TIMBER FRAMING

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Portable Mortisers

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On the front cover, portable mortising machines for timber framing from Germany, Switzerland and Japan. Review page 10. Photo by Ben Weiss. On the back cover, view from inside timber-framed rectory, ca. 1760, on St. Kitts, Leeward Islands. Note dovetailed shutter battens. Photo by Douglass C. Reed.

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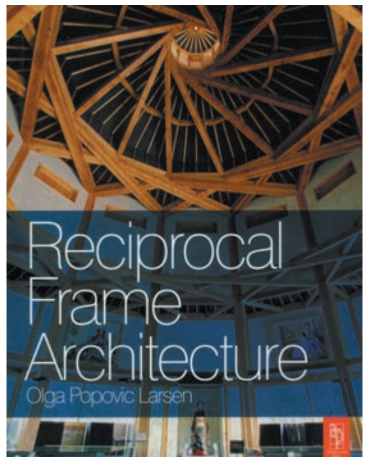
TIMBER FRAMING, Journal of the Timber Framers Guild, appears in March, June, September and December. The journal is written by its readers and pays for interesting articles by experienced and novice writers alike.

1985

BOOKS
Reciprocal Framing

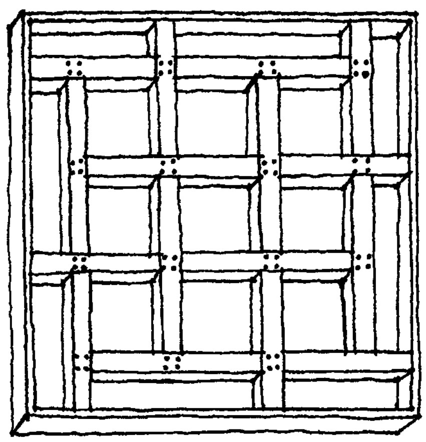
Reciprocal Frame Architecture, by Olga Popovic Larsen. Oxford, UK, Architectural Press, 2008. 7½ x 9¾, 196 pp., copiously illustrated. Paper (Smythe-sewn), $52.95.



I TEND to buy almost any book that has anything to do with timber structures (Charlotte Cooper at Summerbeam Books loves me). I was particularly intrigued by this one, written by an architect and engineer now teaching at the University of Sheffield in England, because it deals with a technique that I had only just recently explored, in the time-honored American style, diving into the engineering of a reciprocal-framed structure with no clue that others had preceded me, and by centuries.

In the book's foreword, structural engineer Tony Hunt offers this pithy definition of reciprocal framing: "a structure made up of mutually supporting beams in a closed circuit." The circuits can be closed in many shapes, from triangles to circles, and in many heights, from floors to steeples. The "mutually supporting" aspect of this framing scheme is its most fascinating. It also means that, during erection, all subassemblies have to be temporarily supported until the final, keystone component, is installed. Conversely, the entire structure is subject to disparate and progressive collapse if only one of the mutually supporting members should fail. These are just some of the complexities innate to reciprocal framing.

Reciprocal Frame Architecture is divided into two parts: the history of reciprocal framing, and a discussion of contemporary designers and built examples in Japan, the UK and the US. Given reciprocal framing's current obscurity, it should not be a surprise to learn that its historical origins are vague. Ancient North American building forms that exploit reciprocal framing principles include igloos, tepees and hogans. The earliest recorded drawings are found in Leonardo's notebooks (before 1519) and in a 1537 work of Sebastiano Serlio. Our own timber guru in English, Thomas Tredgold, devoted a chapter to them in his *Elementary Principles of Carpentry* (1820) describing ways to frame floors with timbers that are shorter than the minimum plan dimension.



Serlio's 1537 drawing of a floor frame made of timbers too short to span.

Buckminster Fuller drew inspiration from reciprocal framing, to the point where John Chilton, a structural engineer and professor at the Lincoln School of Architecture

(UK), compared it with "a collapsed tensegrity structure." Louis Kahn included reciprocal floor framing in a clever design that remains, sadly, unbuilt. The modern European timber master Julius Natterer has incorporated reciprocal principles in several of his amazing quiver of built timber structures, some very large.

Popovic Larsen provides a fairly thorough discussion of the geometric parameters that describe reciprocal frames, and an unusually well-illustrated analysis of some "typical" configurations. The section on morphology is a fine summary of the remarkable variety of shapes that can be supported. A computer analysis of a "very simple," four-member reciprocal frame is clearly and elegantly presented and discussed. Although, as a typically anal-retentive engineer, I was able to find some very minor glitches in that discussion, it was only because the writing and illustrations were both clearly enough presented (if not overwhelmingly thorough) that I actually bothered to check it all out. In fact, this book has some of the best presentation of fairly technical material that I recall reading, certainly in a relatively mainstream non-textbook.

The author discusses four of the more active reciprocal frame designers in the world, three Japanese and a wild Englishman. The first of these, architect Kazuhiro Ishii, is the sort of driven and absolutely tenacious builder you can easily imagine pursuing reciprocal frames, and a consummate salesman, always handy when trying to get costly and unconventional systems built. I found two of his projects especially interesting. The Sukiya Yu house includes an unusual, but conveniently rectangular in plan, linear reciprocal framing scheme over the vaulted swimming pool. The house itself is a fascinating combination of a double-ring reciprocal frame supporting a Fuller dome roof. The double ring, cut with very elaborate compound joinery, employs no metal fasteners at the intersections.

Ishii's Bunraku Puppet Theater (book cover at left and detail at right), in Seiwa, is entirely remarkable, starting with its scale. One might think a puppet theater would be small, but the exhibition hall is 13m tall, its height restricted only by Japanese code limits on post length. Those posts are so tall and slender, in fact, that there is a mid-height ring of reciprocal framing to prevent their buckling. The roof itself is a stunning example of reciprocally framed principal rafters, supporting a ring of principal purlins and light radial common rafters.

Yoichi Kan is a structural engineer who built Torikabuto, a life sciences laboratory for ecological research and design, in rugged mountainous terrain northeast of Nagasaki. Kan's work augments the first structure built at the site, another Fuller dome, reinforcing the link with Bucky's work. The New Farmhouse, as it is called, is a sweet example of reciprocal framing, square in plan—handier in many ways than the more common wholelottagons that reciprocal framing supports. The 8m-square room is capped by an eight-membered reciprocal frame of four hips and four jacks, surmounted by a small cupola, a common way of handling the complex area where all the members mutually support one another. The space below is divided only by shoji screens, with no ceilings, so the entire roof frame is exposed to view. Don't we wish this style would catch on with our timber-framed buildings?

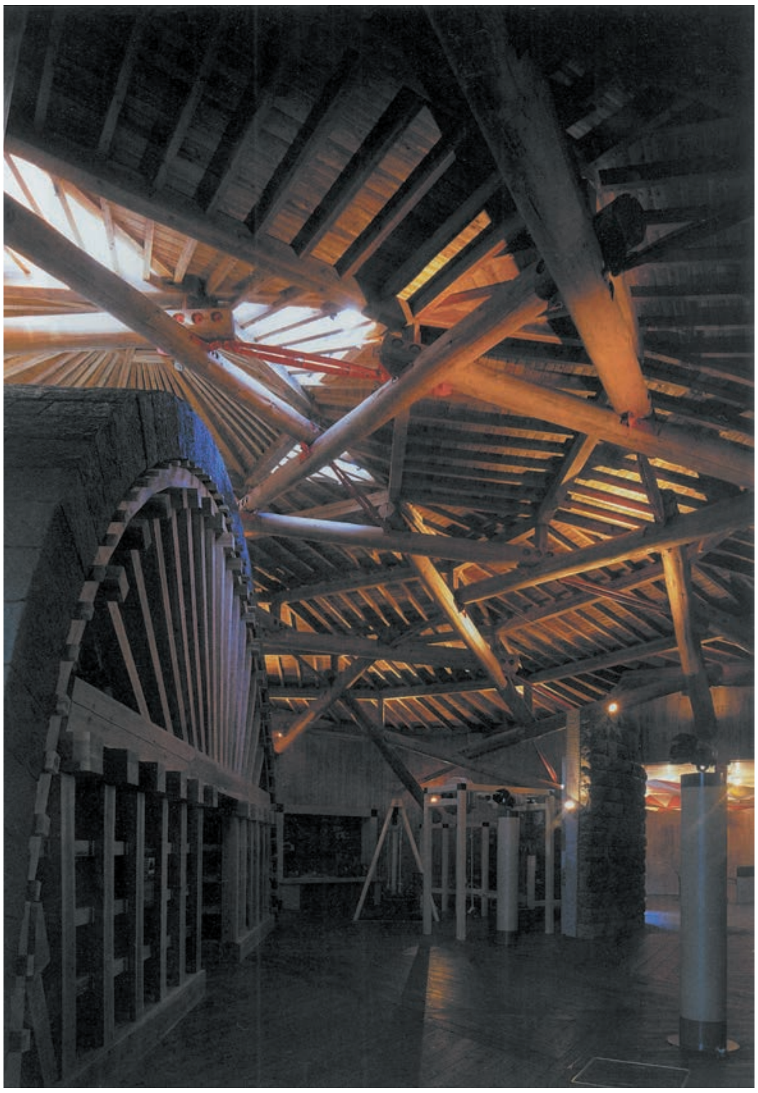
The third Japanese the author invokes is the late architect Yasufumi Kijima. His remarkable Toyoson Stonemason Museum, predictably, has walls of stone, but the roofs over the extensive tripartite structure, which has no straight walls, are "truly unique" reciprocal frames that completely upstage the stone. "On first view the exposed round-wood cypress poles look as if they have been arranged in a chaotic way: there are poles pointing in the most unexpected directions," observes Popovic Larsen. While the roofs are framed with peeled logs, the connections rely on steel plates and pins, and steel rods guarantee the stability of these large and fairly flat domes (overleaf). The steel elements are painted bright red, in an enviable nod to honesty in structure.

All illustrations from *Reciprocal Frame Architecture* except where otherwise credited

Ishii's Sukiya Yu house (1989), Okayama Prefecture, with double ring supporting dome. Structural engineering by Tadashi Hamauzu.

Framing at cupola of Ishii's Seiwa Bunraku Puppet Theater (1992).

Yoichi Kan's Torikabuto (1993), near Nagasaki, framing up.



Toyoson Stonemason Museum (1994) by Yasufumi Kijima (Keikaku-Inc.), Kumamoto Prefecture. Log elements assisted by steel fasteners and tension elements. Masonry arch retains heavy timber centering.

Graham Brown's Colney Wood Chapel (2003) near Norwich, Norfolk, UK, with flared roof panels following framing beneath.

Finally, the author takes us to an acupuncturist-turned-reciprocal-framing-zealot in the UK, Graham Brown. Perhaps because of his clear hippie leanings, Brown ended up starting nearly from scratch—that "eureka moment"—in developing reciprocal framing from toothpicks on his table to standing buildings. In fact, he felt as though he had so gone from scratch that he ended up patenting Reciprocal Framing in the UK, Australia and Canada. Not to worry our Canadian members who might be intrigued by reciprocal framing, Brown has come to regret even bothering with the patent and now happily answers all sorts of questions, mostly from enthusiastic reciprocal framing neophytes with too little money. (Does that sound familiar, timber framers?) Brown's firm, Out of Nowhere (OON—he is, still, a hippie), has built 30 reciprocal frames to date, always in timber and ranging from very small gazebos to spans up to 13m. His home in Saorsa Ardlach, Nairn, Scotland, is crafted from very precisely made timbers, some compound-tapered on their top surfaces to create a flat ring for the central skylight. I found that effort a bit ironic when compared with the complex roof surfaces surrounding that skylight—the eight stepped radial gables running up each of the hips must have driven the roofers mad. Brown's award-winning Findhorn Earth Sanctuary in Morayshire uses peeled logs and recycled whisky barrels ("highly sustainable design that harmonized with the woodland setting"), and his Colney Wood Chapel (Norfolk, England) complicates the roofing required on a reciprocal frame to nearly compelling madness. The eight hips not only step to create radial rakes, but they flare at the tops, absolutely and fully expressing the reciprocal framing within. While the Japanese use shoji screens within to fully expose the reciprocal framing, Graham Brown does the same on the outside of his buildings.

Popovic Larsen wraps up the reciprocal framing examples with a few remarkable buildings. The 12m-dia. Roundhouse in Brithdir Mawr, Wales, near Newport, looks like a log web built by Spiderhulk on hallucinogens. The builder was so certain that the authorities would not approve this zero-energy adventure that they only found out about it two years after he had moved in. (This building may already have been torn down, or perhaps has fallen down.)

The Gunn residence in North Garden, Virginia, designed by Fred Oesch and built by Bruce Guss of Fluvanna Woodworks, has an eight-membered reciprocal frame supporting an octagonal skylight (facing page). The design avoided roofing complexities by using the eight radial hips to support lighter and simpler common rafters above. The entire house seems to have been very professionally crafted and was raised with a decent crane—in fact, it looks like it could have been built by one of our own members.

My own efforts in reciprocal framing were on two ski house buildings in Vermont designed by Randall S. Walter AIA and built by Benson Woodworking. Randall's innovations included asymmetric knee braces, tipped posts and random window mullions, mimicking and celebrating the mountain skyline outside. The first reciprocal frame (not shown) was a safe set of ties between the purlin plates supporting the master bedroom common rafters. These, having supported themselves as hoped and having failed to break the budget, inspired a glass-roofed gazebo in the backyard (facing page). That remarkable retreat, "inspired," quoth Randall, "by growing trees and a canopy of branches," surrounded a noteworthy chimney that spiralled as it launched out through the classic hole left in the middle of reciprocally framed roofs. I learned on this structure another aspect of reciprocal frames, the potential for twisting. Most reciprocal frames are symmetric about a central vertical axis, which leaves them prone to rotation unless some form of circumferential bracing resists. Since the gazebo walls were to be screened, I knew that the walls were not going to prevent twisting. I considered braces, of course, but they were going to be both astoundingly compound and, if long enough, too intrusive for the design. We built the gazebo knowing that it might wiggle more than the glass roof might accept, but we had a Plan B in place. The light framing around the screened walls conceals steel moment framing.

