

# TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD

Number 107, March 2013



*Timber Framing for the Homestead*



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*On the front cover, Kevin Kiwak adjusts choker strap on wall plate for English tying joint in cruck-framed outbuilding at his homestead in Sandisfield, Massachusetts. Cherry post and braces, white pine plate. Photo by Nikolas Geilen. On the back cover, shingle making at the Jüri Metsalu workshop, Karilatsi, Põlva county, Estonia. Complex action produces curved shingles of uniform thickness. Photo by Piret Uus.*

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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.



## Complex Roof Framing

*Advanced Timber Framing: Joinery, Design & Construction of Timber Frame Roof Systems*, by Steve Chappell. Brownfield, Maine, Fox Maple Press, 2012. 8.5x11 in., 348 pp., profusely illustrated. Hardcover, \$75.00.

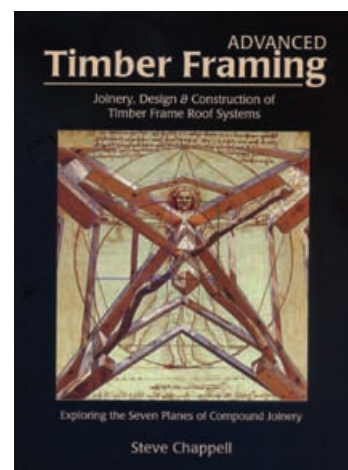
STEVE CHAPPELL'S *Advanced Timber Framing*, 25 years in the making, is the magnum opus of one of the Guild's founders and the supplement to his 1998 work, *A Timber Framer's Workshop*. While *advanced* may seem a rather lofty adjective that promises a book of challenges veteran timber framers may have to face, this book is solely about roofs. It doesn't include steeples, bridges or trusses, but rather focuses on that milieu where timber framers worldwide usually "show their stuff": roof framing.

This volume is actually two books about timbered roofs, the first on design and history, the second on geometry and joinery. Each could stand on its own as a valuable addition to a timber framer's library. Together they provide the most comprehensive coverage of the subject that I know of. A few things are missing that we who do things differently would have liked to see, but not much.

The first section begins with the fundamentals of traditional design. This includes the Golden Mean and sacred geometry, how they are evident in the natural world and how they contribute to good design in the built environment. Then the author moves to the evolution of timber framing and vernacular architecture, focusing on the development of roof systems. Engineering understanding evolved at the same time, presumably sometimes through painful lessons, since empirical test methods were the only ones available.

Stunning photographs of roof structures, from Scandinavian stave churches, Western European tithe barns and market halls to Asian pagodas, illustrate the progression of building traditions and craftsmanship up to the dawn of modern technology. The book offers valuable examples of the development of scribe layout systems to achieve this soaring geometry with irregular timber.

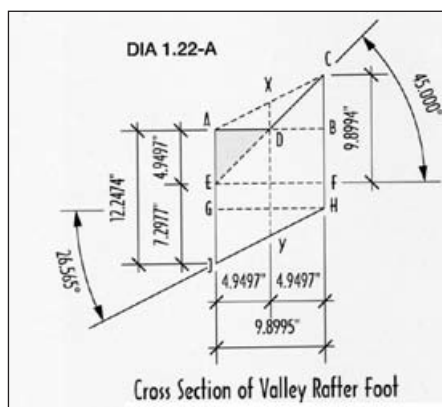
But there is a bit of a disconnect here with the rest of the book. Chappell's approach to solving the many complex roof problems posed later (covering nearly every imaginable combination of hips, valleys, jack rafters and purlins, ridges and plates) relies on mathematics, higher level geometry and trigonometry. An innumerate medieval carpenter would have used drawing and lofting to achieve the same results with irregular timber. It may be thought silly today not to use math and calculators if one knows how, but there is more





Photos and drawing from *Advanced Timber Framing*

Valley rafter foot before backing cut. At right, rafter section before tenon layout. Far right, unequal-pitch valley foot joining level plate.



than one way to do this work. Lofting is given a cursory explanation, yet this is how the extraordinary roofs shown were built.

Wattle-and-daub enclosures, regional roof styles and a few subjects I had never seen treated in such depth also appear: dragon beams and rotated hips and valleys, where the member is normal to one roof surface instead of having plumb sides, as in the so-called English hip. This configuration allows the jack rafters on one side of the roof to have a simple square top cut, and other advantages are revealed in the text.

