper surface of the hip rafter was placed in the plane of the hip roof or the main roof with one arris forming the hip line. This is the so called pre-Georgian hip the sides of which are not plumb as with later hips. This kind of hip was probably arrived at because the hip had to be framed over the tie-beam which stood higher than the plates, and a simpler, standard rafter notch could be made if the hip passed "flat" over the outside arris of the tie-beam. Also there was no need to back or drop the hip. Framing the jacks from the hip side was just a matter of cutting the roof plane angle to the hip and nailing. From the roof side a compound skewed birdsmouth notch must be cut if the jack is to fit accurately over the hip's lower arris. This involves scribing the jacks in place or some rather entertaining geometry to arrive at a layout.

One of the joys of conservation work comes from examining the timbers for evidence of the original construction such as tool marks, layout marks and numbering. We used a strong side light to heighten surface contrast, revealing the wide, shallow scoops made by the side axe in conversion from tree to timber. In normal light the major timbers at Charlton Court have a near-planed finish, such is the quality of the hewing, and very few scoring axe or stop marks can be seen. One mark of particular interest is the X between parallel lines apparently roughly scratched with a point without lifting it from the timber. At first we thought this was a levelling mark used in layout as in French scribe work (one per timber) but here there are up to four such marks on a single hewn surface. The king posts are hewn to a very consistent 7½ x 9½ in the original three bays and display many of these marks especially in the vicinity of the ridge brace and principal mortises. On the undersides of the two principal rafters in Truss 4 (clearly from the same tree) we discovered a series of these marks which match, the X marks having been sawn through indicating that they were made during the conversion after or during finish hewing and before sawing, rather than during framing. Longer timbers such as the purlins were see-sawn (over a trestle) as shown by the opposed slanting sawmarks either side of a triangular break-off where the saw kerfs met.

A typical crossframe. Note early repair strap.

The exact nature of the layout method used has not been determined but scored lines for brace positions, centre marks, peg placement and joint boundaries can still be seen. Only the principal rafter numbering in the original section appears to make sense although most timbers are numbered in some way. We have discovered several divided circles marked out with dividers on a brace and a tiebeam, and also an X-shaped cross (each diagonal composed of three parallel scored lines) at the top of a king post facing the central bay of the original three bays. A maker's mark perhaps or a mark of faith? The tenons are generally 1½ in. thick, 4 in. to 5 in. long, and fit loosely into approximately 1¾-in. mortises drawpegged with ⅞-in. round drawknifed pegs. Mortise ends were drilled with a round-end bit and appear to have been chopped out with a twybil or mortise axe. This is indicated by the ½-in. wide curving tool marks on mortise bottoms and on the curved sloping end of the brace mortises. These are indicative of the swinging cut of the twybil as are the stop marks on the mortise sides. Tenon shoulders were cut using a very wide-kerf saw and cheeks probably were cut with an adze. During raising the frame was shored using long poles inserted into the rearing notches (or scotches) cut into the posts.

View South along the west arcade plate. The barn has been covered by a temporary steel shed for the duration of the repairs.

Economical use of trees is evident in most vernacular timber buildings. At Charlton Court the largest possible scantling was hewn from each tree and many of the main timbers are boxed heart with waney arrisses, including the impressively long plates and purlins that span three bays. Not all of the larger timbers are boxed heart, some of the arcade posts being halved from very large old oaks which explains the degree of heart rot in them. The more-roughly-hewn common rafters taper with the shape of the trees they were cut from and some replacement rafters are in the round, peeled of bark. This very irregularity in the materials and shape of old buildings provides much of their fascination. Each timber and stone was individually hand-shaped according to the qualities of the material to take its place in the regular forms of frame and roof. These patterns of variation and rhythm, still abundantly alive to the eye here after six centuries, have a subtle richness worthy of preservation.

In addition to repair and replacement of aisles and rafters a number of other structural repairs have been carried out over the centuries. Effective hook-over-and-twist blacksmith-made wrought iron straps, made from wagon tire material, help to connect plates to tie beams and other straps reinforce joints elsewhere. Large applied timber strapping has been placed to reinforce posts and one replacement elm post was added. Wherever possible we have retained these historic repairs and alterations.

OUR first task was to address the problem of subsidence. The arcade posts had subsided resulting in deflections of the wall plate of up to 36 in. The undue stresses fractured five of the posts at their weak point in the area of the brace mortises. As a result a large split in the roof was evident where the roof had been racking north and south, and at one roof crossframe the bottom of the king post was being dragged out of the tie-beam into space. Rainwater penetrating the roof had caused extensive wet rot, allowing death watch beetles to start eating and resulting in failure of three tie beams and deep voids in posts. Although the rafters and purlins may be undersized in engineering terms and are heavily deflected under the roof load, only one of the purlins had actually failed and that at a knot over the longest bay. We decided to restore the structural integrity of the barn by raising posts, reinstating braces and partially righting the frame ensuring tight joint shoulders to resist future racking. In combination with new footings and a repaired plinth wall the existing timbers could be retained and, moreover, function as a frame again.

Thick oak weather-boarding clads the exterior.

Having given each and every timber a temporary identification, the roof stone and some of the rafters were carefully removed and stored. A structural scaffold of 2-in. steel pipe was erected providing a work platform below tie-beam level as well as support for the structure. Ladder beam cradles on screw saddles were assembled around post heads to support the arcade plates and roof frames during movement. With the scaffold in place, posts were lifted using hydraulic jacks and held up using specially made clamps, again supported to allow for movement. We then used winches to slowly pull the badly-racked east arcade into a more upright position, tapping braces, plumbing posts and removing obstructing scaffolding as the arcade moved.

Once the frame was repositioned the actual repairs began with the aim of minimizing dismantling. Most repairs to the aisles, arcade posts and plates were carried out in place. The most seriously decayed roof crossframe had to be taken back to the workshop for repair. The need for new footings made it possible to repair three rotted post feet with strong and stable scissor-scarfed timber carefully inserted from beneath. The fractured posts were strengthened with stainless steel flitches placed in grooves cut using a chain mortiser and a circular saw with attached counterweights to help to make the vertical cuts. The posts were then rebuilt around the steel, using bolted and glued timber. Extensive repairs to the aisles and wagon porches were carried out including several new aisle cross sills replacing badly rotted ones. Where possible joint shoulders were fitted tightly and joints repegged. Missing braces in the nave and aisle were reinstated, using curved timber accurately cut with shoulder angles referenced to a string stretched between the ends of the brace's existing mortises.

Finished repair to a tie-beam...

Woven into the old fabric of the crossframe.

Some of the tie-beams also needed major repairs, especially at the ends where rainwater had caused large areas of wet rot. In one case new timber was added to both ends with bolted and glued wedged table scarfs and using level lines to ensure a match with the original. Several of the principal braces were given new tenons. In the roof one purlin was flitched with stainless steel and two end purlins extended with bolted timber. The south hip roof has been rebuilt in new oak and a few nave and aisle rafters have also been replaced in oak. Many of the short aisle rafters have been effectively retained by using bolted and glued horizontal stop-splayed scarfs.

IN designing repairs to retain existing fabric we have to consider the properties of the repair materials—timber, steel and structural adhesives—and the practicality of making these repairs. The major drawback to using large-section oak in repairs is the lack of dry oak available in these sizes. Oak therefore often has to be used green and as a result considerable shrinkage can be expected. This may not be a major problem where whole pieces are replaced or reinstated and joints are drawpegged. However, in bolted or glued repairs fixings may need tightening over time and there is potential for fracture near glue lines or splitting due to shrinkage stresses.

As carpenters we often prefer to make timber repairs to the frame but the demands of conservation may dictate otherwise, especially if a large amount of decay has to be removed to reach sound timber. In inserting patch repairs it is important to establish good reference data to ensure accurate measurements and a tight fit. Where it can be reasonably hidden, stainless steel can be an excellent repair material, strengthening major timbers which might require replacement. Hidden straps can secure failed joints with minimum loss of original fabric. Structural adhesives and consolidants have their applications but must be used with care in conservation work. In particular, they form impermeable layers that may trap moisture leading to future decay.