Framing of Gunn residence in Virginia (2007), designed by Fred Oesch.

Gunn stovepipe opening is framed to accommodate planned chimney.

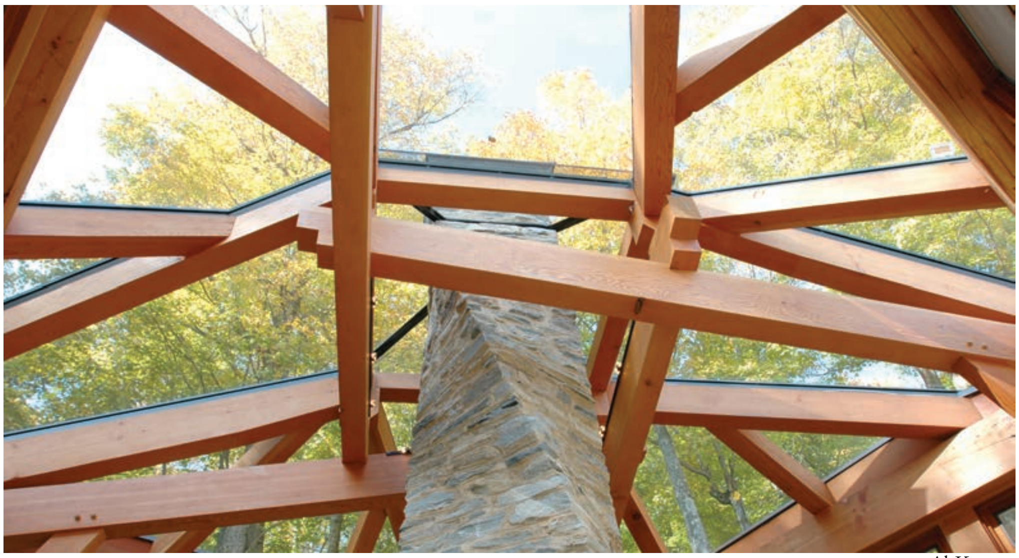
Reciprocal Frame Architecture concludes with an extremely rich set of references. There may be no telling how much money I am going to end up investing, through Charlotte Cooper, in books on this fascinating topic.

My summary thought on reciprocal frames, as informed by experience and by reading this book, is that there are enough compelling reasons to build them to overcome the fairly significant hurdles. They can be complex enough to warrant a computer analysis. The timber joinery is almost invariably complex and compound. Reciprocal frames share some behavior with domes and, like domes, the flatter the structure the larger the forces and stresses involved. The shear forces at the inner ends of catawampus hips can be significant, and the bending stresses at those joints can easily be the limiting parameter. While reciprocal frames have been built with green materials, the compound joinery and elegant geometry are perhaps better suited to dry, stable repetitive timbers. Reciprocal framers probably ought to establish an early rapport with the eventual roofers of their buildings, with whom they may share an intense relationship. Finally, the issue of circumferential stiffness must be considered.

I recommend this book, particularly to designers and engineers with a reciprocal frame project on their desks and to any timber framers still on their irresistible quest for another cool way to lose money.

—Ben Brungraber

R.L. Ben Brungraber, PhD, PE (ben@ftet.biz), after directing operations for 20 years at Benson Woodworking, Walpole, N.H., is now a principal in Fire Tower Engineered Timber, Providence, R.I.



Al Karevy

Above and below, glass-roofed reciprocal-framed gazebo in Vermont (2005) designed by Randall S. Walter AIA.

Randall S. Walter

Paedomorphosis

THE photos are of two recent projects, Weston House in Massachusetts and Unity House in Maine. Weston is a traditional design inspired by barn vernacular and has a full timber frame (or *timberframe*, as I will henceforth call it, and ourselves *timberframers* and the craft *timberframing*); Unity is a contemporary design with very few timbers and no real timberframe. For this journal's readers, the inclusion of Unity House may seem odd, but its lack of timbers supports one of my themes: as timberframers, the last several decades' worth of maturing and improving hasn't only sharpened our chisels and refined our structures; it has also led to the development of effective construction methods, good design principles and high standards for building performance. If we take the timbers away, the remaining attributes and characteristics that have come to typify our work as designers and builders may be more important.

And if we leave the timbers in, as with Weston House, the timberframe and most everything else about the house are likely to be radically different from their historical counterparts. Try as we might to do otherwise, our work today reflects us, our high-technology era and the good and bad of the culture we live with.

After listening to a talk I gave about our company's history, one of our very smart clients (they are all quite brilliant!) told me that the contemporary timberframe movement is akin to a concept from evolutionary biology called *paedomorphosis* (also *pedomorphosis*). He may be right. Paedomorphosis is a term coined by the marine biologist Walter Garstang in 1928 to explain how an evolution could escape from a blind alley. Arthur Koestler wrote about it fairly extensively. Two passages, the first from *Janus: A Summing Up* (1978), the second from *The Ghost in the Machine* (1967), get the idea across.

> The principal cause of both extinction and stagnation appears to have been over-specialization with its concomitant loss of adaptability to changes in the environment. . . .
>
> To put it simply, the phenomenon of paedomorphosis indicates that in certain circumstances evolution can retrace its steps, as it were, along the path which led to a dead end, and make a fresh start in a new, more promising direction.

Paedomorphosis is a useful concept. It's another way of thinking about the idea of paradigm shifts that Thomas Kuhn analyzed in *The Structure of Scientific Revolutions* (1962). It suggests that the process of change isn't necessarily transformational (metamorphosis), but instead can simply recreate something familiar in a new way. I'm already out of my area of expertise, so I won't push this too far, but I must admit that I like the implications relative to modern timberframing. Were we unwittingly driven by some deep genetic impulse? Have we been on an ambitious paedomorphic mission all these years? I don't know, but I'm flattered by the prospect.

In any event, paedomorphosis does reflect the idea that some of us had in mind when we started in the timberframe revival in the early 1970s. We intended to approach the work with modern tools and allow the timbers to be a prominent design feature. Mainly, it was our hope to use the timberframe as a basis from which to develop an improved building system. Just as a bridge is not normally the destination, the medium (in this case) wasn't intended to be the entire message.

I've been in business for 36 years, 34 of them with a focus on timberframe homebuilding. As a young carpenter, I had enough good experiences to inspire me to be a builder and enough bad

Patrick Ziselberger

Above, upper gable end of house under prefabrication in Walpole, N.H., shown completed on facing page. Below, using similar track system to construct wall panels for house in Unity, Maine, shown completed on facing page, lower. Both houses were intended to be high-performance buildings, including renewable energy systems (photovoltaic arrays and solar hot water).

Patrick Ziselberger

Anthony Tieuli

Weston House, 2008, designed by Chris Adams at Bensonwood, Walpole, N.H. Below, Unity House, also 2008, designed by Hilary Harris and Randall S. Walter at Bensonwood and Kent Larson at MIT's Open Source Building Alliance.

Naomi C.O. Beal

Naomi C.O. Beal

Unity House is designed for flexible use of space and exhibits a creative use of materials in a bright contemporary style.

experiences to be motivated to develop a viable alternative to conventional building methods. In an attempt to make a leap forward, I decided it might be useful to step backward.

My initial fascination with carpentry was probably simply an outgrowth of my innate impatience. I was a sucker for the immediate gratification of the work. When asked, "What did you do today?" I liked answering with a physical description of what specifically had been accomplished. (As builders, we are able to literally measure the dimensions and precision of the work achieved in any time period and know, with some objective certainty, that what we have constructed will have lasting effect.) I also liked the team sport of it, the action and energy of working with others to make buildings rise from piles of parts and pieces and raw materials. From the good carpenters, I learned to appreciate that dissatisfaction is healthy, and eventually accepted the continuous refrain that bounces back and forth between "not good enough" and "not fast enough."

But I also learned about how dismal the work of building can be. I spent some time as a framing carpenter in tract home developments. It stigmatized me about stick framing, causing me ever after to have difficulty appreciating its better possibilities. I am still stuck with the memory of the crudest possible work cultures: building sites polluted by a pounding rain of curses, insults and verbal pornography, and a pervasive coworker attitude that seemed to suggest that information was for nerds, communication for sissies, and therefore communicating information was jobsite heresy and nothing but profanity filled the air. Before I knew much of anything about building, I saw a place where shoddy workmanship was encouraged, making shortcuts and deceptions standard practice. ("It's %&*$#@ good enough! They don't %&*$#@ check that.") I saw—and was complicit in—homes being built like miners' shacks.

Later, I worked with carpenters who did excellent stick framing, but the damage was done; thereafter I was looking for a better way to build. This is what charged my interest in timberframing. I yearned for a building process that would be more directly defined by a disciplined craft, and I hoped for buildings in which a certain inherent beauty and durability would be a natural outcome.

I had become fascinated with early American timberframing and couldn't understand why it had been abandoned. If it had proven to be labor intensive and inefficient in the days of hand tools, why wouldn't it fare better in the age of electric power tools and powerful material-handling equipment? And if the old-style timberframe house—with its typically poor insulation, low ceilings and dark spaces—was obsolete, then what about a modern version with expanses of glass, open living areas and superefficient insulation? I essentially squinted hard and saw timberframing as a structure upon which to build a bridge to the future of homebuilding, not as a reversion to ancient methodologies.

I did some trial projects in 1974–5 and by 1976 I was a full-time timberframer. I soon discovered that my idea was synchronous with a few others who had also started to timberframe at about the same time. By the late 1970s, scattered timberframe revivalists were communicating regularly about projects and progress. In the early 1980s, we founded the Timber Framers Guild to help support and encourage each other and the growing ranks of new enthusiasts and professionals.

Timberframing has indeed proved to be an excellent basis for rethinking and reinventing a building process. While relearning elements of the craft, we've invented and innovated much about process and about whole-house systems. What has emerged after decades of development has its own identity, vastly different from its historical antecedents, and it is not constrained by the loggerheaded assumptions of the more dominant conventional methods. We've been in the fortunate position to borrow processes and ideas from anywhere in the world and from any time in history, and then layer on the best of today's knowledge. The constraints are only in our imagination and abilities. The challenge of recreating an ancient building for the needs and aspirations of 21st century homeowners has led us to be primarily forward thinkers and innovators by necessity, if not by inclination. And it's certainly not all about the timbers. Here are a few things we've learned and developed along our paedomorphic journey.

1. The discipline of off-site fabrication of exacting building elements is a solution in itself. Contemporary timberframers have become masters of prefabrication. One of the significant decisions made in the early days of rediscovering the craft was to move the cutting and shaping operations indoors where efficiency and quality could be better controlled. The specific manner in which the work happens greatly defines our businesses and our competitive differences. We are learning that the same skills and procedures that allow us to assure highly precise fits in timbers miles and miles from where the assembly will take place are easily transferred to other building units, such as panelized floor, wall and roof sections. Step-by-step, we are getting the entire construction process out of the mud.

2. "Virtual before actual" is the modern equivalent of "Measure twice, cut once." Advanced CAD software improves quality and efficiency. One of the challenging skills of timberframing is visualizing the individual pieces in the context of the entire framework. It can require some fairly high-level mental gymnastics to be able to properly lay out an individual timber by looking at 2D plans and elevations. Before 3D software was truly helpful in conventional building, it was a great boon to timberframers. Now that we are lead users of 3D architectural software, we have the tools in our hands to model not only the frame, but also every other detail in the building, from finishes to mechanical systems. In other words, we build it before we build it, with great advantages to the homeowners and the construction team. These software tools are improving quality, reducing errors and increasing efficiency.

3. Applying advanced tooling to the building process can help to make buildings better and more affordable. Twenty-first century manufacturing technologies and processes make it possible for many industries to improve overall quality and lower costs. The secret to this apparent magic is technology, much of which is focused on eliminating repetitive and dumb work. Since timberframers usually ply their trade from off-site facilities with the opportunity for fixed tooling, they are also prone to invest in systems, jigs and tools that help to improve production and enhance quality. Everything from large, automated tools to basic Lean Manufacturing strategies are being employed to keep the quality in and get the wasted effort out. This wouldn't be notable if the industry were not so behind in adopting the methods and innovations other industries have long taken for granted.

4. Buildings are better when there is evidence of well-executed and visible craft. Not all buildings can have a handcrafted timberframe, nor should that be the goal, but we know that good work matters. Whether drywall or tile or stair building, there's broad territory between craft and hack that infuses the building with its standard, for better or worse. Architecture and the crafts and trades of building should not be separated. A mutual respect and sharing of intentions, ideas and capabilities is how the best possibilities emerge. Timberframers and designers are usually closely aligned out of necessity, and the experience has given us a deep understanding of both the problems that can arise from lack of integration and the opportunities that are possible when designer and builder work in concert. We have learned that both designing and building involve teams—not individual efforts or egos—to the benefit of all. Good workmanship can help to heal bad design, but bad workmanship ruins anything.

5. Sustainability means durability. The design and construction goal should be projected in centuries, not decades. One of the inspiring aspects of timberframing is the certainty of very long life. Two hundred years is not an uncommon age for existing timberframe buildings in this country, and it is not at all hard to visit buildings 400 or 500 years old overseas. With better knowledge of materials and engineering, we ought to attempt to do at least as well. It's not possible to know whether a building will do well over time, but just the intention of longevity tends to have a powerful effect on quality. The absence of any such intention does, too.

6. In sustainable buildings, shell and infill are respectively static and dynamic. These elements should be designed and built accordingly. Timberframers commonly know about a lot of old buildings because surviving structures often contain unique information and inspiration. If you know the history of old buildings, it becomes evident that the pace of change to the building's exterior shell is quite different from the occupant-initiated churn that happens to the interior. Two examples: an Internet cafe I visited in Italy turned out to be in a building constructed in the late 1300s; the home I grew up in was built in 1895 for a gold magnate's sister, later became three apartments and later still housed 11 raucous children and two saint-like parents. Both buildings obviously have been reconfigured and remodeled and absorbed various mechanical systems and technology, yet both belie these changes on the exterior. One of the biggest ideas we can bring to the conversation for improving buildings is to develop ways in which shell and infill can be designed and built to respect and facilitate both the stasis and the change we intend.