The design and history section of the book ends with yet more exuberant examples of timbered roof framing, and leaves us with a question. Why would carpenters expend so much time and energy to invent and execute such elaborate and complex systems? The author provides a valuable answer: because they could. He observes: "Once you've seen something that allows you to create a mental image of what it looks like, it is easy to then figure out how to replicate it. But if you've never seen something, never conceived of the form, then what do you have upon which to build a mental image? This is the mark of true genius, in art or science, to create the obvious from nothing." The photographs in the first part of *Advanced Timber Framing* could stand as their own book, enticing us to look at them at leisure, often in amazement, and for inspiration from carpenters wanting to show their skill and clients wanting to show their wealth.

IF the first part of the work is for the coffeetable, the second part is for the workbench, a reference book. After providing the basic methodology for developing a geometric model for the roof, the author provides step-by-step graphical and mathematical procedures to master hip or valley rafter systems. Valleys to principal rafters, hips and valleys landing on posts, valleys or hips meeting dragon beams or headers, polygons with king posts (boss pins), roofs with unequal pitches—all are dealt with here. This is really heady stuff and earns the term *advanced*. As mentioned earlier, there are other ways of doing this work (traditionally with drawing and more recently with the Hawkindale angles), but the author has clearly mastered it through the use of mathematics, particularly trigonometry. Like any method, until you've seen it at work, it's hard to imagine what it's supposed to look like.

The photographs help immensely here; it would be difficult for a novice to use the methods here on a full-scale project without practicing on some spare wood first. Math is a tool, and extremely useful for saving time and mistakes once one knows how to apply it. In practice, a timber framer is likely to do this work in a limited range of configurations, so once the techniques are mastered they can be used with confidence in cases where only roof pitch and other variables change.

Great value lies in the 19 "axioms," as the author calls them, given at the end of the book. These are trigonometric rules of thumb, giving formulas that can be applied universally across most, if not all, roof systems regardless of irregularities in pitch and plan angles. Although examples of polygonal plans (hexagons, octagons) are shown in the drawings and photographs, they assume equal pitch on all roofs in a given example. The unequal-pitched roofs

described assume 45-degree deck angles (where the hip or valley meets the walls in plan view). There is no treatment of irregular-plan, irregular-pitch roofs, where the roof pitches are different and the deck angles are other than 45 degrees. If one understands the axioms and the other techniques in the book, however, these roofs pose only a slightly elevated challenge. The axioms cover irregular-plan, irregular-pitch roofs, and are the same formulas from which the Hawkindale angles are derived (see TF 19 or [tfguild.org/publications/software](http://tfguild.org/publications/software)). Timber framers who have used the Hawkindales in their roof work will find familiar ground here.

What may not be as familiar is the long section on joinery design for compound roofs. Most timber framers eschew mortise and tenon connections for jacks, hips and valleys, since the mortises weaken the receiving timber (critical in valleys) and we now have mechanical fasteners that can do the attachment better and with less damage; and housings alone can usually handle the design loads. (Some framers, however, may want the extra security of pegged joinery if lifting an assembly from the ground rather than assembling the pieces in place.) The author concedes that in some cases, such as joints in pure compression, tenoned joinery may be unnecessary. If the joinery is of questionable value once the timbers are in place, if it represents a lot of extra work and can cause interference during assembly when not cut accurately, then why do it? We go back to the idea mentioned earlier: because we can. Tenoned joinery is "cool" and gives the builder a sense of accomplishment and pride to have pulled it off. It's extremely useful to see the examples in the book, because until one sees a problem solved in a model or photograph it's hard to imagine what the solution might be.

Assembly considerations and a desire to retain maximum cross-section in the mortised member increase the complexity of tenoned connections. In the photo at top left, the valley tenon has been sharply tapered on its top cheek to allow entrance to a principal rafter while retaining the overlapping tail that completes the backing for the adjacent roof surface. The corresponding mortise repeats the difficult shape.

In the photo at top right, the end of a different valley joins a level plate. Here the tenon is again reduced and for the sake of the plate must present its bottom surface parallel to the plate's. The consequence is short grain for the tenon (its grain is mostly discontinuous with the valley's), undesirable on general principles, though here the tenon is undoubtedly thick enough at its root to serve well.