Charlton Court barn is a good example of the different methods and choices involved in timber frame conservation and repairs. After cladding and roofing Charlton Court barn will have been repaired and righted in time for the 600th anniversary of its raising, with plenty of nesting holes left open for the returning bats. This sturdy frame stands as a testament to its medieval hewers and carpenters. —PAUL PRICE

Paul Price is a member of Woodwrights Timber Framing in Wimborne St. Giles, Dorset.

Photos Paul Price, Charles Brentnall and Henry Russell

Views of the reconstructed pre-Georgian hip. Old timber at the bottom is an end-wall tie-beam. Hip is laid in plane with one of the meeting roofs, jack rafters in the adjacent roof are scribed and bird's-mouthed.

Introduction to French Scribe Layout

AT THE base of the French system that we used to lay out the timbers for the gazebo at Georgian Bay (see page 14 of this issue) is a practical grasp of geometric drawing. In order to produce working drawings using compass and straightedge we have a repertoire of techniques (*traits de charpente*), one of which we call the *traits carrés*, or, translated literally, "square strokes."

These marks are the principal and essential lines of reference for the drawing and the building alike, and they are found with the aid of the compass by constructing two perpendicular straight lines crossing at a right angle. These lines are the basis for the construction and study of the *épure*, or working drawing. The working drawing itself is the plan or pattern for a structure or an element of it, drawn on paper or tracing paper at 1:10 scale, or on the ground at 1:1 scale, in order to represent the different pieces of wood constituting the desired structure (a roof truss, for example).

In general, the perpendiculars correspond respectively to the axial line of the vertical—for example, the kingpost of our truss—and to what we call the *ligne de trave*, the horizontal, sometimes representing the level at the top of the walls but most often the level at the top of the tie-beam. Using the compass, we can represent other angles as well, for example roof slopes and brace inclinations.

When working full-scale on the ground, we can by means of a chalk line represent the placement and orientation of the different pieces of wood that constitute an assembly. Then what follows is the aligning of the timbers over the lines, leveling them for layout, and so on through cutting and raising. But the first step is geometric.

—MARC GUILHEMJOUAN

Now in Vancouver, B.C., Marc Guilhemjouan has practiced his craft on four continents. Drawing descriptions were edited by Ed Levin.

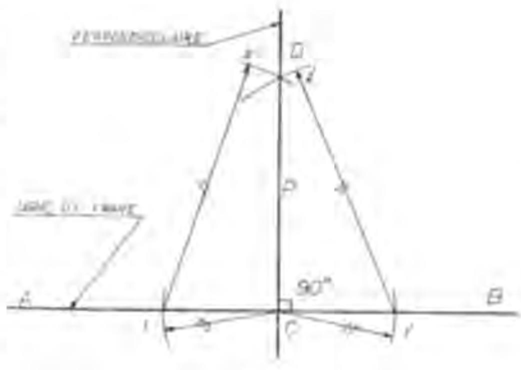


Fig. 1

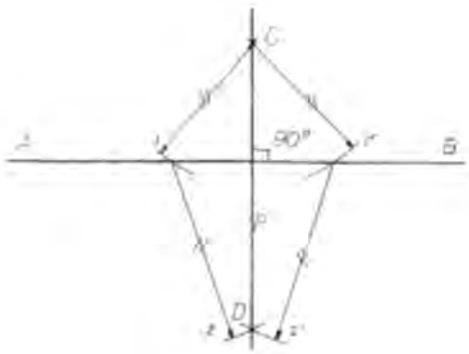


Fig. 2

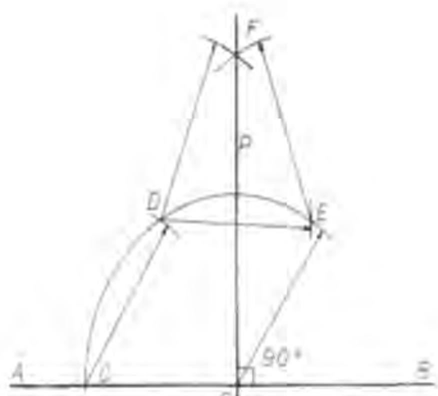


Fig. 3

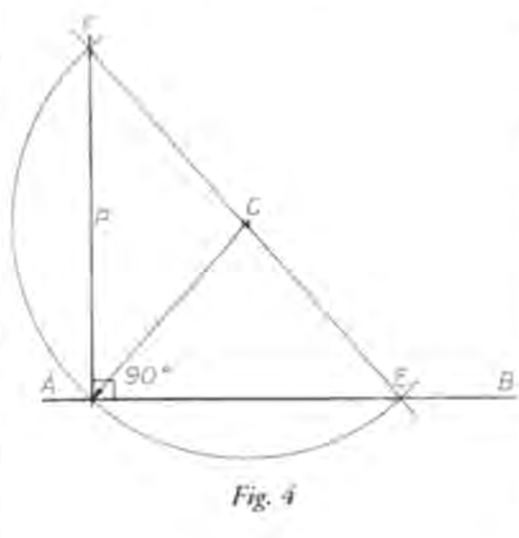


Fig. 4

Fig. 1 enables construction of a perpendicular to a line through a given point on that line. Starting at point C on AB, swing an arc cutting AB at 1 and 1'. Then with centers at 1 and 1', swing arcs 2 and 2' of identical radius. The intersection of 2 and 2' locates point D, and CD is perpendicular to AB. All operations take place on one side of the original line, so, the method works even when AB falls close to an edge of the layout surface.

Fig. 2 shows the construction of a perpendicular through a given point *off* the original line. From center C swing arc 1 and 1' to intersect AB. From 1 and 1' swing equal radius arcs 2 and 2' to locate D on the opposite side of AB. CD cuts AB at 90°.

Fig. 3 uses five arcs to accomplish the same task which figure 1 managed in four, but does it using a single, unchanging compass opening. This is handy if you are using fixed dividers or trammel points where the radius may be difficult or impossible to change. Starting from G on AB, draw a semicircle above the line. Where this arc cuts AB at C, draw a second arc to locate D on the semicircle, then from D find E by the same means. Arcs swung from D and E locate F. FG is perpendicular to AB.

Fig. 4 takes advantage of the Euclidean theorem that given two lines drawn from diametrically opposed points on a circle and meeting at a third point on the circumference, their angle of intersection is 90°. With this in mind, to raise a perpendicular at A on line AB, pick a point C above AB. With center at C, swing an arc of radius AC which cuts AB at two points (A and E), continuing the arc up past its probable intersection with the line you are looking for. Strike line EC and extend it on to its meeting with the arc at F. Thanks to Euclid, we know that angle FAB equals 90°. Since the entire construction takes place inside the quadrant defined by angle FAB, this method is especially useful where a right angle must be drawn close to the corner of the layout surface.

Fig. 5 uses the principles presented in Fig. 4 to generate 30°, 60°, 90° and 120° angles. With center at A, set the compass to radius AC and strike an arc above AB. Holding the same radius, find point D by arcing from center C. Triangle ACD is an equilateral triangle since its three sides (AC, AD and CD) are all of equal length so, by definition, its three interior angles (CAD, ACD and ADC) are all equal to 60°. To complete the construction, extend line CD upwards. Point E is located at the intersection of this extension with an arc of radius CD swung from center D. As in Fig. 4, angle CAE = 90°. Keeping in mind that the interior angles of a triangle always sum to 180°, since angle ADE equals 120° (180° less 60°) and triangle ADE is an isosceles triangle (AD = DE), it follows that angle DAE = angle AED = 30°.

Fig. 6 shows a derivation of 45° and 22½° angles. From line AB raise perpendicular CF using one of the methods described above. With center C, swing an arc to mark points 1 and 1', then from centers 1 and 1' swing equal arcs at 2 and 2' to locate point D. Line DC bisects angle BCF, and since BCF = 90°, then BCD = DCF = 45°. Taking this one step further, arc from center C to mark points 3 and 3', then draw arcs 4 and 4' centered on 3 and 3' to find point E. As before CE bisects angle BCD, and since BCD = 45°, BCE = DCE = 22½°.

Fig. 7 follows the same pattern to generate 30° and 15°. First, generate an equilateral triangle CDE with angles DCE, CDE and CED all 60°. To bisect angle DCE, find 2 and 2' where an arc centered on C crosses CD and CE, then find F by swinging equal arcs 3 and 3' from 2 and 2'. ACF = ECF = 30°. Repeat this process with arcs at 4, 4', 5 and 5', to bisect angle ACF into ACG = FCG = 15°.