7. With a more symbiotic relationship between structure and insulation, all homes can be energy misers. Structure and insulation can be separated, with benefits to energy efficiency and potential building durability. One of the most urgent aspects in the early days of rethinking timberframing was insulation. If we simply copied the old buildings, our attempt for viability would have failed. It needed a new approach. The first step was to separate the structure from the insulation, which had inherent construction efficiency as well as thermal benefits. The second step was to use rigid foam insulation and insulated panels (originally known as stressed-skin panels) to eliminate thermal bridges and structural redundancies. These developments have made timberframes among the most remarkably energy-efficient structures being built on a regular basis. While we do not expect that all buildings will be built in exactly this manner, what we know for certain is that a much better standard for all buildings is possible. There's a fundamentally simple solution: develop systems that complement and support one another rather than cause conflicts and compromises.

Hilary Harris

Weston House, inspired by several barns in the area, reflects agricultural influences in its traditionally framed interior.

8. A beginning of the definition of a better way to build is more challenging and uplifting work. The central part of the mission statement of our company is "Through process and product, to improve people's lives." It has double meaning. By our work, we are striving to improve the lives of our clients. It is our fervent hope that they and future generations will deeply benefit from a building with deep attributes. But it is also about us. Through the work and the manner in which we do it together, we are also trying hard to ensure that our lives are made better. These are two sides of the same coin. Whether the work is done in a shop setting or on site, we have an imperative to develop entire processes that engage the head, heart and hands of those who are doing the actual building. When all work is blind compliance, the soul of it is lost. There is no bettering the building industry and no hope for consistently better homes, unless we conceive of a system in which the process lifts the practitioners of its crafts and trades, so that the product can lift its occupants.

ON our paedomorphic journey, much of what we've learned was already known, but had been forgotten. The oldest surviving book about design and building was written by the Roman architect Vitruvius over 2000 years ago. His proposition was that good buildings are balanced compositions of function, strength and beauty (*utilitas, firmitas, venustas*). When buildings are conceived and built in this manner, they are also sustainable because they are loved for their beauty and appreciated for their usefulness, and they survive the rigors of time because they are resilient and strong. The Vitruvian principles are about results, not methods.

The final lesson from the theory of paedomorphosis is that deepening ruts ultimately go nowhere, that continual flexibility and adaptability are keys to relevance and survival: change is constant; we are either its beneficiaries or its victims. —TEDD BENSON

Tedd Benson (tedd@bensonwood.com) is a Company Steward with Bensonwood, Walpole, N.H.

Four Portable Chain Mortisers

PORTABLE chain mortisers are machines designed specifically for timber framing. Powered by electric motors, they use chains with sharpened teeth running on a bar to produce rectangular holes in wood. Because of their limited production, mortisers are expensive but, with the ability to complete a mortise in minutes, their cost can easily be justified in time savings.

Mortisers in this Review. Four different mortisers were evaluated in this review—the Hema 7KS15, the Mafell LS103, the Makita 7104L, and the SwissPro KSP16. (A fifth mortiser on the market, the ProTool CMP150, differs from the Hema only in name plate.)

The Hema and Mafell are sold as slotting machines that can be upgraded to mortisers by adding an optional mortising base and fence. For this review, the base-and-fence option was added to these machines, making them comparable with the standard configuration of the Makita and SwissPro.

Cross-Grain vs. With-Grain Cutting. The manufacturers of these mortisers have taken two different approaches to cutting wood. The Hema, Mafell and SwissPro machines all cut across the grain. The counterclockwise rotation of their chains pulls a fence inward toward the timber. This design keeps the machine stable during the cut and no clamping is necessary. There is no lunge at all upon entering the wood, an advantage of cross-grain cutting.

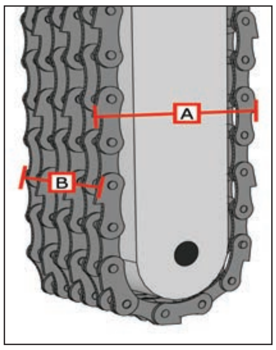


Fig. 1. Relevant bar and chain measurements.

The combined bar width and chain size (A in Fig. 1) of the cross-cutting machines dictates the minimum width of the mortise. Sizes of 1½ in. and 2 in. are available for the North American market. By sliding the machine's fence along the timber and plunging, a mortise of any length can be easily cut.

The Makita mortiser, by contrast, cuts with the grain and must be clamped to the timber to work safely. Its built-in clamping system works well yet requires more setup than the cross-cutting machines. Since the bar is oriented with the grain, the Makita's chain width (B in Fig. 1) determines the minimum mortise width. The supplied chain is 18mm (others are available from 15 to 24mm), or a little under ¾ in., so most mortises require the cutting bar to be repositioned across the timber for a second plunge (and a third plunge for a 2-in. mortise). The clamping system provides a lever mechanism to move the bar an adjustable, repeatable distance between near and far edges of the mortise, with a screw for fine adjustment or obtaining an intermediate position. Mortise lengths up to 5⅛ in. can be cut from one clamp position.

Setup and Maintenance. The set-up of chain mortisers is straightforward—install the bar and chain, set the chain tension and, for the Mafell and Hema, attach the mortising base. Tensioning the chain is easiest on the Mafell, since its sprocket cover doesn't have to be removed and the two Allen wrenches needed are stored in the handle.

Periodic maintenance is focused primarily on the chain. On a daily basis the chain should be cleaned, sprayed with a lubricant designed for cutting chains (a can of lubricant is included with the Hema, Mafell and SwissPro) and checked for proper tension. In addition, Mafell recommends that its chain be bathed in thin oil every two hours.

The Hema and SwissPro mortisers require greasing the bar and nose roller. These machines have a brass cap attached to the bar loaded with a lithium-based grease. Tightening the cap forces grease into the bar and nose roller (SwissPro recommends tightening the cap after every 15 minutes of use). The cap needs to be refilled periodically with grease.

Electrics. All of the mortisers are amply powered, with electric motors ranging from Makita's 1.9 hp to Mafell's 2.8 hp. Mafell and SwissPro provide 110v and 220v models, while the Makita is 110v only and the Hema is 220v only.

The Mafell and Hema come equipped with 30 ft. of cord while the Makita has 16 ft. and the SwissPro 10 ft. The 110v Mafell unit ships with a plug that works only in a 20-amp receptacle (horizontal and vertical terminals). The Hema ships with a curved-terminal 220v plug. The plugs on both units can be easily changed (they are the screw-on type) but, with machines this expensive, you'd expect the retailers to supply more popular plugs.

Ergonomics and Safety. All of the mortisers are fairly heavy machines, ranging from the 30-lb. Mafell to the 37-lb. Makita. All are well balanced when lifted using their handles, but there are significant differences in the on-off switches. The Makita does not have a safety on its switch and it's possible to accidentally turn the machine on when lifting it by the operating handles (the Makita should instead be lifted by its fixed handle on top of the motor). The SwissPro's safety is not thumb-operated like the rest and is a bit awkward to use.

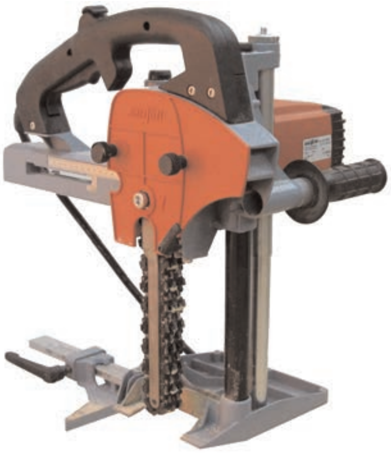
Depth Stop and Fence Settings. All four machines are equipped with stops to limit the depth of cut. Only the SwissPro includes a gauge in inches, although its ⅛-in. graduations are not much differentiated (Fig. 2), making them difficult to use if you lose sight of the inch marks. The Makita has centimeter graduations. The Mafell and Hema stops must be measured with a ruler or tape.

The Hema, Mafell and SwissPro all have fences that control the distance of the mortise from the edge of the timber. Like its depth gauge, the SwissPro's is the only fence with a gauge in inches (increments in sixteenths). The SwissPro also includes a unique and innovative registration plate (Fig. 3). This plate is sized to match the bar-chain size (1½ or 2 in.) and allows the mortiser to be registered to the limit lines of your mortise. Mortise left edge, right edge and distance from timber edge can all be set by sight before starting plunges. Unfortunately the plate on the SwissPro evaluation unit was misaligned to the bar, limiting its immediate usefulness and requiring mental calculation at each mortise.

All photos and drawings Ben Weiss

Fig. 2. SwissPro's inch graduations.

The Hema and Mafell fence gauges have their own problems. Their gauges are inconvenient (Fig. 4) because of alignment scales



Mafell LS103/FG150. **Light, fast and easy to use. Plunging smoothest in group, though chip-out can occur when retracting carelessly. Accurately sized chain for US mortises. Fence gauge confusing; no depth stop gauge. Most expensive.**

Hema 7KS15/15M. **Plunges and retracts smoothly. Slightly undersized chains "allow for" chisel clean-out after the cut. Fence gauge referenced only for European chains; no depth stop gauge. Available only with a 220v motor.**

SwissPro KSP16. **Only mortiser with scales fully adapted for US market. Innovative scribe plate makes mortise alignment fast and easy. Smooth plunging with gas spring return; exhaust from motor keeps chips at bay.**

Makita 7104L. **Most popular, least expensive mortiser on US market. Only one to cut with grain, yielding flexible mortise widths but making bulky clamping system a necessity. Gets job done, but slow and difficult to use.**

based on metric bar-chain sizes (30, 35, 40 and 50mm on the Mafell and 40 and 50mm on the Hema). After establishing desired fence settings by trial and error, I wrote them down and taped them to the motor for future reference.

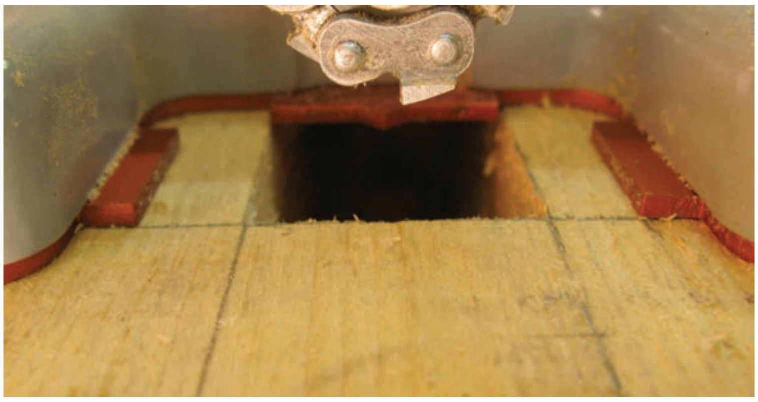


Fig. 3. SwissPro's registration plate aligns at mortise ends and width.

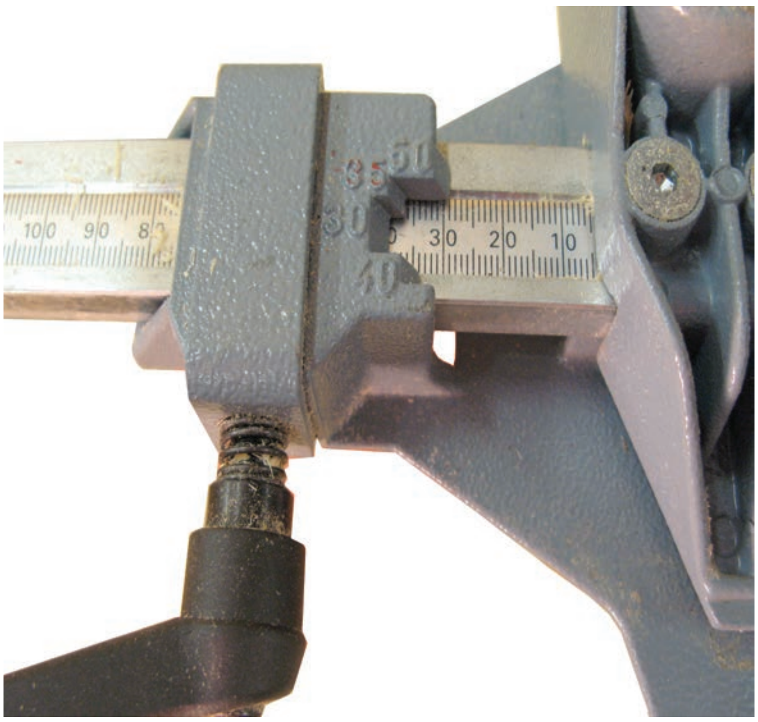


Fig. 4. Mafell's fence gauge, above, and Hema's require translation to inch measure; the four pointers are not coordinated with US chain size.

Since the Makita clamps to the workpiece, its effective fence setting, fore-and-aft range and length of cut are all established at once.

Plunging and Chip Extraction. Only subtle differences distinguish the plunging of the Mafell, Hema and SwissPro. All three of these machines provide some resistance when plunging and some assistance when retracting, helping you regulate the plunging speed. The Mafell plunged the easiest, with the Hema and SwissPro being comparatively a bit stiff.

In its fully extracted position, the Makita motor and cutting bar are suspended on a hook. When released from the hook, the Makita free-falls, requiring the operator to take its weight and lower the moving chain into the work, after which gravity assists the descent of the chain. The penalty is that the Makita doesn't help you extract the chain from the mortise. The operator must lift the heavy cutting head and return it to the hooked position.

The SwissPro excels in chip extraction, keeping the top of the timber virtually free of chips by feeding exhaust air from the motor into its chip chute (Fig. 5). The Mafell and Hema do a fair job of chip extraction, until their chutes clog up, which happens quickly when cutting green timbers. The Makita, ripping along the grain, leaves its curls in the mortise or on top of the timber.