With his sons, students and crew at Fox Maple, Steve Chappell's company may have done more compound roof framing than any other in North America. I for one am grateful that he has published his experience in this book and augmented it with the photographs of historic roofs built by master carpenters around the world. Those who have ventured into compound roofs at any level know that until one sees what is possible, it's difficult to imagine what to do. The author has done the imagining and the execution for us, at a level of detail that shows us the genius behind the work. Every timber framer should own *Advanced Timber Framing*, at least those who build roofs—and who doesn't?

—WILL BEEMER



# Timber Framing for the Homestead



Photos Kevin Kiwak unless noted

1 House of 17th-century rural French design measures 30x40 ft. with 16x24-ft. extension off the southwest corner. Nontraditional cupola accessible by steep winding stairway around central chimney. Woodshed well spaced from house to ward off insects and pests. Lime plastered, autoclaved aerated concrete blocks, porous but closed-cell, infill between timbers in *colombage* style.

MY timber framing odyssey began in 1993. Entrenched in an all-consuming profession at the time, I sought temporary escape in a one-week introductory timber framing course at the Heartwood School in the Berkshire hills of Western Massachusetts. The following summer I returned for a second weeklong course that dealt primarily with scribing techniques. It would be more than a decade before building my own house would become reality.

During that decade I read everything I could about timber framing. I talked to timber framers. I joined the Timber Framers Guild. I dreamed timber framing. I had met the architect and timber framer Jack Sobon at Heartwood in '93, and during those intervening years I asked him to help with my house and homestead design.

More important, I spent a large portion of that decade readying for a new lifestyle. Disillusioned with the status quo, I educated myself on alternative lifestyles—self-sufficient, self-sustaining, “green” in the nonconsumer sense. My notions of self-reliance were bolstered by a visit to the Scott and Helen Nearing Homestead, in Harborside, Maine, in meeting the yurt guru and homesteader William Coperthwaite, and in brainstorming meetings with Jack.

With only a notion of what lay ahead, an overall plan slowly developed. I found a suitable (and affordable) property in the Berkshires and began serious discussions with Jack about the overall layout and organization of the house and outbuildings as well as specific plans for the house itself.

Initially, my ideas for the house were inchoate except for two principal notions: first, as I would be spending a large portion of the next few years constructing the frame, I did not want that work covered over with clapboard or other siding; and second, I wanted the structure to be as environmentally friendly as possible both in its construction and its subsequent decades of use. We spent nearly two years designing and planning.

My first principal concern was solved by deciding to do a half-timbered or *colombage*-style European design, wherein the timber frame is typically infilled with wattle and daub or bricks. Inspired by Elsie Burch Donald's 1995 book *The French Farmhouse*, we finally settled on a 17th-century design from Alsace (Fig. 1), with certain modifications despite the architect's full-out attempts to keep the design historically correct. The frame, infilled rather than covered, would be exposed to the weather. As I did not want any chemical treatments on the wood, we were left with a choice of three possible native species known to be relatively rot resistant:



white oak (*Quercus alba*), black locust (*Robinia pseudoacacia*) and black cherry (*Prunus serotina*). My property had little white oak and no black locust, but a good supply of sizable black cherry, large enough to mill heartwood timbers of adequate size, mostly 9x9s.

The second concern, environmental impact, we addressed step-wise and at each stage of planning and construction. The native timber from our own property I harvested carefully and sustainably and always used as much of each tree as possible, milling the timber on an LT40 Wood-Mizer portable sawmill, minimizing transport of materials and maximizing the yield from each log, unusable portions ending up as firewood. Every piece of wood in the house, excluding window units, was obtained in this way. (The four 32-ft. 9x9 white pine and hemlock tie beams in the main section of the house, seen in Fig. 2 with carved ends, proved difficult to saw and required a lot of maneuvering, as my Wood-Mizer mill bed is only 22 ft. long.) Finally, the house was designed and oriented to maximize passive solar gain in winter, minimize it in summer.

I cleared the house site by hand over the course of a year, preparing for a foundation of 4-ft. concrete frost walls bounding a 6-in. concrete slab, thickened to 12 in. under support beams and masonry stoves, and housing hydronic heating coils and rough plumbing. The slab sits over foam insulation and the (future) heating lines over reflective foil. A shelf on the frost walls supports 24 in. of stone facing, gathered from the fields and a dry riverbed on our property and placed a section at a time using small, hand-mixed portions of cement mortar.