Fig. 8 shows how to make a protractor. The idea here is to create a circle whose circumference equals 360 units. The base unit can be millimeters, centimeters, inches or fractions of an inch, depending on the system and the scale you are working in. The circumference of a circle equals pi times twice the radius

$$C = 2\pi R$$

so our protractor must have a radius of

$$360 \div 2\pi = 57.2958 \approx 57.3 \text{ units.}$$

Since the protractor circumference of 360 is equivalent to the number of degrees in a circle, each unit marked off on the circumference subtends an angle of 1°. To use the protractor, make an exact geometric construction of an angle close to the one you are seeking (using combinations of 15°, 22½°, 30°, 45°, 60°, 90°, etc.) then add or subtract the appropriate number of degrees incrementally on the protractor. In the two examples shown, we draw a 27½° angle by first constructing 22½° and stepping off five units on the protractor, also a 66° angle (60° plus six units).

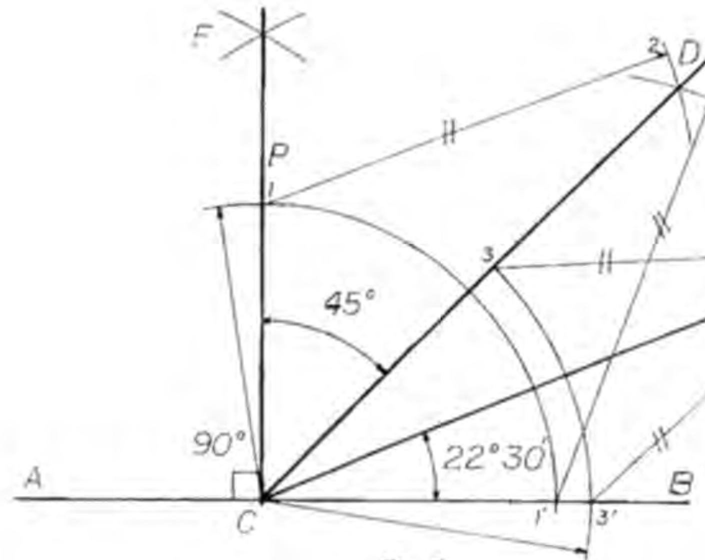


Fig. 6

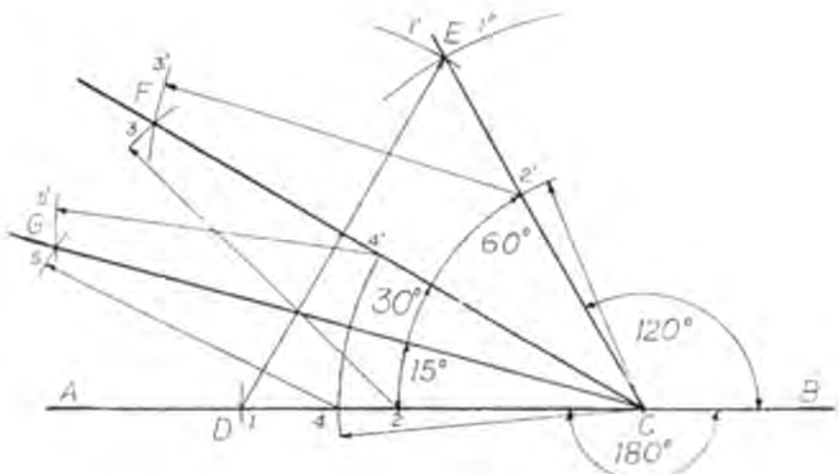


Fig. 7

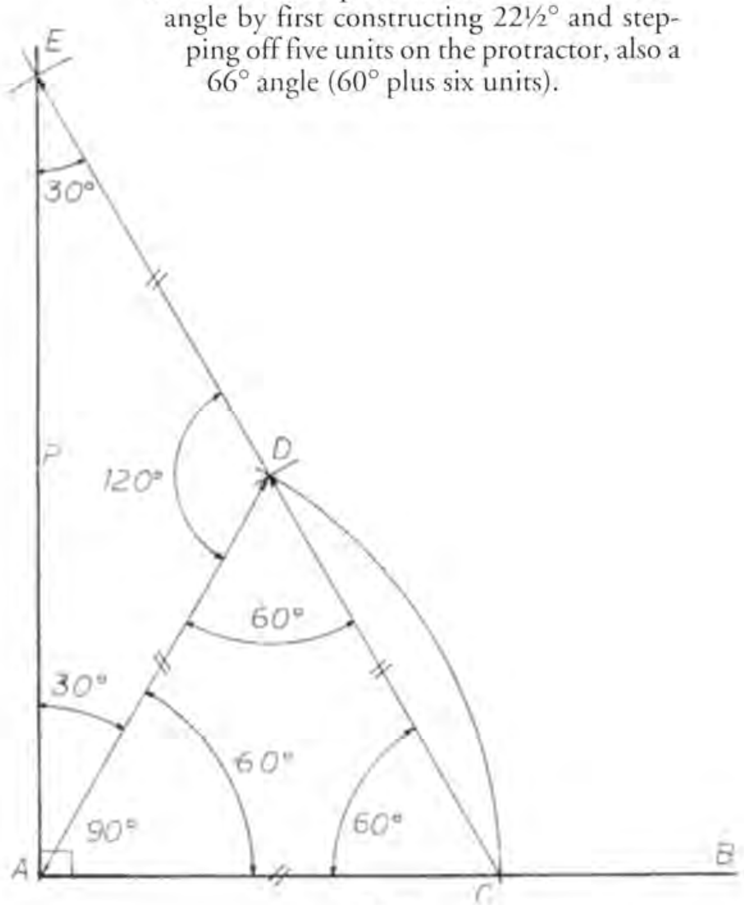


Fig. 5

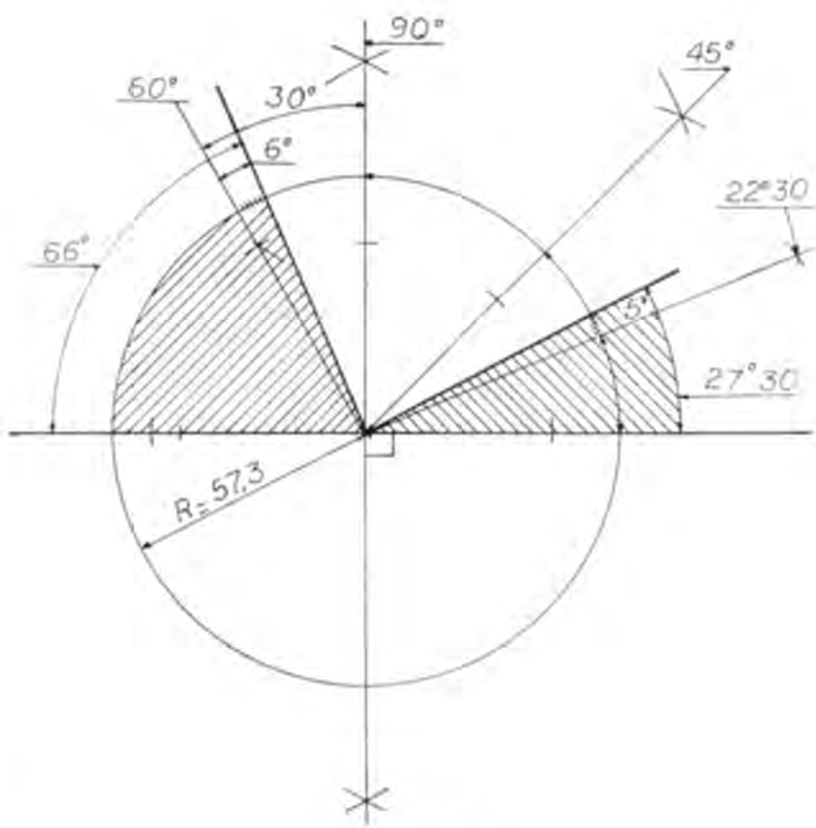


Fig. 8

German Roof Layout: II

IN "German Roof Layout: I" (*TF* 33), we found the lengths and angles needed for a gable roof by drawing alternate roof plans and profiles (sections). In this sequel, we extend this method to the layout of hip roofs.