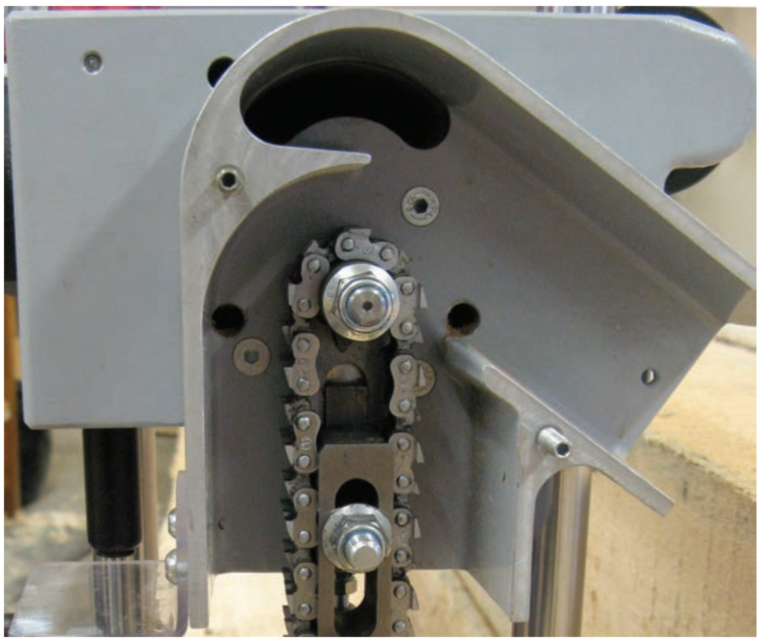


Fig. 5. SwissPro's generous dust chute is kept clear by steady breeze from motor fan sent through top of chute.

Quality of Cut. Since the inside of a mortise is never visible, I don't put a lot of importance on smoothness of cut, with two exceptions. First, one edge of the mortise shows at barefaced tenon brace joints and both edges at through mortises, so controlling chip-out there is important. Second, the amount of chisel cleanup required after putting aside the mortiser can affect your overall efficiency.

A fair analysis of cut quality was difficult when using the demo machines because some chains were sharper than others. The SwissPro yielded the smoothest mortises, but it was also the only machine with a new chain. Cutting white pine, I found chipout to be a problem with all of the cross-cutting machines (but not with the ripcutting Makita) when extracting with the chain running. But this problem is easily solved by letting the chain stop before extraction. The Hema and SwissPro cut mortises smaller than their nominal bar and chain size, making some chisel cleanup necessary. Hema advertises this as a feature. Personally, I use a chain mortiser for speed and don't want to spend additional time cleaning up.

Mortising with the Cross-Cutting Machines. The mortising procedures for the Hema, Mafell and Swiss Pro are naturally very similar. After the mortise is marked and scored, the first step is to set the depth stop. Since these machines leave mortises with rounded bottoms (Fig. 6) you need to add ½ in. to your required depth or plan on removing the fillets with a chisel. The chain of the mortiser should be touching the timber when setting the depth stop.

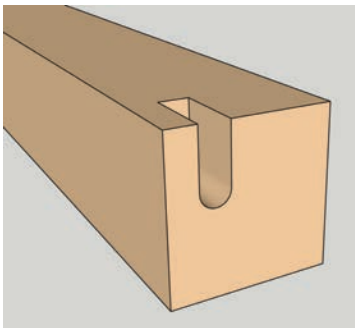


Fig. 6. Cross-cutting machines leave rounded-bottom mortises across the grain.

The next step is to set the fence, establishing the distance of the mortise from the timber edge. Since the Hema and Mafell lack an inch scale, and you can't confidently sight the cutting limits of the chain, partial plunges in the middle of the mortise are necessary to establish an accurate fence setting.

The final step is to make the plunge cuts. I like to cut the ends of the mortise first, taking care. The material between the two ends can then be removed quickly, without worrying about cutting too far (Fig. 7).

Fig. 7. Cross-grain mortiser (here the Mafell) has fixed width of cut, adjustable distance from edge and no limit on mortise length.

Mortising with the Makita (with the Grain). Cutting mortises with the Makita is quite a bit more complicated. After the mortise is marked and scored, the first step is to position the machine to cut the right-hand end of the mortise and then clamp it to the timber. The clamp has a quick-adjust jaw to set to the width of your timber and a lever to apply the pressure.

Next, the depth stop should be set. Since the Makita cuts with the grain, the cheeks of the mortise will be flat right to the bottom, and the depth stop can be set to the actual mortise depth. But the depth setting is complicated by the fact that the machine's cutting head can be pivoted to two angled positions (Fig. 8). The angled cuts allow the mortise to be lengthened without moving and

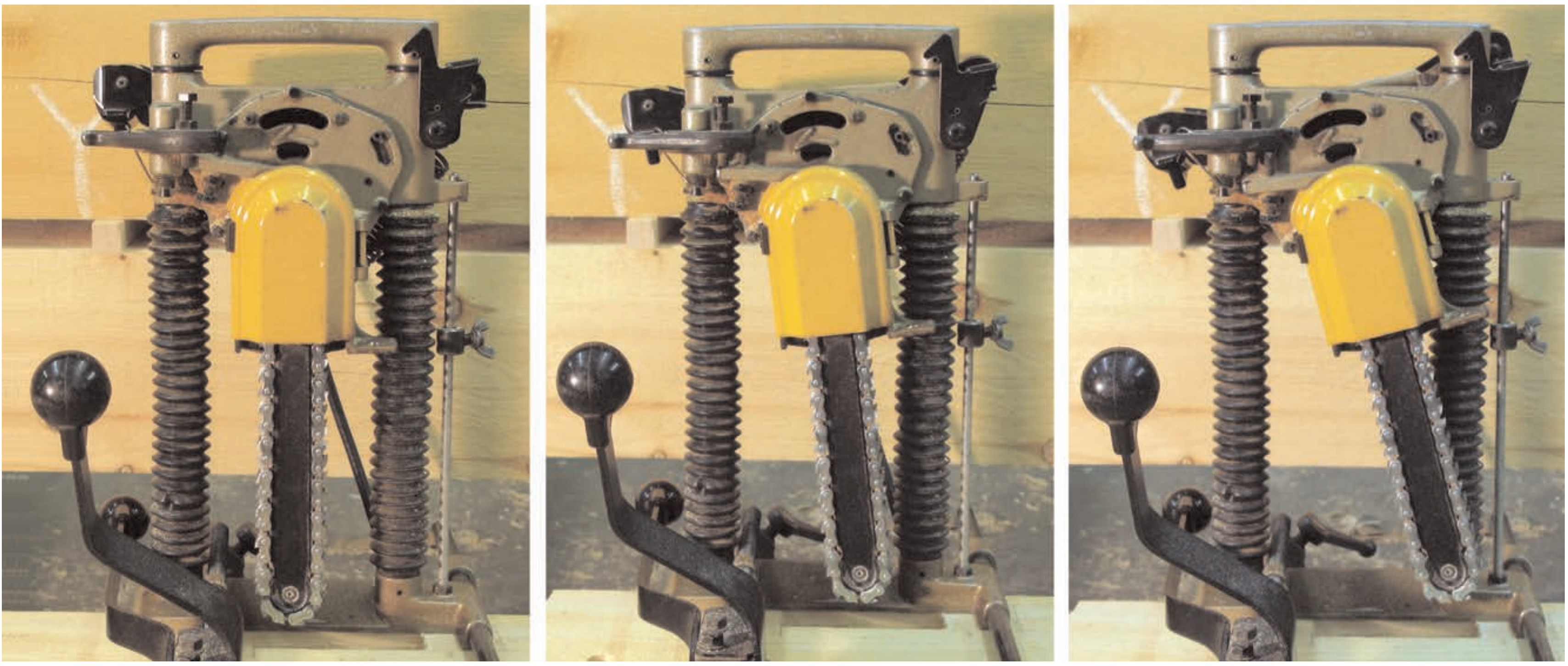


Fig. 8. Makita mortiser operation steps. Total range is a bit over 5 in. from a single clamping position.

	Hema 7KS15/15M	Mafell LS103/FG150	Makita 7104L	SwissPro KSP16
Weight	33 lbs.	30 lbs.	37 lbs.	31 lbs.
Motor	2.68 hp	2.81 hp	1.93 hp	2.68 hp
Power supply	220v	110v or 220v	120v	115v or 230v
Trigger safety	Yes	Yes	No	Yes
Cord length	31 ft.	32.8 ft.	16 ft.	10 ft.
Cutting orientation	Cross-grain	Cross-grain	With-grain	Cross-grain
Chain width	28mm	28mm	18mm	28mm
Bar–chain size	1½ or 2 in.	1½ or 2 in.	1 15/16 in.	1½ or 2 in.
Max. cutting depth	5 7/8 in.	5 7/8 in.	6 1/8 in.	6 3/8 in.
Bar greasing required	Yes	No	No	Yes
Chain adjustment	Good	Excellent	Good	Good
Chip extraction	Fair	Fair	Fair	Excellent
Instruction manual	Good	Fair	Fair	Good
Depth gauge	No graduations	No graduations	1cm	1/8 in.
Fence gauge	½cm	1mm	No graduations	1/16 in.
Fence type	Sliding rail	Sliding rail	Clamp	Sliding rail
Spring plunge/retract	Yes	Yes	No	Yes
2009 US street price	$3,090	$3,946	$1,275	$3,410

Sources

Mafell N.A. www.mafelltoolstore.com 888-736-3812
- Mafell LS103

Timber Frame Tools www.timbertools.com 800-350-8176
- Hema 7KS15
- SwissPro KSP16

Timberwolf Tools www.timberwolftools.com 800-869-4169
- Mafell LS103
- Hema 7KS15
- Makita 1704L

reclamping the unit, but unless the depth stop is lowered to compensate, the angled cuts will be too shallow. A reasonable tactic is to add ½ in. to the depth of cut to begin with (as we did with the cross-cutting machines) and not readjust the depth stop for angled cuts.

The next step is to align the cutting bar to the front and back edges of the mortise. Equipped with its standard 18mm chain, the Makita can be set up for cutting 1½ in. mortises by properly adjusting the travel distance setscrews.

Now the machine is ready to make six plunge cuts (Fig. 8). The initial cut is vertical, followed by two angled plunges, accomplished by pivoting the bar to the first and second preset angle positions. After returning the bar to its vertical position, it is cranked over to the far edge of the mortise using the width enlargement lever. If you require mortises longer than 5⅛ in., you will need to unclamp, reposition and repeat the plunging process. The final step is to square up the rounded ends of the mortise bottom with a chisel. You may have some cleanup also on the angled plunges. Or you can make the mortise sufficiently over-deep to avoid all handwork after setting aside the machine.

AUTHOR'S CHOICE. After using all four of these machines to make a variety of different mortises, significant differences become apparent. If you are looking for the fastest and easiest machine to use, one mortiser stands out. The Mafell LS103 (with FG150 mortising stand) is a well-designed machine that's a pleasure to use. It's the lightest and most powerful in the bunch, but its refinements are what really separate it from the contenders, including ease of plunging, comfortable controls and simple maintenance.

Honorable mention goes to the SwissPro KSP16, for its inch scales on fence and depth stop and its innovative features, including chain-alignment plate and exhaust-aided chip ejection.

The Hema 7KS15 (with 15M mortising stand) has many similarities to the Mafell, but it's only available with a 220v motor, limiting its versatility. The Makita 7104L is the most affordable machine (a third the price of the Mafell), but it's more complicated and time-consuming to operate than all the other mortisers, especially when mortises longer than 5 in. are required. —Ben Weiss

Ben Weiss, an enthusiastic newcomer to timber framing, has a website, www.frame1.org, where he reports on his progress and discoveries.

Caribbean Timber Framing

THE islands making up the long fishhook-shaped chain beginning at Cuba, 90 miles south of Florida, and ending a few miles north of the coast of Venezuela with Trinidad and Tobago, vary in size, culture and history. Until visited by 15th-century sailing expeditions from France, Spain and England, among other countries, some of the islands were uninhabited. Others such as St. Kitts (at first called St. James, then St. Christopher by the Europeans) supported an indigenous population long before European discovery and colonization. A century-long struggle between the native Kalinago peoples (themselves not the first people of the islands) and Europeans culminated in the 1626 Kalinago genocide at Bloody Point on St. Kitts.

While little documentary history exists of the development of the islands, remains of many early structures are to be seen. Stone forts, sugar mills, lime kilns and churches dot the landscape. Even more surprising are the wooden houses that have borne the savage storms each season from June through November. We need only remember Hurricane Katrina and the vivid images it left in our collective memory to imagine the damage such storms can bring to an island. When we encounter a 250-year-old or even older island wooden structure, we have to marvel at the ingenuity of the settlers who sought out protected harbors and building locations and built timber frames that have stood intact over centuries of violent weather.

Timber framing was a well-known and developed craft in Europe and the British Isles by the time these islands were settled. Many of the islands had scarce resources. Virtually everything had to be shipped in for European colonists to be able to settle and live. Economy of materials and the strength of its joined structural skeleton made the timber frame a natural choice for houses and other structures, since materials and labor, even if performed by slaves brought to the islands, were both scarce and costly. (Many slaves were shipped in to the islands, including 25,000 Irish during the 1650s, but their keep was costly compared with that of slaves on North American plantations, which could easily produce the necessary sustenance.)

The timber frames remaining on the Caribbean islands exhibit appropriate adaptations to their environment. The warm island climate allows an exposed and finished frame on the interior, without a finished wall surface such as the plaster used in colder climes. Lacking the need to bear up under heavy snow loads, frame members could be smaller in section—but, since the buildings had to withstand terrifying storms, roof wind-bracing reached a developmental stage here not typically seen in mainland structures.