As it would in part determine one dimension of many of the frame elements, the material to be used for exterior wall infill had to be determined in the early planning stages. I chose 8x8x24-in. autoclaved, aerated solid concrete blocks (Safecrete), originally a Swedish invention from the 1920s (Fig. 3). The heat of the autoclave produces a honeycomb-like closed-cell structure in the specially formulated concrete that increases its R-value substantially. (Eventual R-value of the 9-in. masonry walls was likely about 15.)

Knowing the infill block dimensions, all exterior wall members—sills, posts, plates, girt braces—could be specified at 9 in. wide to accommodate the 8-in. block while still allowing ½ in. on inside and outside faces for application of plaster. As a first framing step, I laid out, cut and mortised the sills of solid 9x6-in. cherry heartwood and assembled them over ½-in. threaded rods cast into the foundation.

**Layout and joinery** To lay out the timber frame, I used several scribing methods, including tumbling, compass-scribing, double-fitting and plumb-bob transfer. Each individual wall was scribed, cut and assembled while in position over its respective sill (Fig. 4). During scribing assemblies, I used drift pins made by Malcom Carsley, an 84-year-old blacksmith, to my specifications, with a ring rather than a T-handle for easier storage and transport than the classic design. (If extraction from a pin hole was difficult, a second pin could be fitted through the ring of the first as a temporary handle.) Once judged satisfactory, a scribed assembly was disassembled and its timbers stacked and stored for later raising.

All mortise and tenon joints in the frame are 2 in., drawbored with 13/16-in. pins, wall timbers 9x9 (corner posts, door posts) or 8x9 (horizontal braces, oblique braces, window frames, girts, etc.). The first floor has eight exterior walls and nine interior walls, all framed. In the face of this complexity, I devised a numbering system to mark each post: a large Roman numeral labeled each wall (with half-circle added to designate an interior wall) and each timber in a given wall was assigned a Roman numeral subscript. (By convention, numeral IV was always scribed as IIII and IX as VIIII.) Brace numbers accorded to their adjoining posts. Interior posts on the second floor used a full circle rather than a half circle (Fig. 5). There were no second-floor exterior posts to identify.



2 Tie beams 32 ft. long with decorated ends in place over completed wall.

3 Insulating concrete blocks before shaping.

4 Wall scribe layout begins with sills in place. Note design of driftpins.

5 Timber marking system kept order in building with 17 framed walls. Here, ground floor interior wall 5, post 4 from reference.







6 Gin pole helped lift what two men could not.



7 Wood-Mizer shingle mill could tilt and present six blocks simultaneously to passing horizontal blade.

8 Piles of shingles awaiting fastening to roof. House and ell used 32,000, all 7 in. wide.



I spent two years cutting some 600 joints in the frame, using a Millers Falls boring machine, a 2-in. Barr framing chisel, a rawhide-head mallet, and crosscut and rip handsaws. Cherry is a hard wood, particularly as it dries, and I found joint making labor intensive.

**Pins** I split out 1x1x12 pieces of cherry from logs and then used drawknife and shaving horse to finish them off to produce the necessary hundreds of pins. My spouse, children and friends had helped shape many pins over the preceding years, and we all had the pleasure of driving them home. By specification of the architect, all pins were  $\frac{13}{16}$  in. Uncertain about the structural significance of this specification, I queried Jack Sobon, who replied that he had once found a “nice, long”  $\frac{13}{16}$  auger bit at a yard sale and had used it ever since. Jack also said, “If it isn’t drawbored, it isn’t timber framed.”

**Raising** Having cut and stacked all the necessary frame elements, I hired one friend to help erect the frame. Plates or assemblies too heavy for two men we hoisted with a gin pole (Fig. 6). My level of anxiety increased as each new element was added to the standing frame—I was certain that each new wall would not join correctly to the previous wall, nor to the one that followed. When all was said and done, there were no hitches and all went together smoothly. What had taken me over two years to cut, the two of us raised in the course of one week!