We build on the same 10 x 20 m base as in our first example. Our new roof has both main and adjacent sides, giving a total of four roof slopes, all pitched at 40°. Framed over a rectangular base with all pitches equal, this is a regular plan, regular pitch roof, the simplest of hips. Ridge and gutter lines are level, overhang is 1 m.

When the pitches are even, the run of the hip always bisects the included angle of the walls. In our rectangular structure, the hips bisect 90° corners, and so run at 45° in plan.

Fig. 1 is a roof plan with main and adjacent slopes shown in profile. Adding 1.0 m overhangs to both sides of the 10.0 m span between the walls gives a total roof span of 12.0 m, and a common run of 6.0 m (A in fig. 1). Rise (5.035 m) and length (7.832 m) can be found either by drawing or calculation:

Slope = 40°
Rise = 6.0 m x tan 40° = 5.035 m
Length = $\sqrt{(6.0\ \text{m})^2 + (5.035\ \text{m})^2}$ = 7.832 m
Length = 6.0 m ÷ cos 40° = 7.832 m

To lay out the hips, extend the rise in both profiles of Fig. 1 onto the plan. The intersection of these lines locates the meeting point of hips and ridge (Fig. 2). Since point L is the foot of the hip and point U the peak, the distance L-U is the run of the hip. The rise being identical for hips and commons (5.035 m), we can draw the hip profile abutting the common profile (Fig. 3) and derive both the hip length and slope:

Hip Run = 6.0 m ÷ cos 45° = 8.485 m
Hip Length = $\sqrt{(5.035\ \text{m})^2 + (8.485\ \text{m})^2}$ = 9.867 m
Hip Slope = Arctan (5.035 m ÷ 8.485 m) = 30.682°

Now it is time to account for the width and depth of the timbers. The hip is cut from 10 cm thick stock and centered on its base line, extending 5 cm to either side. It must be deep enough so that the jacks do not underhang where they join it. Commons and jacks are 8 x 16 cm, so the height of the jack plumb cut is

16 cm ÷ cos 40° = 20.89 cm.

On the hip, this translates into a depth of

20.89 cm x cos (30.682°) = 17.96 cm

measured perpendicular to the length of the hip. This last dimension plus the height of the backing gives the minimum overall height of the hip (Fig. 4).

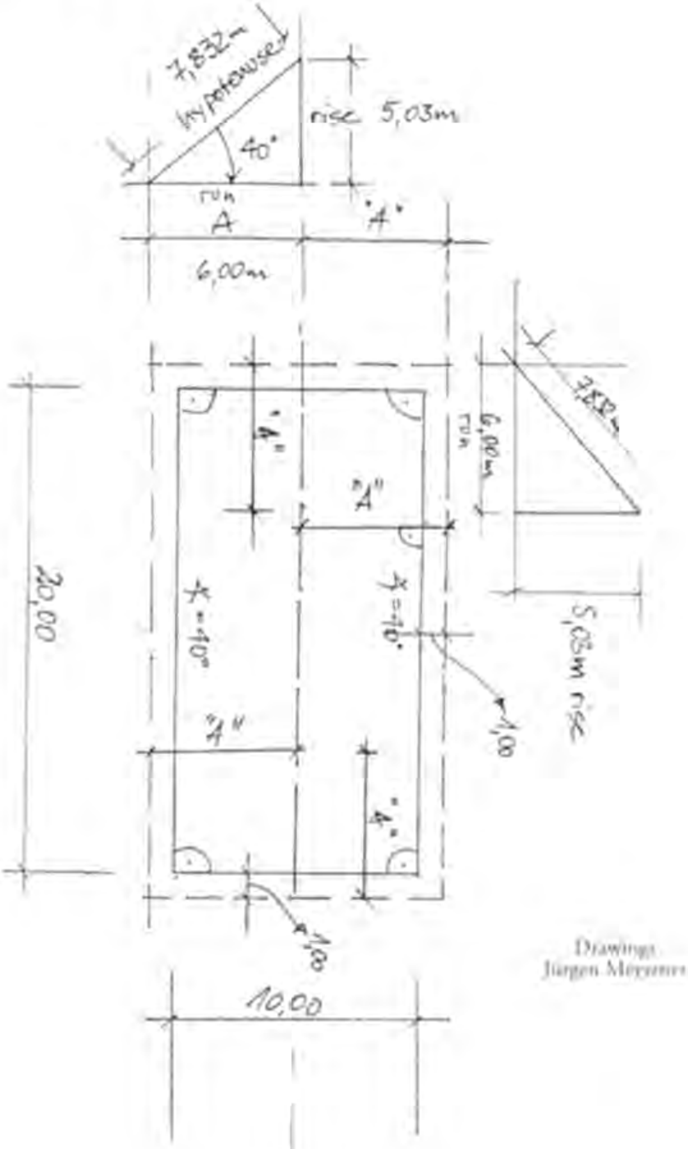
You can find the backing using a small plan and profile of the hip rafter foot. Length "C" in plan is the level distance measured along the hip run from the gutter line corner to a point opposite the intersection of the gutter line with the side of the hip (Fig. 5). Since the base angle is 45°, C is equal to the half width of the hip or 5.0 cm. Laying C off in profile locates the hip and backing lines, giving you the height of the backing B (Fig. 6):

B = 5.0 cm x sin 30.682° = 2.55 cm

So the overall depth of the hip must be at least

17.96 cm + 2.55 cm = 20.51 cm.

Rounding up the nearest even number, we conclude that the hip should be gotten out of a 10 x 22 cm timber. Knowing the thickness and depth of the hip, and the backing height, we can now draw it in cross-section (Fig. 7). In the process, we have also



Drawings
Jürgen Meyerer

Fig. 1.
Profile and plan views. Not to scale.

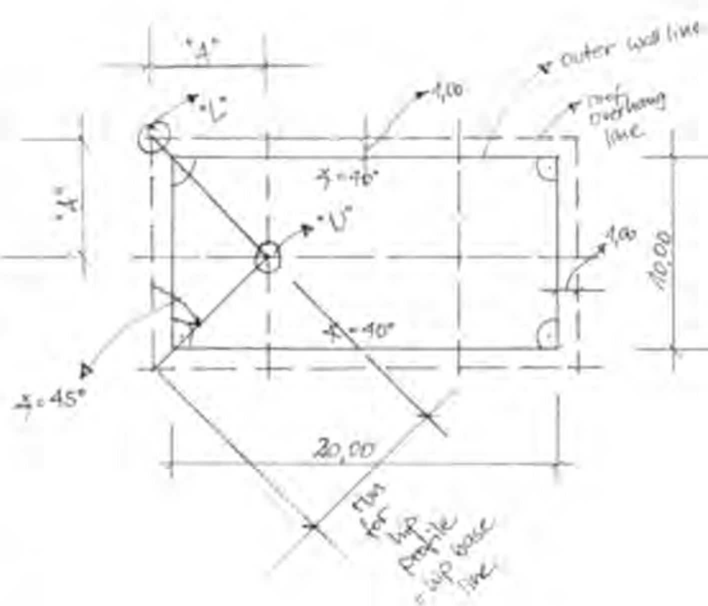


Fig. 2.
Plan view of hip. NTS.

arrived at the backing angle, which can be taken directly from the drawing, or expressed as the backing height divided by the hip halfwidth. Thus the backing angle equals

Arctan (Backing Height ÷ Hip Halfwidth)

or

Arctan (2.55 cm ÷ 5.0 cm) = 27.034°.

The profile drawing is fleshed out in Fig. 8, showing rafter depths, plate, ridge, post and brace locations, notch depths, etc.

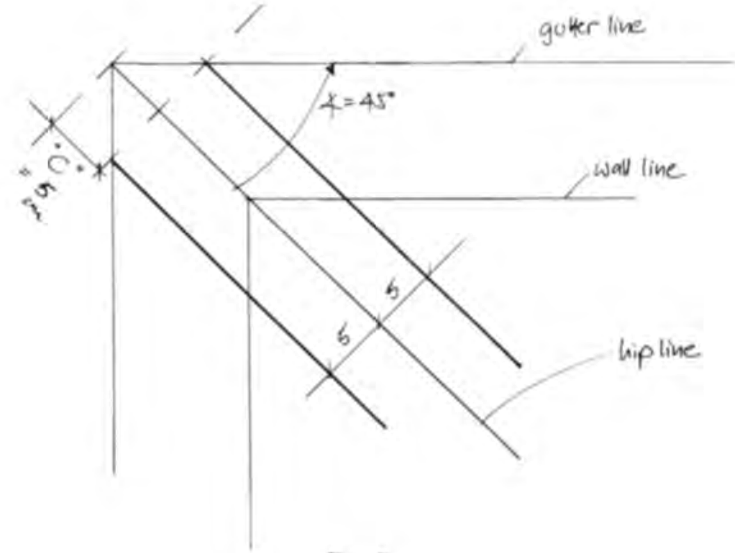


Fig. 5
Plan of hip foot, nts.