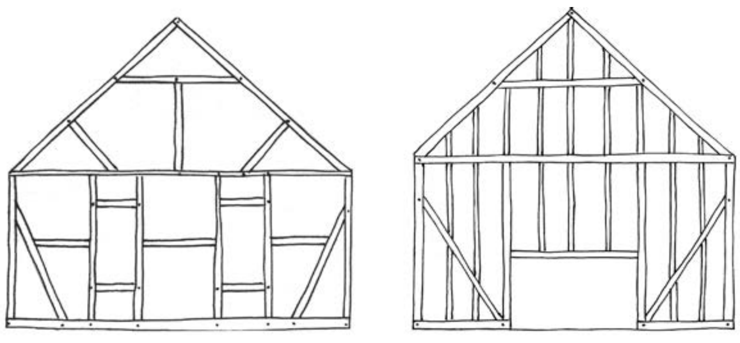
As far as I know, no typological survey of timber frames has been undertaken throughout the islands. There are many intriguing survivors. In 1996 when I first visited Antigua, I went to the island's only national historic park, Nelson's Dockyard, in the English Harbor Historic District. Within this unique collection of late 18th-century and 19th-century structures is Admiral Nelson's house. When I first walked inside the small structure, its window openings not glazed but shuttered, I was pleasantly surprised to see the framing exposed, hand planed, beaded and painted white. Since then I have seen dozens of structures on many different islands. (I have also examined several early timber frames in Guatemala and Nicaragua.) In February 2008, my wife Mary Jo and I explored St. Kitts in the Leeward Islands, and in particular a ca.-1760 framed rectory we found there. After leaving St. Kitts, we traveled the narrow roads of Nevis, its smaller sister island about two miles away across a shallow channel, where we found a building with an unusual braced roofing system dating between 1750 and 1770.

St. Kitts is home to the first Anglican Church established in the Eastern Caribbean islands. The Middle Island Anglican Church was organized in 1623 by John Feathley, a Fellow of All Souls, Oxford, under the direction of the first governor of the island, Sir Thomas Warner. There has been a continuous presence on the site since then, though the original buildings have long since been replaced. Both Warner (d. 1640) and Captain Samuel Jefferson (d. 1649), the great-grandfather of Thomas Jefferson, are buried in the small graveyard on the grounds of the church under large carved slabs of stone. A carved stone tablet set into the main façade indicates the current church sanctuary structure was erected in 1880. It stands just to the leeward side of a shallow sloping hill on the southwest side of the island. The Atlantic Ocean lies on the other side of the island and the hilltop provides some protection from prevailing winds.

A timber-framed rectory (possibly a former church) stands about 100 yards west of the stone sanctuary and slightly lower on the hill (Fig. 1). The long side of the building faces east, toward the sanctuary. The main part of the frame measures 21x64 ft. approximately. A small entrance vestibule of 8x12 ft., appended to the south gable end, is accessible by a long set of stone steps and a small landing. Set off the north end of the west side is a framed ell, living quarters for the priests. The main portion of the building was open and, though poorly maintained, obviously still in use. It may have served as a church building in the 18th and during much of the 19th century.

Dating the Building. It's likely the rectory's timber frame was constructed between 1760 and 1765. The style of the frame, trim and hardware indicate 18th-century origins, and in the details the date can be refined. Using associative architectural research, I compared the St. Kitts rectory with a dated British colonial building in North America and found nearly identical molding profiles, joinery, framing techniques and hardware.

The sketches below indicate the close resemblance between the St. Kitts rectory and the earliest portion of the Clermont farmhouse, Berryville, Virginia, a representative mid-Atlantic frame. Except for their timber sections, these two buildings exhibit nearly identical framing styles. The latter building has been dated to 1760–1770.



St. Kitts Anglican Church rectory endframe at left compared with ca.-1765 Clermont house frame in Berryville, Virginia.

Foundations and Floors. Built high off the ground of cut volcanic stone fully bedded in lime mortar, the foundations are in very good condition (Fig. 1). Large built-in ventilators allow for ample air flow under the structure to keep the framing dry. Heavy stone piers carry sawn floor girders at midspan between the sidewalls supporting the 4x8 wood joists (Fig. 2).

Fig. 1. St. Kitts rectory, ca. 1760, from southeast. Note shingled end with decorative treatment under rake and contrasting clapboards (planed and beaded) on eaves wall, whose doors open onto a stone terrace. Graceful ironwork and skilled stonemasonry are in good condition.

Fig. 2. Sawn girder and joists under rectory. Despite apparent ventilation, a radiating fungal decay has infected girder and joists.

All photos and drawings Douglass C. Reed

Fig. 3. Matched room-length yellow pine floorboards butt-joined under a partition.

The flooring on the main level is a single layer of tongued-and-grooved 1-in. yellow pine boards fastened to the joists with T-head hand-wrought nails. Each room is floored with single-length boards butted under partition walls (Fig. 3).

Fig. 4. St. Kitts rectory wall framing is as light as possible, with intermediate girts and horizontal sheathing used to stiffen the studs. All connections are pinned mortise and tenon. Some tie beams appear to lap over wall plates, as in Fig. 7, others join flush as in Fig. 8.

Wall Framing Details. The main frame of the rectory is made of scribe-ruled pine timbers, probably the same species as the flooring and probably shipped in to the island. The framing is all visible inside the finished structure and all exposed edges were beaded. Every structural framing member is carefully trued and finished with hand planes. The joinery is simple but expertly fashioned for neat fits (Figs. 4 and 5).

Roof Framing. The roof is framed in paired and collared common rafters joined at the top with an open mortise and tenon joint. The collars were higher than midway up from the top plate, their ends tenoned into the underside of the rafters. The lower ends of the rafters are birdsmouthed over the top plates, likely secured with wooden pegs to the top plate (Figs. 5–8).

Doors and Windows. Often the hardware in a building is the most precisely datable material. Doors and windows and their casings are the next most datable features. In the rectory, doorlocks matched hardware in use in 1760s colonial North America, and the rectory's door casings were mitered in the same fashion as those seen in the mid-Atlantic colonies from the period. Fully mitered casings such as shown in Fig. 9 were replaced with a more complicated miter after ca. 1775 and used until ca. 1880.

Fig. 5. Wall post subsided from termite damage in sill, mysteriously splitting wall sheathing; plate and rafter held up by roof sheathing.

Fig. 6. Rectory roof framing comprises paired, collared rafters with mortise and tenon joinery and all members planed, beaded and painted.

Fig. 8. Corner bracing is thorough, with relatively long down braces for the walls and short ties for the endwall and sidewall plates. Wall braces are further stiffened by intermediate girts.

Fig. 7. Tie beam at some locations apparently laps over wall plates, though joint is invisible.

Fig. 9. Rectory double-fielded door casing. By 1775, miter for interior field and square cut for outer field had replaced full miter cut.

Fig. 10. L'Ermitage, Nevis, ca. 1770, thought to be oldest standing wooden house in Caribbean Islands. Masonry structure at left is part of rainwater collection system.

L'ERMITAGE. St. Kitts's neighboring island of Nevis is home to the plantation known as L'Ermitage chartered in 1680, with an early timber-framed house on the grounds (Fig. 10). The best dateable evidence in and on the building indicates a range from 1740 to 1780. (I believe the actual date for the building falls in the 1770s.) Traditional island lore holds that L'Ermitage is the oldest surviving wooden house in the Caribbean islands. In any case, it is a beautifully executed timber-framed structure built from native lignum vitae, one of the densest of all woods at about 84 lbs. a cu. ft. (dense white oak is 47), unfortunately now extinct on the island. The lignum vitae frame appeared sound and termite free, with no visible rot or repairs.

Like the framing of the rectory, the timbers of L'Ermitage were converted by a method now invisible to us because of the finishing of the timbers. Again trued nearly perfectly, here the very hard wood was planed as smooth as glass in most areas, cured with almost no visible checks, beaded on exposed edges and assembled with perfectly executed joints.

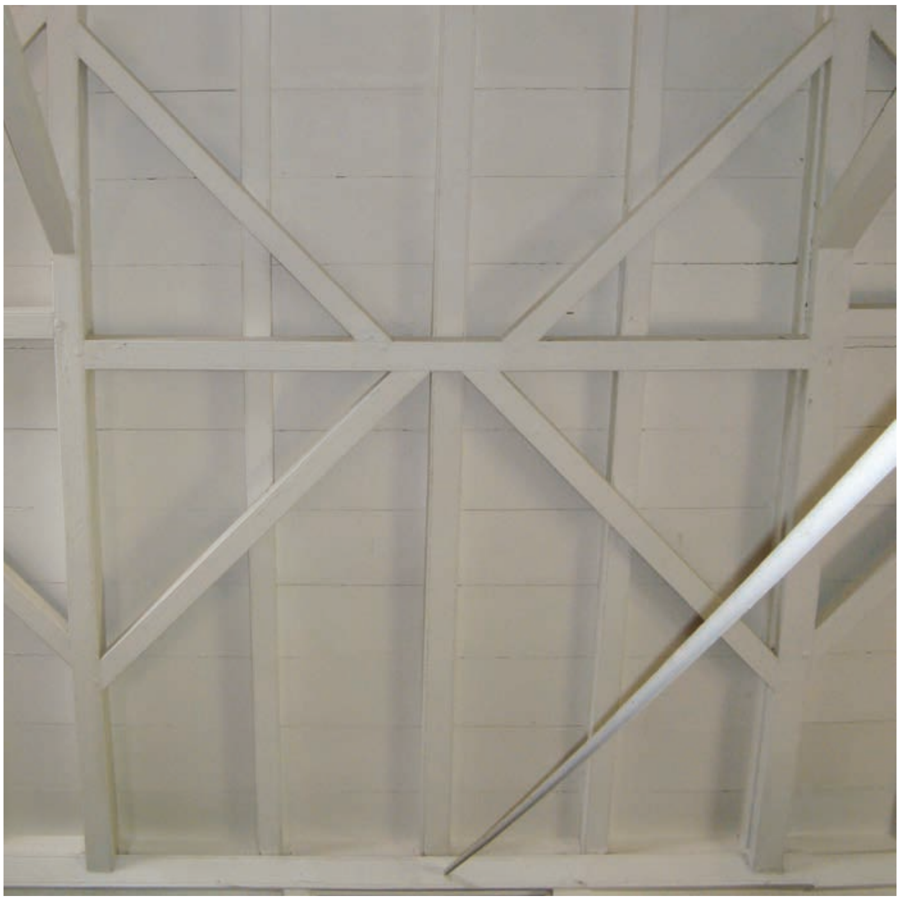
The structure of Nevis's L'Ermitage is very similar to St. Kitts's rectory, but the roof framing, particularly the significant bracing, is different. The rectory's roof is a common rafter system with collars set fairly high on the rafters. The L'Ermitage roof is composed of principal rafter trusses with purlins and common rafters. Set flush with the bottom side of the principal rafters and purlins is a series of braces forming near-*X*s between principal rafters on both slopes of the roof (Figs. 11–13).

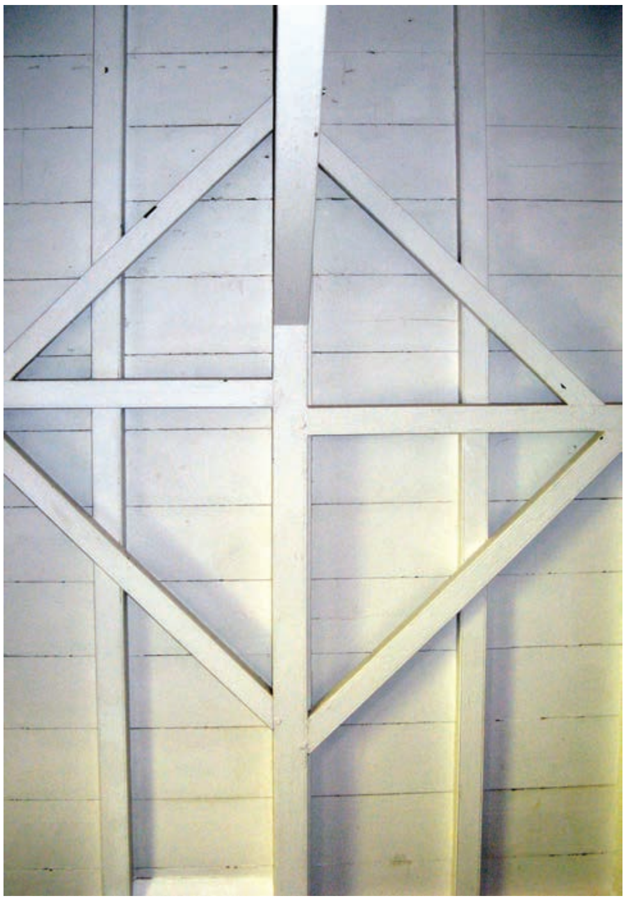
If differently framed in the roof, the rectory and house frames described are otherwise similar in joinery and bracing, and particularly in timber sections. Mid-18th-century hardware and molding details similar to theirs can be found in other Caribbean buildings and along the eastern seaboard of North America. Yet, as was natural in the American colonies from one climatic region to another, the mid-Atlantic characteristics of the Virginia frame, relatively heavy timbers and closed-wall construction, are different from those of the Caribbean islands. The colder climate of the mid-Atlantic region inevitably required insulation, most commonly provided in the form of "filling-in" or nogging, and generally plastered interior walls to seal the interior against unwelcome drafts and keep warm air inside during the winter months. The smaller, more delicate-looking, decorated and exposed timbers in open wall constructions that we have seen in our two island buildings were regional adaptations to the very warm climates of the Caribbean, which did not include the problem of snow loads.

The sheathing boards found in both structures indicate tree diameters of at least 12 in., either native to the islands or shipped in. But in Nicaragua and Guatemala, not all that far by sea, there are very large trees, and millions of acres of them, and still I have never seen a "heavy" timber frame in Central America. There is much work to be done to undertake an island survey of remaining timber-framed structures and to learn their evolutionary characteristics through the centuries. An in-depth study might help us better understand the construction techniques, stiff rather than heavy, the island carpenters used to withstand the frequent hurricanes that pass through the Caribbean. —Douglass C. Reed

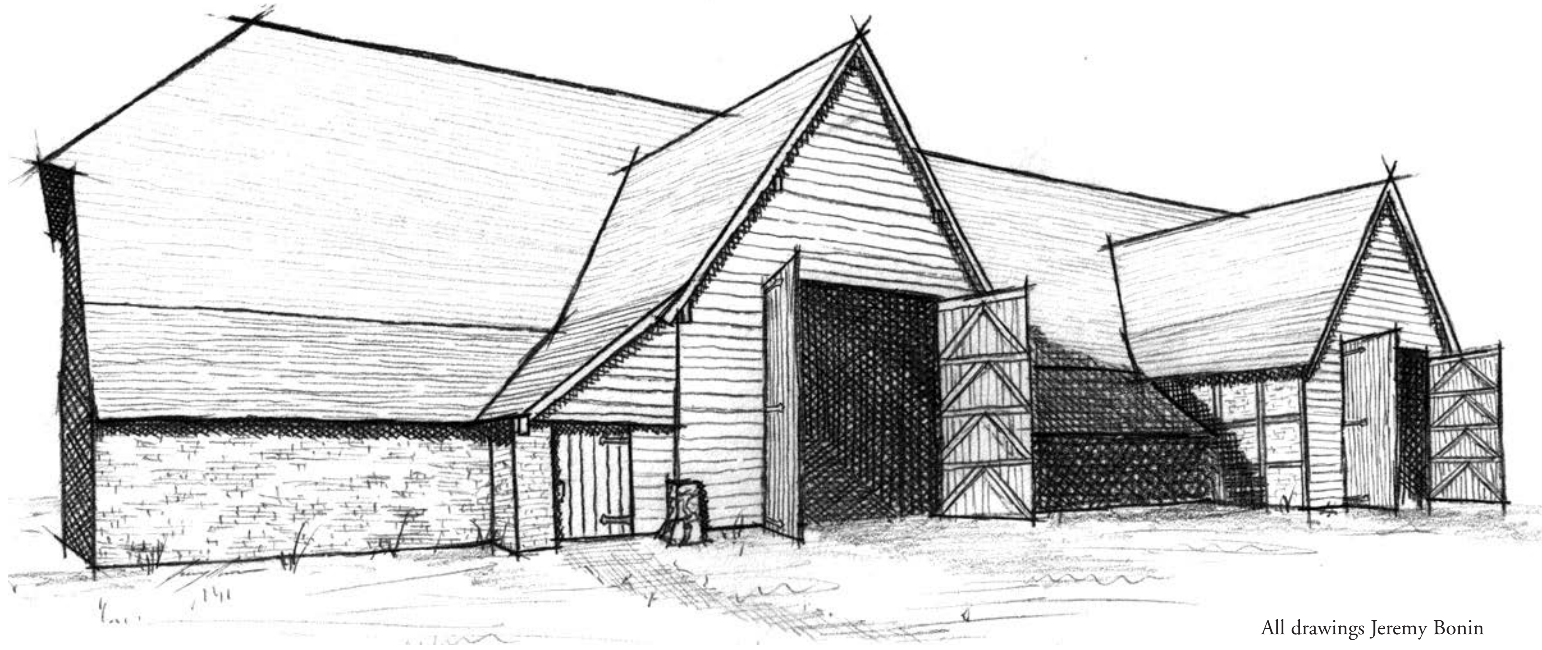
Doug Reed (douglasscreed@myactv.net), a historic structures consultant, owns Preservation Associates, Inc., in Hagerstown, Maryland.

Figs. 11–13. At right, view of earliest part of L'Ermitage, with exposed wall and roof framing. Common rafter roof has few collars but purlins and many windbraces in second, inner layer. Tie beam at endwall laps over plates and is replaced at middle of room by iron tie rod passing through plates, below; near-X-braces join purlins and rafters in staggered connections, below and below right. All framing timber is lignum vitae, planed and painted.





English Frame Typology Primer



All drawings Jeremy Bonin

Fig. 1. Leigh Court barn, Pershore Abbey in Worcestershire, UK, early 14th century. Sketch after a photo in *Barn: The Art of a Working Building,* by Alexander Greenwood, David Larkin, and Elric Endersby.

MOST American frame types are of European and particularly English descent. To pause and consider their origins and functional and aesthetic inspiration, as well as their endurance throughout history, is not without benefit. Timber frame components evolve in connection detail and form as well as title. Exploring the origins of timber framing can enhance our confidence and give us ideas. Nearly every problem in timber building has been faced before.

Among the early large framed buildings in Europe were the tithe barns of the Middle Ages, used for the collection and storage of the farm tithe, a 10 percent levy on what the independent farm produced in livestock, grain, wheat, etc., to support the church. Tithe barns are sometimes referred to as grange barns; the term *grange* (the French or Norman word for barn) also describes the entire farmland and buildings of a British gentleman farmer.

Some early tithe barns consisted of bearing walls laid up in brick or stone with timber trusses to support the roof loads coming down on thickened piers, pad-stones or plinths, such as at Ter Doest in Belgium (see TF 62) or Pilton Barn in England (see TF 81), both from the 13th century. Fig. 1 shows a 14th-century example.

Any traditional timber structure is routinely described by orientation of the walls with respect to the roof ridge and by the divisions of the building. In typical gable-roofed buildings, the most common form, internal crossframes running transversely from eaves wall to eaves wall divided the interior into bays. For example, the familiar English barn in America (see TF 80) typically consisted of four crossframes and three bays defining use—harvest storage, threshing or livestock stalls.

Early English timber frames were of three types: cruck, aisled and box. Crucks were the earliest form of crossframe (Fig. 2). The primary load-bearing members were the paired arched rafters, also referred to as blades or crooks, cut (ideally but not invariably) in a matched pair from a curved or crooked bole. Acting as both rafter and post, the blades carried the roof loads to ground through low foundation walls or stone piers. In a few instances cruck blades were earthfast.

The blades of the cruck frame were braced transversely by a gusset near the peak, a collar beam in the upper third, often arched, and sometimes a second collar close to midheight of the frame. The collar was braced downward to a lower portion of the blade via a gently curved member with a strut spanning from its midpoint back to the blade, or via a true knee brace, solid and making extended contact with tie and blade along both connections.

A cruck spur, half-lapped to the blade, projected outward to tie a wall post, plate and the principal rafter to the blade, which in turn supported the vertical wall and eaves.

Both the blade and principal rafter would then support purlins and common rafters, with wind braces in plane with the roof frame. Smaller intermediate wall rails, studs and braces completed the framing of the structure.

Cruck frames did vary in the connection detail of the blades; some blades met at the ridge to support a ridge purlin while others terminated at the upper collar or the gusset, where a short post rose to support the ridge purlin.

An alternate cruck type, the base-cruck, was used in buildings of high status where a wide, uninterrupted internal space could be obtained by spreading the cruck blades. The base-cruck comprised short, curved posts canted inward with the braced collar supporting or clasping plates to carry upper rafters (Fig. 3).

An alternate cruck type, stemming from the shortage or absence of large, like crooked trees, was the composite or jointed cruck. In these cases, a shouldered post and straight or arched rafter would be joined by mortise and tenon or simply face-pegged to replicate the once continuous blade of original intent (Fig. 4).

AISLED frames consisted of a large central nave and narrow side aisles, and apparently descended from the basilica plan of European cathedrals, with roots in early Roman architecture. Buildings requiring great width could be constructed by introducing arcade posts and plates to reduce the span of the main roof members. A tall central nave would have one or more aisles on

All framing sketches based on drawings and information in Richard Harris, *Discovering Timber-Framed Buildings.*

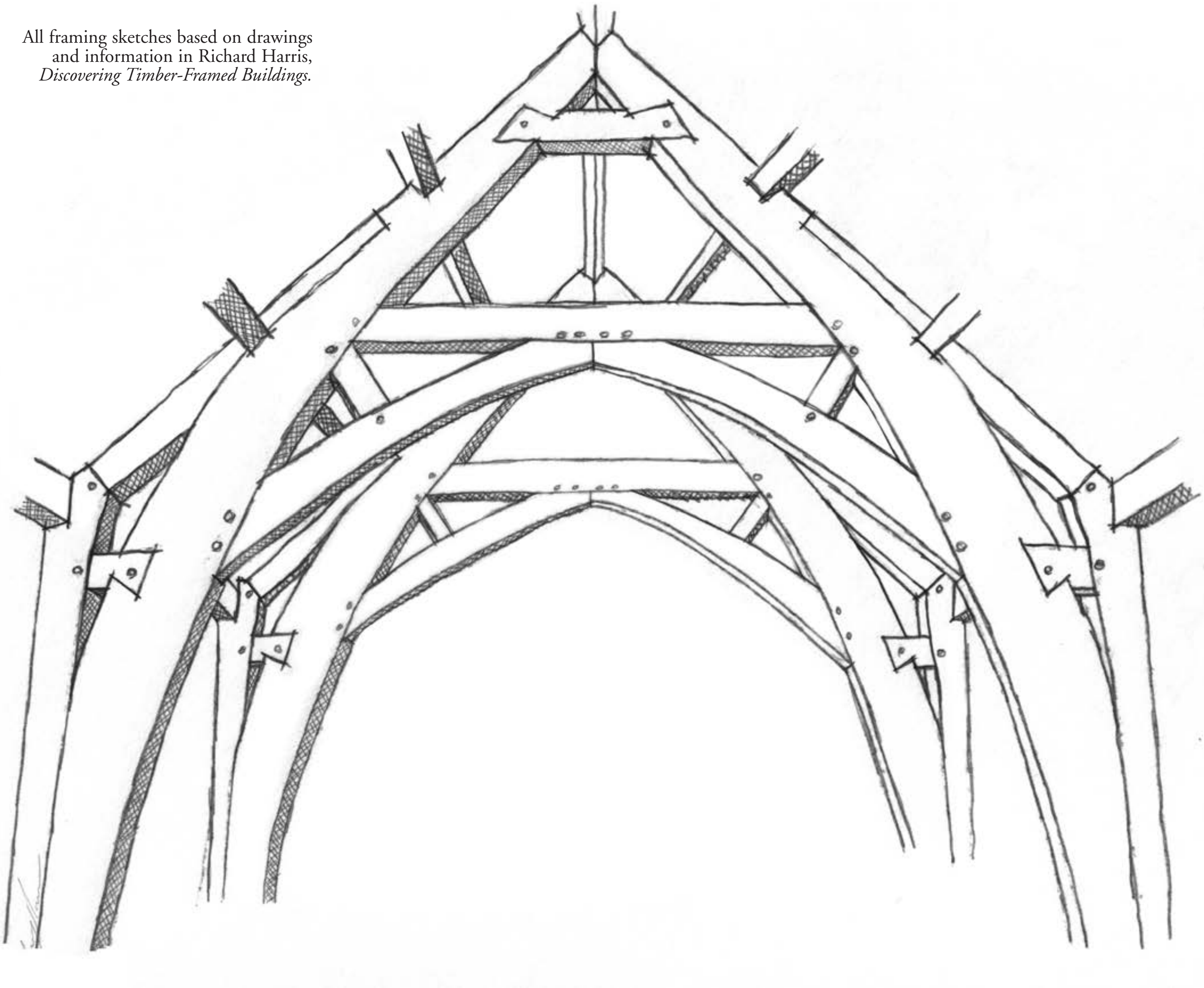


Fig. 2. Full crucks in varying regional style combined post and rafter in one member and supported large halls and barns.

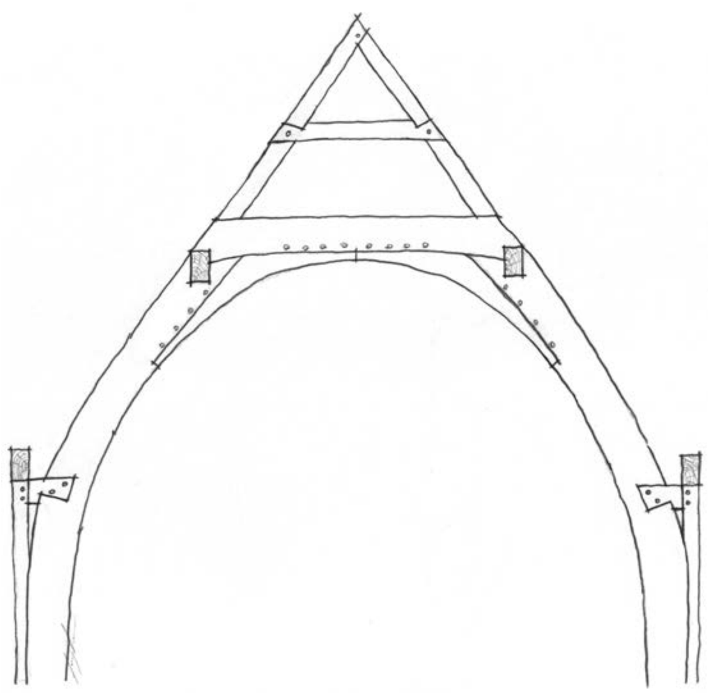


Fig. 3. Base-cruck permitted spreading of crucks for greater span when desired, introduced upper rafters.

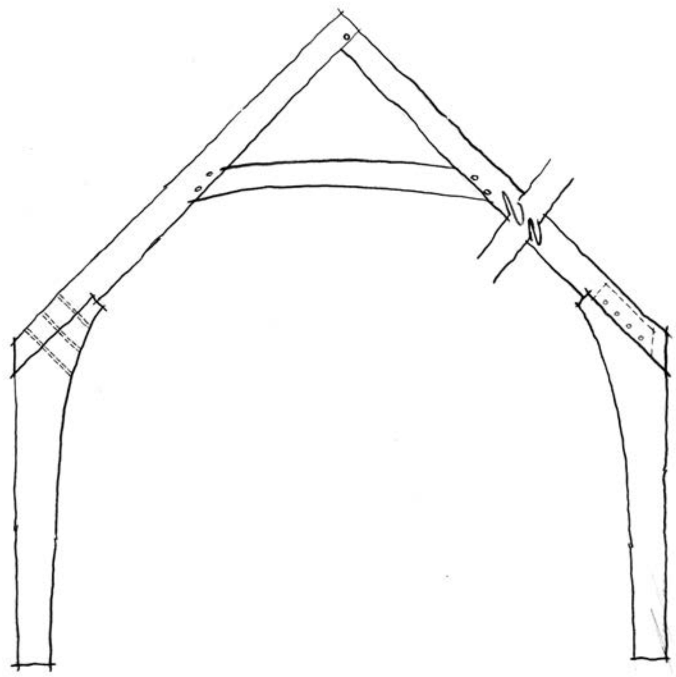


Fig. 4. Jointed cruck, a method arising from scarcity, marked transition to separate rafter and post.