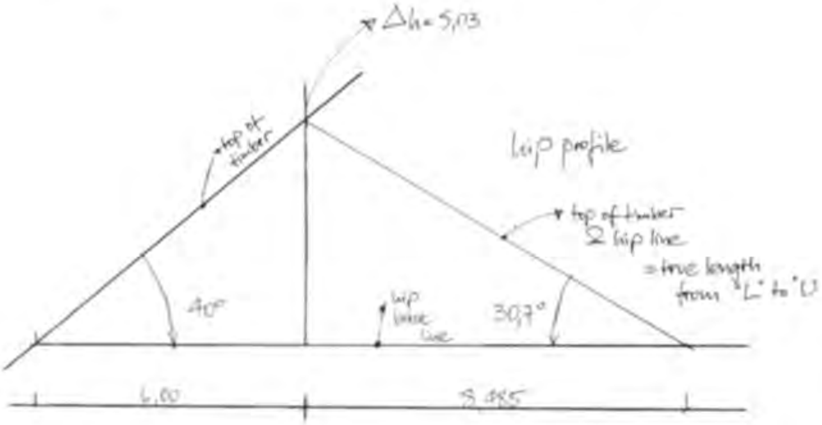


Fig. 3.
Common and hip rafter profile, nts.

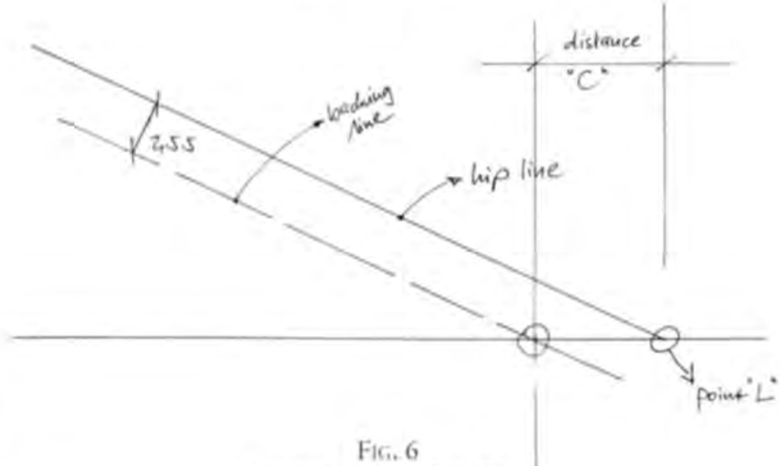


Fig. 6
Profile of hip foot, nts.

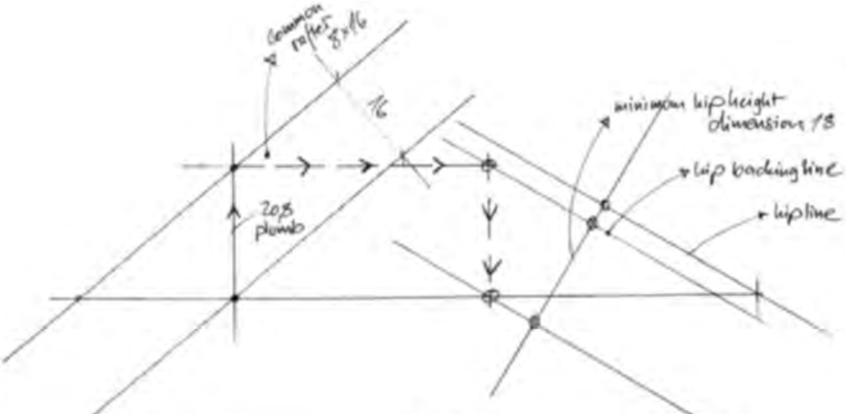


Fig. 4
Obtaining necessary height of hip, nts.

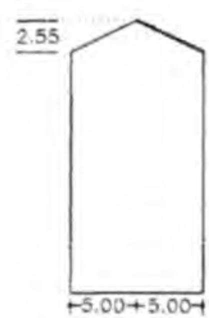


Fig. 7. Hip section.

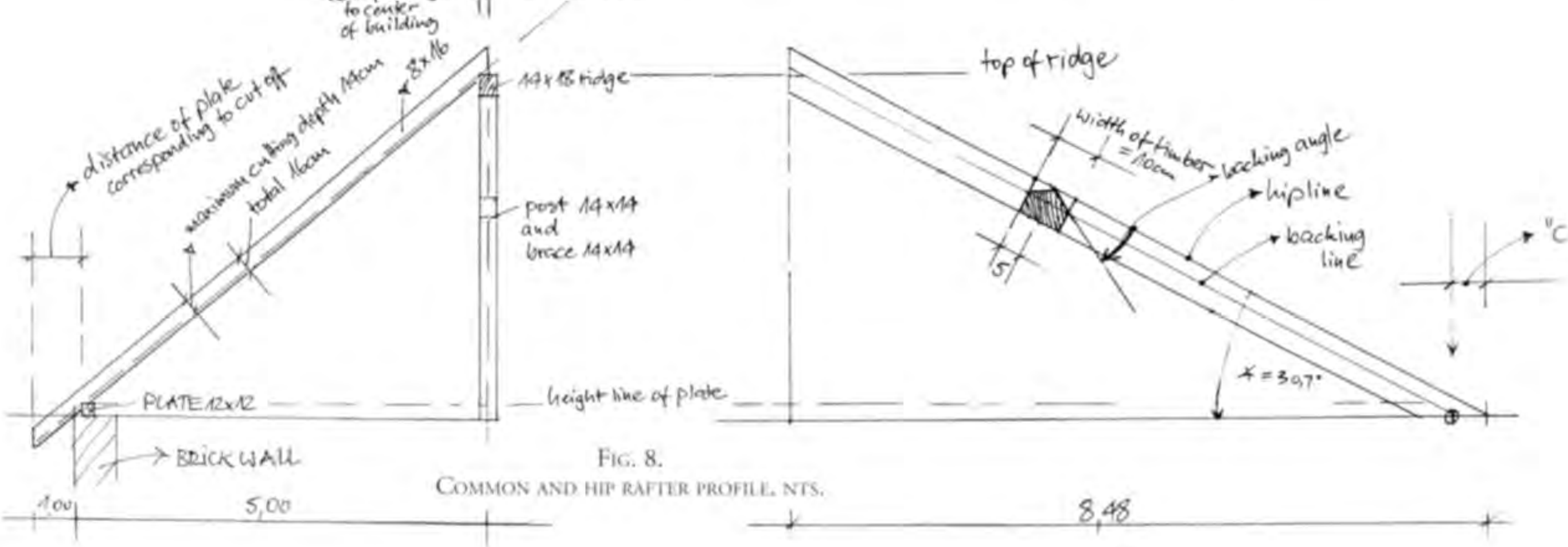


Fig. 8.
Common and hip rafter profile, nts.

The layout of the jack to hip joint is deduced from the jack rafter plan and profile (Fig. 9). The side cut of the jack is simply the complement of the common slope (90° - 40° = 50°). To find the edge cut, carry lines down from the heel and toe of the jack in plan to locate mating points in the profile. Then draw perpendicular lines from the profile to make a complete developed (unfolded) drawing of the jack. Connect the dots to locate the end cuts on side and edge. Note that a line joining the extremities runs at 90° to the fold lines of the developed drawing.

To lay out the foot and peak of the hip, we start from known points L and U in Fig. 2 and draw close-up plans and profiles of both ends (Fig. 10). At the rafter foot, the hip is notched over the plate corner. The darkly shaded area in plan indicates material to be removed. Construction lines locating plate, wall and eave are extended to mark corresponding positions in the profile. This pattern is duplicated at the peak where each hip is notched around the 14x18 ridge and mitered to its opposite number (Fig. 11).

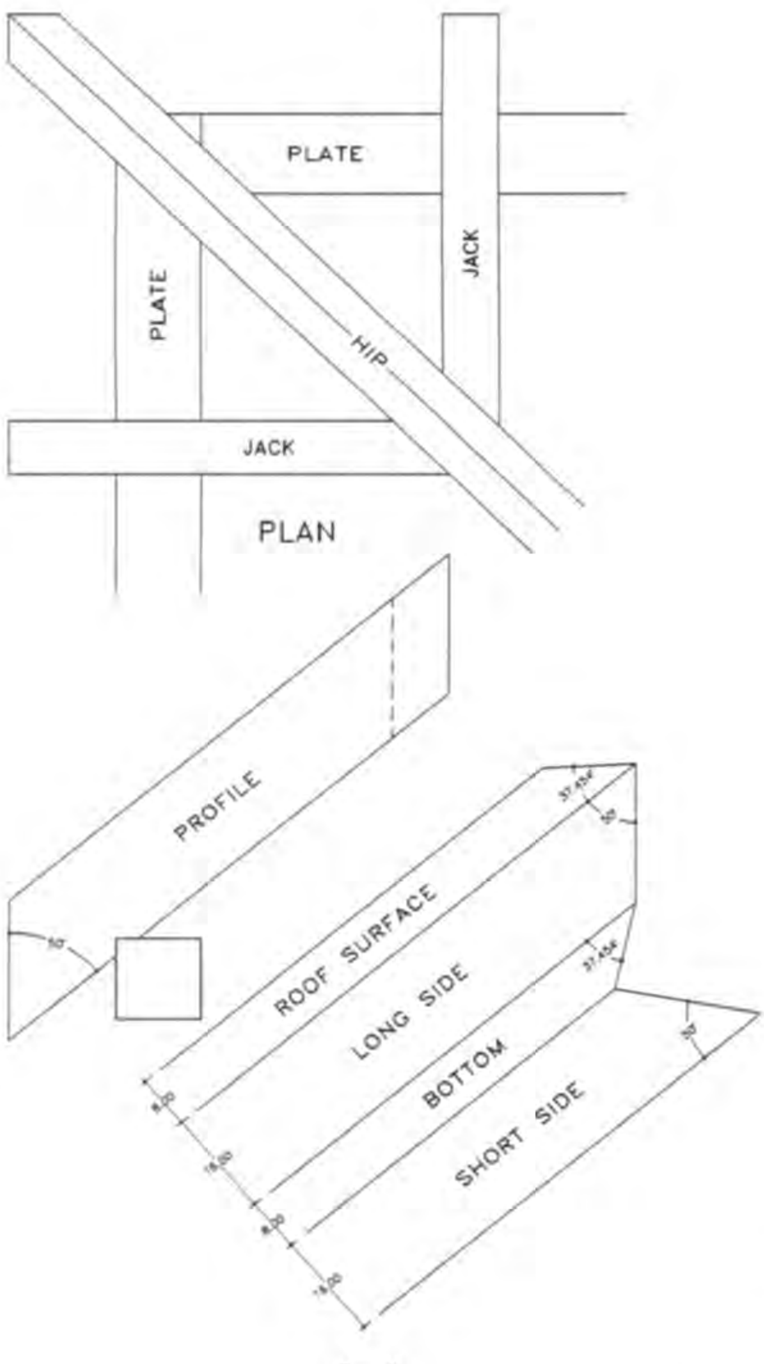


Fig. 9.
Jack rafter plan and profile with developed drawing.

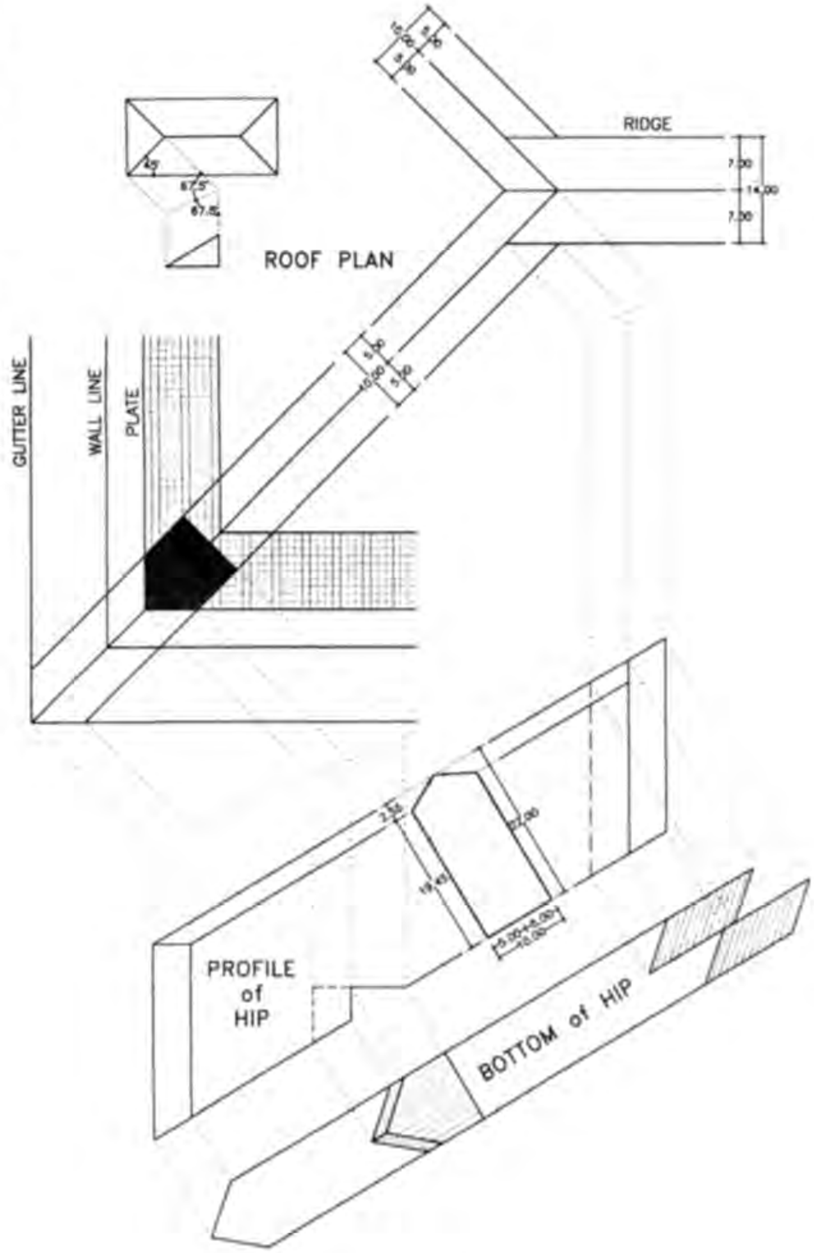


Fig. 10
Plan of assembly and profile of hip.

Drawings
Ed Levin

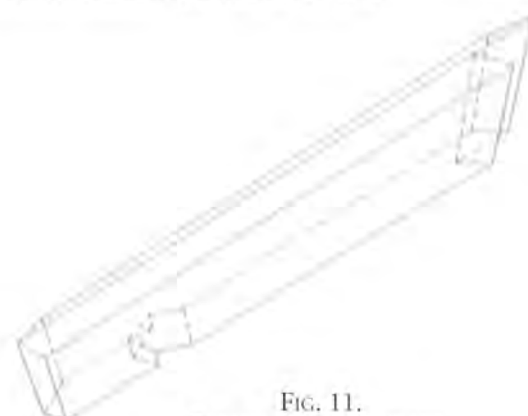


Fig. 11.
Perspective view of hip.

You have now taken the beginners first steps towards a German journeyman's degree. After another three years of apprenticeship you should be able to lay out and cut hips, valleys and their jacks, having derived all necessary information from plan and profile drawings. —Jürgen Meyszner

Jürgen Meyszner builds houses in Landau, Germany. This article was edited by Ed Levin and is the second of a series.

GUILD NOTES AND COMMENT

RENDEZVOUS '94 in Penetanguishene, Ontario, while establishing a new model for Guild events, generated a multitude of memories for those who attended. Some came to learn something of the French Scribe technique, some to renew friendships and take part in the Atlantic Challenge festivities and some to have a family camping trip in a beautiful setting. All were satisfied during five days highlighted by a spirit of international goodwill and cooperation.