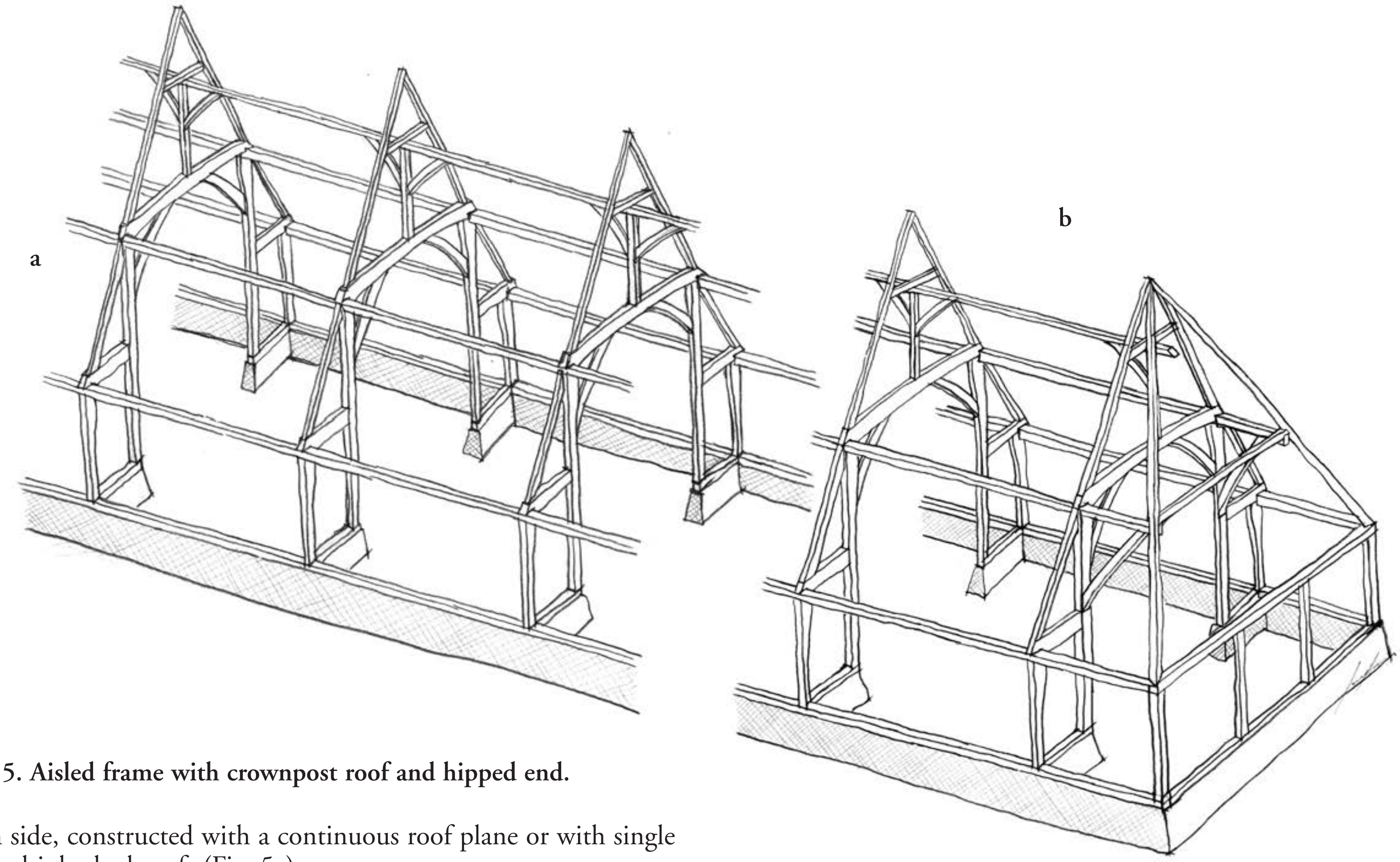


Fig. 5. Aisled frame with crownpost roof and hipped end.

each side, constructed with a continuous roof plane or with single or multiple shed roofs (Fig. 5a).

Aisled frames appear in many varieties and with many variations, for example with aisled gable ends and a hip roof or a gabled hip (or "gablet"). In the hipped roof variation the arcade plates extended beyond the gable end and carried a horizontal member to support the hips. The cantilevered plate was almost always braced back to an arcade post (Fig. 5b).

Arguably the hammer beam roof frame, although not literally aisled below, can be seen as another variation of an aisled frame. To obtain the great width required in important halls yet maintain an unencumbered floor plan, truncated arcade posts (now become hammer posts) terminated at a hammer beam that extended into the building from the eaves wall plate. A substantial wall post was required to resist the lateral forces collected from above and imposed by the hammer beam and lower brace (Fig. 6). Hammer beam roofs over masonry buildings used short wall posts on corbels, with walls firmly buttressed or pilastered behind the posts.

BOX frames, also called post and truss frames, were perhaps the most numerous English frame type. The basis of this frame was the box formed by eaves wall posts, top plates and transverse tie beams (Fig. 7). The wall posts were shouldered or jowled to provide substantial area to join together the plate, tie beam and principal rafter in the remarkable English Tying Joint (Fig. 8). The inner jowl at the head of a post offered a tenoned connection for the tie beam while the rest of the post offered a separate tenoned connection to the eaves plate, flush with the exterior face of the post; naturally the two tenons must be at right angles. In addition, the soffit of the tie beam was lap-dovetailed over the eaves plate, which also tied the opposing walls of the structure together (if but loosely after shrinkage).

The box frame was often characterized by its roof truss, which displayed the majority of variation. In English parlance, the word *truss* has its traditional meanings of a bunch or bundle, with the implications of binding, stiffening or support. It does not include the modern requirement that all members of a truss be strictly in tension or compression, with none in bending.

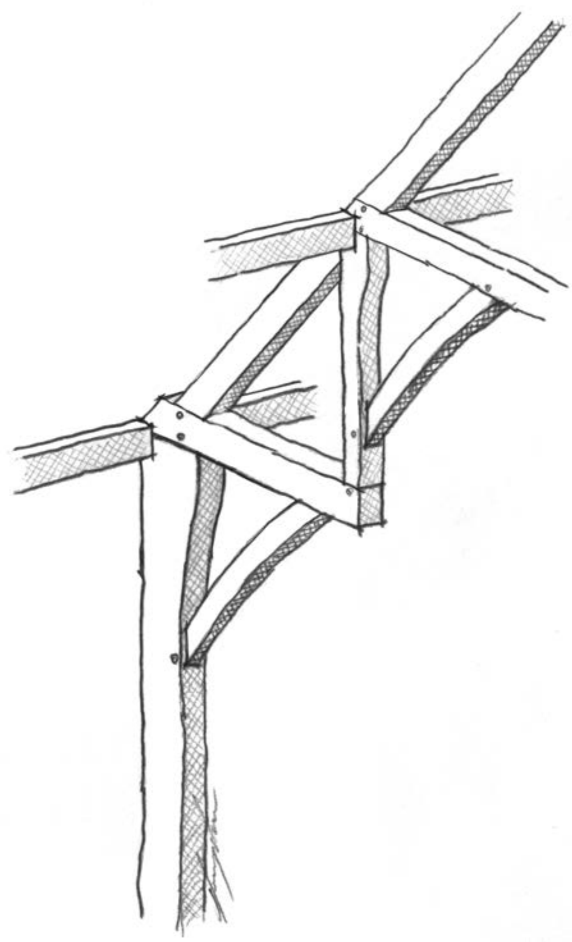


Fig. 6. Hammer beam framing on full-length wall post.

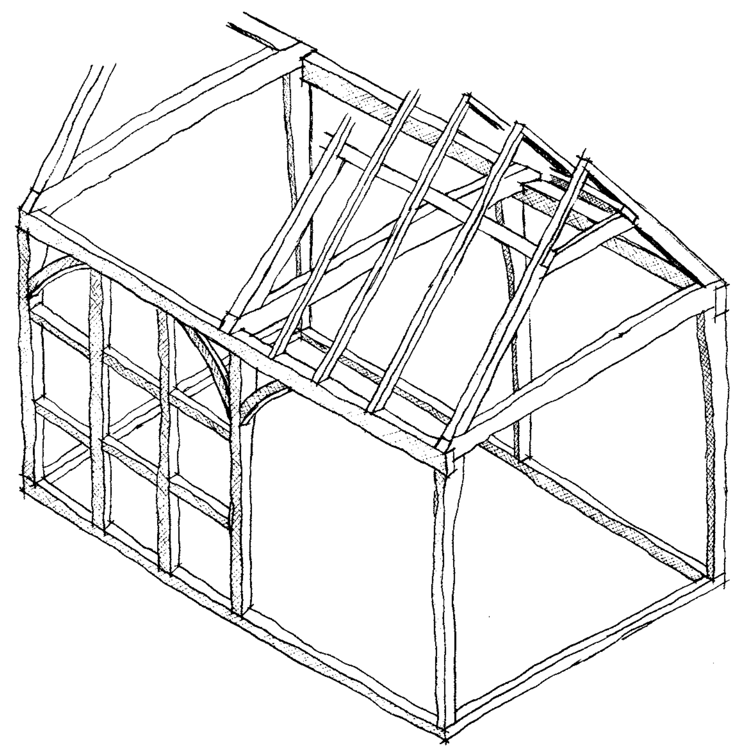


Fig. 7. Box frame with principal rafter roof and clasped purlins.

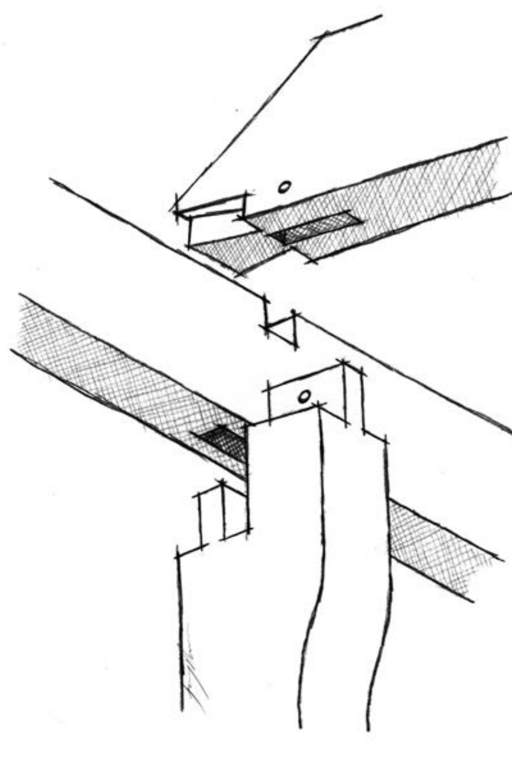


Fig. 8. English Tying Joint uniquely links plate, tie beam and post.

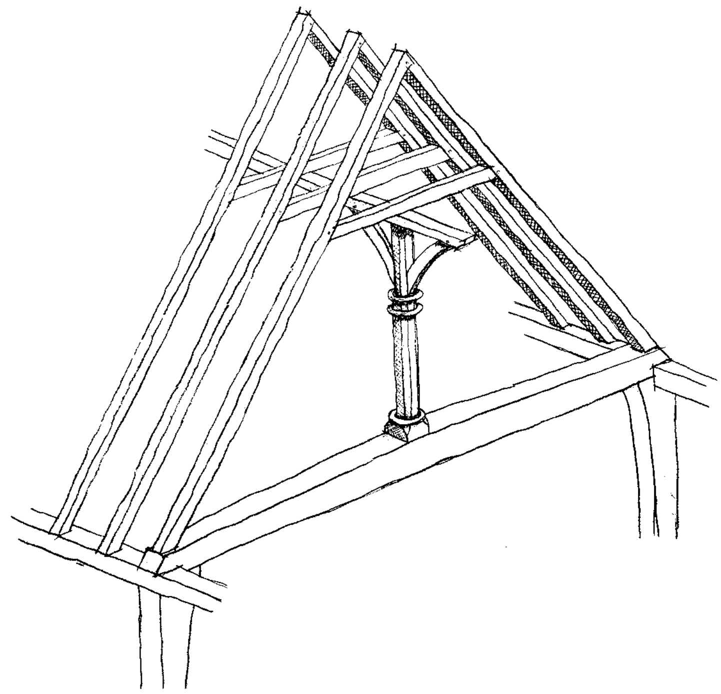


Fig. 9. Box frame detail with crownpost roof.

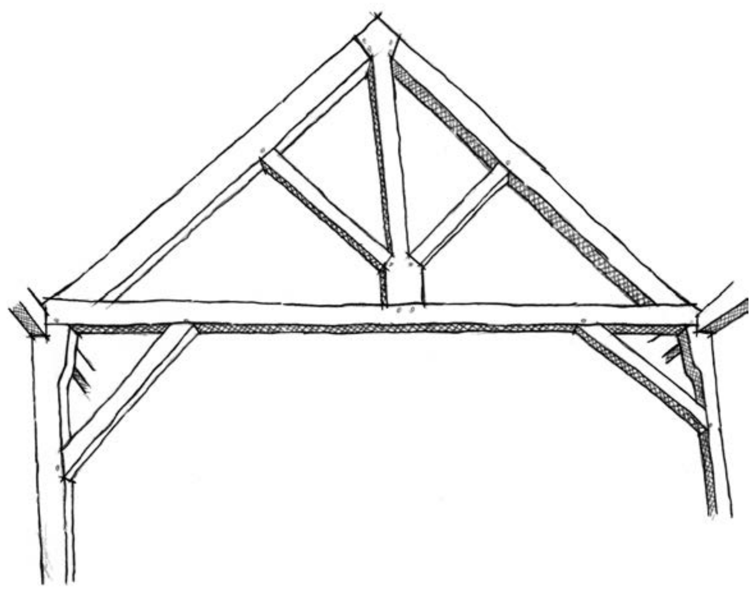


Fig. 10. Kingpost truss with English Tying Joints.