Michele Beemer carves the name of the Russian boat into the kingpost of the central truss for the Guild-built gazebo at Georgian Bay, Ontario.

Impetus for the gathering came from a number of fronts. News that the Russian boatbuilding apprentices based at Shtandart would be participating in the Atlantic Challenge Canada events prompted Sandy Bennett to seek a way to sample the fruits of the Guild's missions to St. Petersburg. Doug Lukian saw an opportunity for a Canadian Guild event, the first since Guelph. I, along with the other instructors from the Gazebo Workshop in Texas, was looking for a chance to repeat that project. With encouragement from Lance Lee, the Director of Atlantic Challenge USA and speaker at our '92 and '93 Conferences, the Guild was welcomed with open arms to participate in the events at Penetang.

Atlantic Challenge was part of the summer-long Georgian Bay '94 Marine Heritage Festival, involving over 45 shoreline communities and featuring visits by 17 Tall Ships. Three local museums had expressed interest in the Guild's services, and at one point four separate projects were being considered. The most promising was an outdoor pavilion for the Centennial Museum, which recalls the history of the logging industry in the area. Originally scheduled as a compound joinery workshop to replicate the Nacogdoches Gazebo, we hoped to hold it during the week before Atlantic Challenge and use the facilities at Discovery Harbor for layout, cutting and camping. Formerly known as the Historic Naval and Military Establishments, this park is located two miles from the Museum and would be the center of activity during Atlantic Challenge. As negotiations proceeded and deadlines approached, it became clear that the Gazebo workshop format would be too ambitious and complex for the Museum's budget and our timetable. We were told as well that Discovery Harbor would not be available for our use until the start of Atlantic Challenge, leaving us with a far less attractive campground out of town and away from the water as our base of operations. A new plan for the Rendezvous was needed.

Marc Guilhemjouan is a French *compagnon* now living in Vancouver who has been working for over a year with timber framers in Canada. He first expressed in interest in leading a Guild project by submitting an alternative Gazebo design for Texas, and with Dan Deschambault's group had built a pavilion which he now proposed for Penetang. The 16 by 24 ft. rectangular structure was simple enough to cut and raise during the five days we would be at Discovery Harbor, and demonstrating the layout using French scribe techniques would provide an educational focus. Eschewing the workshop format (no paid instructors or formal curriculum) and doing the project while we could economically camp with the Atlantic Challenge group made the event much more affordable in time and money.

WHILE Marc and Ed Levin fine-tuned the design and materials list, Dave Marchant was recruited to be the Guild's on-site liason. Since his home in Midland was a only a few miles from the site, he was able to look after details such as checking layout and construction of the foundation, acquisition and quality of the timber (Norway spruce donated by a local sawyer) and, not least, setting up a charge account at the local grocer for the camp kitchen. Scott Murray lined up stove rentals for the kitchen while Joel McCarty renewed the documentation needed to get us Yanks and our tools across the border and back. Doug, Sharon and I tied up the loose ends and confirmed details with those who had responded to the call published in *Scantlings*. By August 1st around 30 timber framers and their families converged on Penetanguishene.

Those of us who arrived a day or two earlier had a chance to visit the Tall Ships moored at various quays in downtown Midland, Penetang and out at Discovery Harbor. These ships, which included the *H.M.S. Rose* (the largest wooden ship in the world in active service) and a replica of the *Half Moon* (Henry Hudson's ship from 1608), provided a vista not seen in these waters for over a century. As soon as we pulled into town Michele and I hopped on board one of the free shuttle busses which efficiently moved people to the different venues. Later we returned to Discovery Harbor to explore our home for the next week. The Guild campground was at the water's edge, providing a spectacular view of the entrance to the harbor at Penetang and a good vantage point to watch the Atlantic Challenge races. Best of all, the swimming area was a shout away and adults were easily able to supervise and join the kids who seemed to be constantly enjoying the warm waters of Georgian Bay. Walking back along the shore towards the inner harbor, we passed the Army tents which were to house the Atlantic Challenge participants and then through the parking lot which would serve as our work area. For the next half-mile we stepped back into the 19th century, as recreated buildings and "re-enactors" depicted life as it was at this most important base of British military and naval operations on the Great Lakes from 1817-1856. Although the pitsaw seemed to be frozen in time halfway through a rip cut in an ancient oak, the blacksmith's forge as well as ordnance and farm equipment were all in working order.

Camp setup began on Monday, with Mike Goldberg and Terry Clark taking charge of amenities and acquisitions. By the end of the day we had a double army tent with gas grilles, coolers, lights, backbar, bonfire pit and picnic tables. A rotating kitchen crew schedule was worked out, with the result that each meal got more impressive as the competition heated up.

The Russian team arrived on this day as well, and there were hugs aplenty as Guild members who had made the long trip to St. Petersburg welcomed those who had made a considerably more arduous trek this direction. Another emotional moment occurred when we went down to a boatyard in Midland that evening to watch the unloading of the Russian gig *Enchanté*. The keel on this 38-ft. Bantry Bay gig was barely laid the last

Marc Guilhemjouan casts the plumb bobs…

Then uses one to find a timber intersection.

time a Guild ambassador saw her, with her future far from certain. The crew and boat almost didn't make it after being abandoned by the Russian Navy in Murmansk, whence they had to work their way across to North America on a fishing trawler, finally to be met on the coast of Nova Scotia and hustled down to Maine. After this harrowing trip from Russia, the finishing touches on the boat were done at Lance's shop in Rockland. One more contribution from the Guild was required before the boat was ready for competition: two oars had broken, so George Nesbitt used drawknife and spokeshave to fashion new ones from extra rafters we had on hand for the Pavilion project.

The layout for the Centennial Museum Pavilion began on Tuesday, August 2. Marc Guilhemjouan, with Pete Cote from Lukian Structures acting as interpreter, started construction using one of the methods of *Les Compagnons du Devoir*, the traditional French craftsmen's guild. Marc first demonstrated the basic steps of the *trait de charpente*, the geometric description of the frame outline. With an outline of the building drawn on the ground (parking lot in our case) the carpenter can solve any number of problems that may occur during the construction of the building. By mid-day the full-scale working drawing of the bent and roof truss was completed and the timbers were next laid over the chalk lines. Aligning and gauging of the timbers was accomplished with the *plomette,* a doughnut-shaped plumb bob molded out of lead on the spot. We were then able do the *picage* (jabbing) of the joinery, eyeballing the gap between the out-of-square joinery face of the timber and the line plumbed over the drawing, and marking the gap at the joint location with dividers. (See "Framing the Cabildo Roof," TF 23.) Later that afternoon, opening ceremonies for Atlantic Challenge took place at the King's Wharf with a colorful parade and launching of the gigs from ten countries.

On Wednesday the layout continued and *l'utilise*, the cutting of timber, began. Everyone had plenty of opportunity to try *picage* while a steady stream of tourists and Atlantic Challenge participants stopped by to view the process. Dinner in camp that evening was a special affair: the Russian team was invited and then presented with three complete tool kits garnered by Dave Crocco from contributors throughout the Guild.

RAIN moved in on Thursday, which postponed an all-day outing to Beausoleil Island aboard the ferry *The Miss Midland.* Beach volleyball and hiking gave way to timber framing as we set up some extra Army tents to continue on the joinery. Later that afternoon, the skies cleared and the boat ride was on, with families from both the Guild and Atlantic Challenge enjoying the spectacular views of Georgian Bay and the Thirty Thousand Islands. While there was no time for the landing at Beausoleil Island, everyone appreciated the break from the intense activity back at Discovery Harbor.

Friday was our last full day of working on the pavilion prior to raising. A smaller than anticipated group of participants had started on Tuesday, and we knew we'd be working late today to finish up. More help arrived to assist in the cutting of rafters, plates and purlins. Scott Murray and John Fedeski contributed the use of much-needed tools from their nearby shops, and by the end of the day around 50 people brought their expertise to bear in the eleventh hour. Remembering a lesson learned in Texas, I contacted the local fire department and arranged for an array of halogen lights and refreshments for after dark. The flurry of activity and wood chips that evening provided much entertainment for what was the largest crowd of observers yet. Earlier in the day, the Russians had taken second place in the rowing race, their best finish yet, and it

Photos Will Beemer

The raising mostly complete…

And the finished frame ready for roofing.

The cheerful Russian team...

seemed to give all of us a boost as we headed down the home stretch.

By noon on Saturday the timbers had been loaded up and delivered to the site, about two miles down the road at the harbor in Penetang. The brick floor of the Pavilion had been well prepared, and the first side wall was assembled and raised without a hitch. The second wall was pegged off and raised by the Russian team, who had taken a break from their events to come lend a hand. Earlier in the day, a crew of timber framers had rowed *Enchanté* from the camp around to the King's Wharf without mishap, although it was a miracle no more oars were broken. The roof trusses were assembled in place, with special care taken on the center truss. "Atlantic Challenge," "1994" and the Guild logo were carved on one side, with the names of the ten Atlantic Challenge boats on the flip side; a crew of carvers led by Mike Langford put on these finishing touches. Removable railings were designed and installed on one side for adaptation during dances and concerts. Purlins and rafters followed, and the wetting bush was nailed on as the sun was setting over the yardarm down in the harbor. As all of us, including the Russians, clambered over the frame for a group photo, "Happy Birthday" broke out in honor of Centennial Museum Director Dave Dupuis, who called this his best birthday ever.

One spot on the frame was left open for Ed Levin, who had looked forward to this event but couldn't make it because of obligations at home. Besides volunteering his design services to fine-tune this frame, he has been instrumental in establishing and maintaining our relationship with Atlantic Challenge and the crew at Shtandart. I read a fax from Ed congratulating all on a job well done, and Lance Lee recited Marge Piercy's poem "To Be Of Use," which reaffirmed that this beautiful building was not our only legacy; we also had the memories of how we created it together.

The Guild has participated in three major projects this year: the Centennial Museum Pavilion, the Nacogdoches Gazebo, and the Malabar Farm Barn. There's no doubt we do these things well; if we do more of them, we should learn to make them more affordable for the members and profitable for the Guild. In Penetang we suffered from a rather lukewarm commitment from the local authorities. The Centennial Museum was on a very tight budget and had a small membership base to support it; the Guild had a project it wanted to build and was stretching to find a client. This put us at a disadvantage in negotiations and the resultant delays in firming up the details gave us little lead time to publicize the event. With more time we would have had more participants and a higher visibility for the Guild in the local media and the literature supporting the Georgian Bay Festival. After arriving on site we had few local resources ready or able to help; we were a sideshow to the Atlantic Challenge events. Dave Marchant was the only local Guild member and was instrumental in the success of the project. With a stronger incentive and investment by the citizenry, things could have gone more smoothly, spreading some of the burden around.

The Rendezvous at Discovery Harbor was a simple, low-cost affair that was lots of fun and gave us the chance to reaffirm our ties to Atlantic Challenge. Just before breaking up and going our separate ways, plans were made for a few of us to meet in Maine for a week in October to discuss how this relationship might flourish to the mutual benefit of us all. Ed Levin, Mike Goldberg, Curtis Milton, Mike Langford and I thus arrived some weeks later at Lance Lee's Apprenticeshop at Rockland where we had a chance to see firsthand how the apprenticeship program works. While we shared meals and ideas with this international community, we framed up and paneled an office loft in the shop with donated materials from New Energy Works, Winter Panel, John Connolly, Jim LeRoy, Tom Lee, Jr. (Great Northern Products) and Bill Alcorn (Wood Structures). After sailing two gigs and a schooner across Penobscot Bay to Lance's enclave at the Powder Hole on Greene's Island, we enjoyed a spectacular three days of sun, wind and fall foliage. Framing up a log tetrahedron with hand tools (there's no power on the island), along with the office project back on the mainland, gave us the opportunity to talk to the apprentices while they learned more about timber framing. Since it may take them a day just to get one plank on a lapstrake hull, they were impressed with how much we could get done in a short amount of time. (We never mentioned anything about our first frames.) We spent our final evening on the island around a woodstove in a wonderful yurt, talking about lessons learned and places we'd like to be, physically and spiritually. We shall return to Greene's next year, with more timber framers, to help build a driftwood *naust,* or boathouse, using hand tools and found timber. —WILL BEEMER

And its lovely 38-ft. gig Enchanté.

The teams line up at King's Wharf before a race.

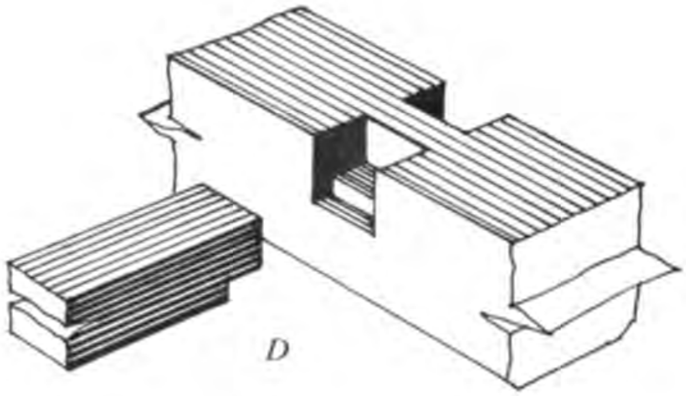
An Old English Joint

BUILT by Lord Scrope between 1379 and 1399, Bolton Castle stands on the northern slopes of Wensleydale, Yorkshire. The mason for the contract was John Lewyn who, it is recorded, also worked upon the upper walls of the choir of Carlisle Cathedral between 1363 and 1395. In 1647 the Commonwealth Committee at York ordered the castle "rendered untenable." However, a large part of the castle was still left, including some leaded roofs on the west range, and these are still there.

The drawings show the joints for this roof, which is original. At A the tie-beam is shown in elevation with the ridge-piece and purlins sectioned. B shows the ridge-piece let into the tie-beam and mortised to the rafters. The joint at C shows how the purlins join the tie-beam, having top tenons with a housed soffit shoulder; this joint was also used at Beaufort's tower in Winchester in 1404—the earliest one known before the discovery at Bolton.

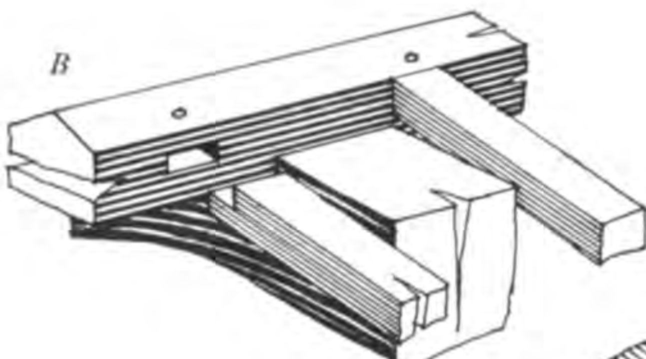
The joint at D is a butt-cogging tenon with bottom soffit shoulder, and is early—1363. This method, employed throughout the late 17th and 18th centuries in England and New England, is without merit, relying solely on the strength of overweight timber in the carrying member.

—Cecil A. Hewett

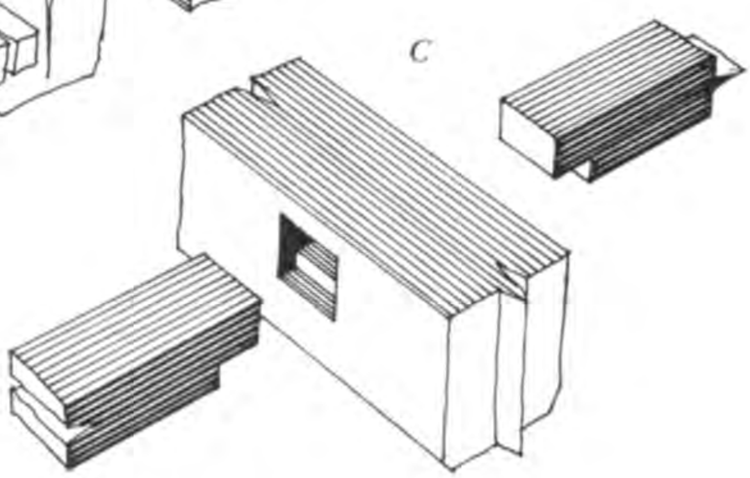


D

B



C



Drawings Cecil A. Hewett

A