The principal rafter roof truss supported relatively small common rafters via principal purlins, themselves carried by heavier principal rafters set over principal posts. Principal rafter pairs typically included collars, sometimes supported by vertical or canted struts down to the tie beam. Frequently a principal purlin was clasped between collar and rafter at the joint (Fig. 7). Alternatively, purlins could be trenched over or tenoned into principal rafters.

The crownpost roof was named after its central post, which might be shaped or decorated, rising from the tie beam to a longitudinal beam below the collar called the crown plate or collar purlin (Fig. 9). At the ridge, such a piece would be intended to tie the rafters lengthwise; here it imparted load to the tie beams, appropriately cambered or thickened at middle. Bracing normally ran from collar purlin to crownpost and sometimes from collar beam to crownpost as well. Less common were struts from crownpost to tie beam.

A kingpost truss, identified by its single post rising from the tie beam all the way to the ridge and receiving principal rafters at the peak, stiffened its rafters via struts descending from about mid-span to joggles near the base of the post, which sustained the resulting tension (Fig. 10). Additional tension in the kingpost would result from the weight of the tie beam, usually substantially joined to the bottom of the post and often strapped to it. The tie beam carried the roof load in tension developed by the outward thrusting of the opposed principal rafters at their heel joints with the tie.

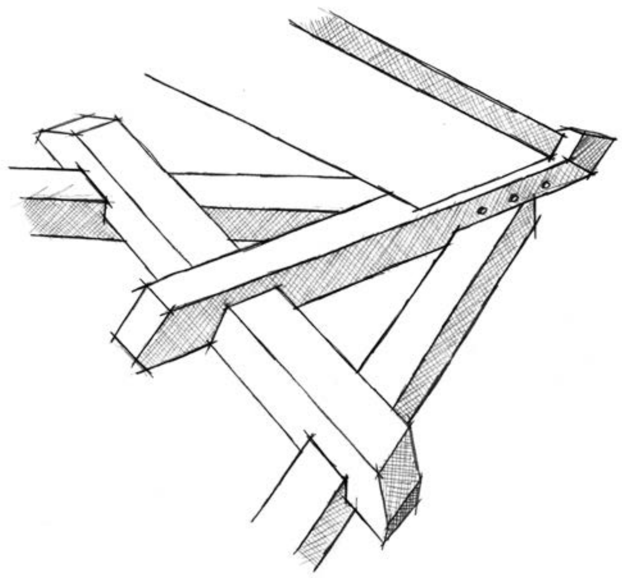


Fig. 11. Dragon and crosstie for hip roof frames.

The Dragon. Common only in hip roof construction, the dragon (-beam, -piece or -tie), provided a secure base for tenoning the foot of the hip rafter, and it could be extended outside the frame to support an overhang (Fig. 11). The short member at right angles, the crosstie, tied the intersecting walls and accepted the interior end of the dragon. The dragon provided correct long-grain bearing for the hip, analogous to that of a tie beam under a principal rafter, and resisted the hip's outward thrust.

BRACE design varied in widely in scale, section, connection detail and the members joined. Some early knee braces left no spandrel (the triangular space between a brace and the members it joins), instead filling the space solidly, with continuous abutments. Like ship's knees, they might be harvested from the root splay of a tree such that the grain would follow the angle of the bracing line itself (Fig. 12a). These braces were variously mortised or face pegged into adjoining members. Face-pegged braces could be affixed both housed and flush, the former structurally more preferable (Fig. 12b). Half-lapped and pegged connections, with or without dovetail, were the most prevalent early connections. Rectangular braces with mortise and tenon joinery at their ends, such as we use today, were the last of the innovations (Fig. 13).

Passing braces, straight or arched, tied at least three frame members together (Fig. 14). The middle member of the three was passed by the brace, and in almost all cases the members were lapped and pegged.

ALTERATIONS. When a second floor was added to an open hall, the tie beam was an inconvenience. Altering or building to allow for passage from one bay to the next required interrupting the tie beam and restoring some resistance to rafter action. One method was to place a post several feet from the wall rising from floor girt to principal rafter. The vestigial tie beam then tenoned directly into the side of the post (Fig. 15a).

The sling brace (Fig. 15b) was an elegant alternative, carrying the roof load down to the post quite near the connection with the transverse floor girder and stiffened by the vestigial tie beam midway, the whole making a fairly rigid connection between roof and wall in the absence of the ideal base-tied truss to resolve rafter action.

—Jeremy Bonin

Jeremy Bonin AIA is a principal at Bonin Architects & Associates (www.boninarchitects.com), Claremont, N.H. Using Richard Harris's Discovering Timber-Framed Buildings *(Shire Publications, 1999) as source, the author built CAD models and then made the pencil sketches.*

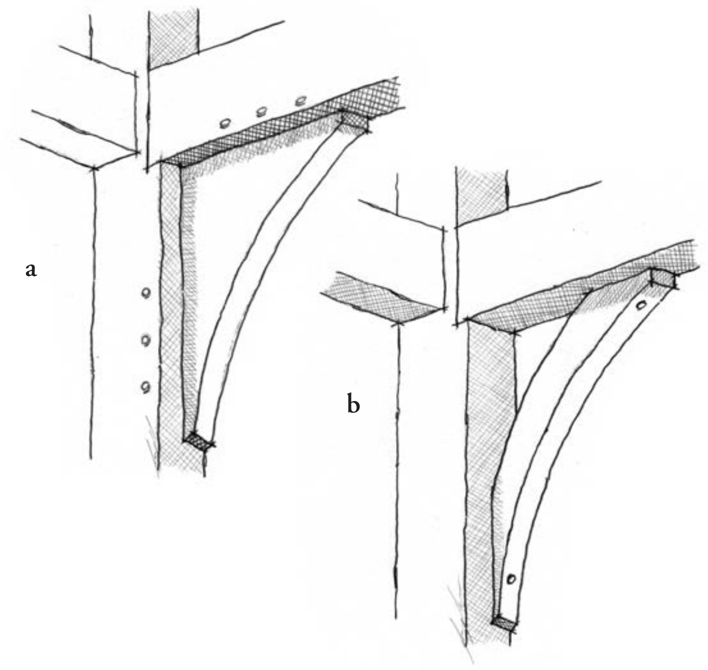


Fig. 12. Knee braces without (a) and with (b) spandrels.

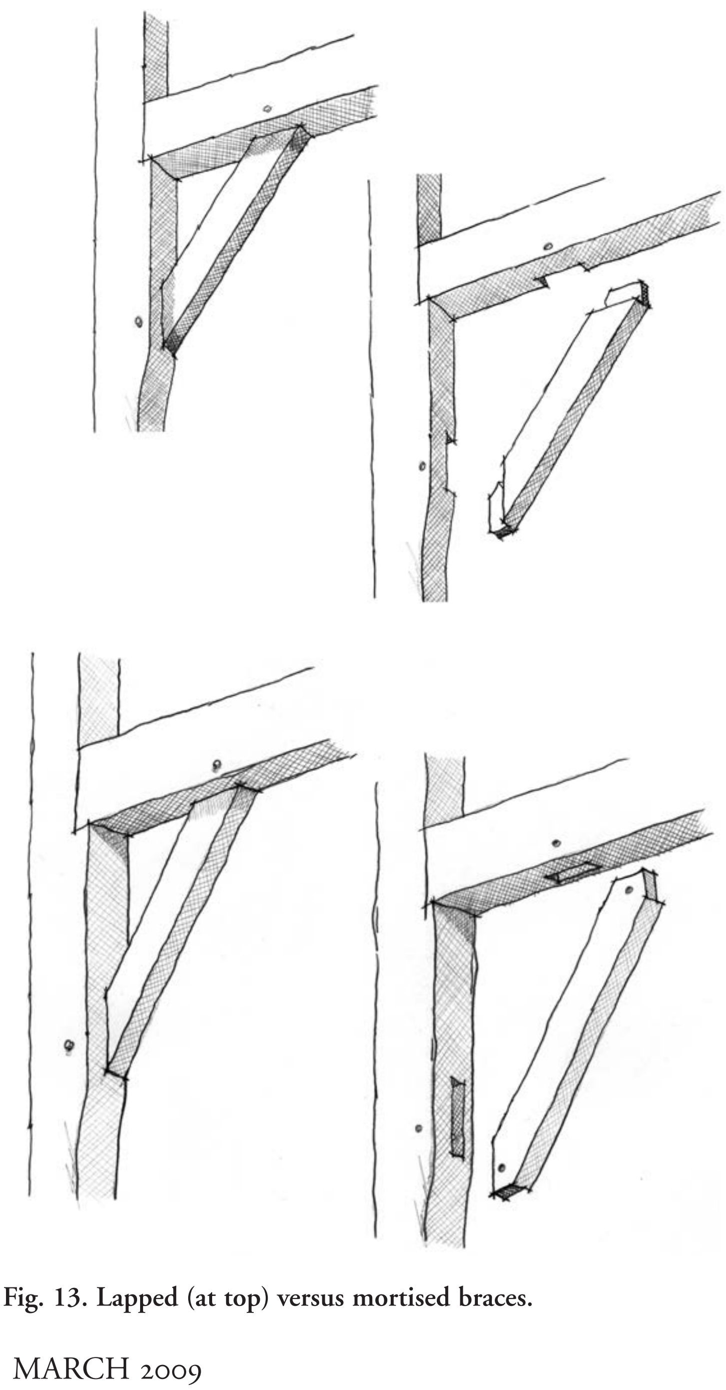


Fig. 13. Lapped (at top) versus mortised braces.

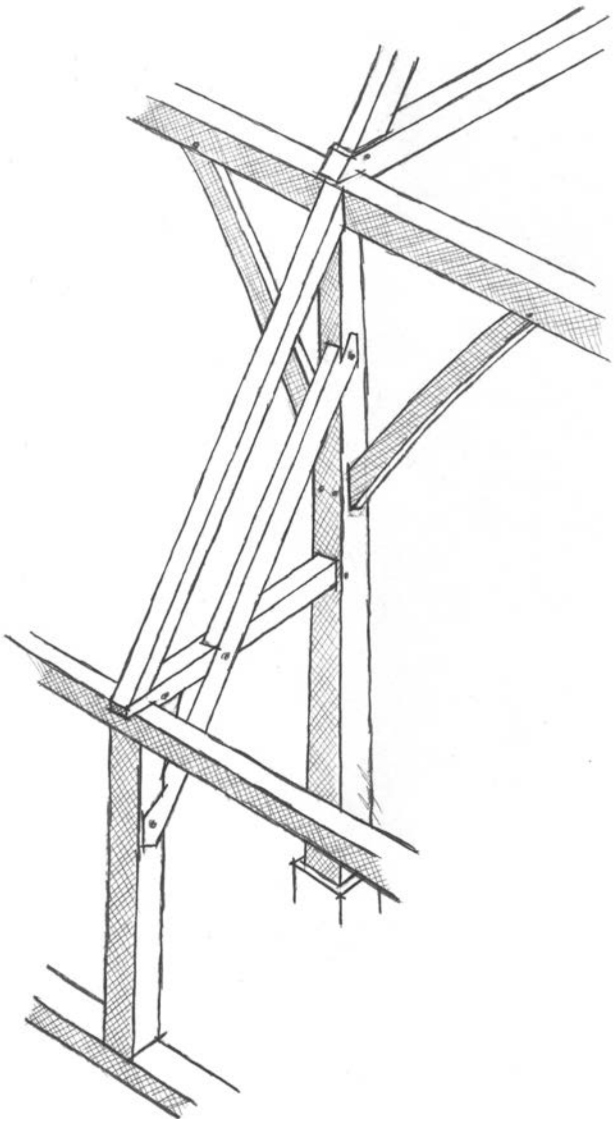


Fig. 14. Passing brace linked at least three members.

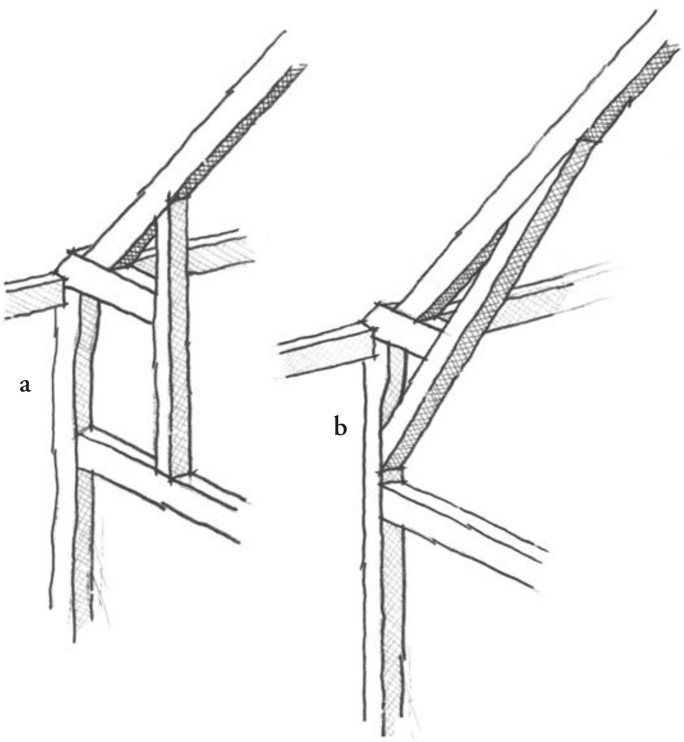


Fig. 15. Sling brace (b) offered stiffer arrangement than post-tie.

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