**Roof and roof covering** The rafters were sheathed with white pine inch boards and the boards covered with 30-lb. roofing felt (or Grace Ice and Water Shield where necessary), and then  $\frac{1}{2}$ x2-in. furring strips to allow breathing space for the planned shingles.

Squared blocks cut from Eastern white pine logs provided the shingles. A review of early New England shingling practices had revealed that Eastern white pine and white oak were the two most common species used, and that to be effective and durable, roof shingles must be free of sapwood and knots.

The Wood-Mizer mill with its dedicated shingle-making attachment accepted six shingle-length blocks at once (Fig. 7). The attachment cants the blocks so that each pass of the blade produces a tapered shingle from each block, here six for each traverse. The typical white pine internodal distance, that between each radial set of knots along the trunk, happens to be about 18 in., thus defining the upper limit for shingle length. As we used uniform-size blocks, the finished shingles all measured 7 in. wide by 18 in. long,  $\frac{1}{2}$  in. thick at the butt. We laid them with a 5-in. exposure, assuring the conventional minimum of triple coverage at any point. The roof required over 32,000 shingles to cover (Fig. 8).

The pitch on the main roof is 12:12. The pitch on the ell is about  $3\frac{1}{2}$ :12. Despite having read in numerous sources that a pitch lower than 4:12 is not suitable for wooden shingles, I covered the ell with them anyway, though over a layer of Ice and Water Shield. Six months and several rainstorms confirmed that the pitch was inadequate and, reluctantly, I removed all the wood shingles and replaced them with asphalt. One day I intend to build a lattice over the asphalt, to provide an airspace, and lay wood shingles again.

**Interior finish** Lime plaster covers all interior block walls and many of the other interior walls. Interior walls not plastered are plank and muntin (Fig. 9) or covered by cherry boards or wide pine. Unlike stuccos of cement, lime plaster moves with the seasonal movement of the frame and does not crack or work free of the block. (There is no spline at the masonry-to-wood seams.) Unlike stucco, lime plaster does not trap moisture beneath its surface. Also, being highly alkaline, it’s resistant to mold and mildew.

I used three coats of plaster—a rough coat, a skim coat and a tinted finish coat—starting with 55-gallon drums of aged (greater



than five years) lime putty. Fine sand and small amounts of water added to the lime putty obtained the desired application consistency. Nonmasonry interior walls first required studding and wooden lath (Fig. 10). In the timber-framed interior walls, arched lintels, circular-planed to shape, headed off most doorways.

There are no knee braces in the house. Most braces run full-length obliquely from sill to plate, with additional stiffness gained from short horizontal girts. One large opening (which can be closed by a rolling door) is braced by a pair of ship's knees, one visible in Fig. 9. The other exceptional brace is the large branch of a maple tree section used as a post in one wall (Fig. 10).

Two Tulikivi masonry stoves heat the house. The main stove, more than 6000 pounds of soapstone, stands in the center of the house and a second, smaller stove in the ell. Hydronic coils in the slab wait in reserve as a future backup heating system. The chimney, 44 ft. tall, is a double-flue, dual-walled system of pre-formed 2x3-ft. Isokern blocks with dedicated same-material liner, assembled with thinset mortar. The liner joints are staggered such that a block joint never lines up with a flue joint. The chimney required little effort to keep plumb during construction.

Initially we considered using recycled cotton insulation between the rafters. Because of significant added expense, but also because of concern that this process is perhaps not so environmentally friendly as has been alleged, I used formaldehyde-free fiberglass R38 insulation instead. I'm still not sure about this choice.

Domestic water arrives by gravity feed from a well situated high enough on an adjacent hill to maintain 18–20 psi at the house. Two solar panels (Heliodyne) on the back porch roof and a back-up coil inside the firebox of our wood-burning kitchen stove, a 1940s refurbished Perfection B, produce our hot water.

Wiring the house to meet electrical code was challenging. The service entrance line to the main panel in the adjacent woodshed is buried and PVC conduit in the slab carries main feeds from the service panel to a subpanel and several junction boxes inside the main house. With all exterior walls solid block, certain areas were difficult to wire adequately. A perimeter knee wall on the second floor, however, allowed wires to be run above and dropped into place where needed.

Floors are stone from the property laid on about an inch of crushed rock on the slab (Fig. 11), or finish floors of maple, ash, beech or cherry I milled and laid over a pine subfloor supported by cherry (rather than pressure-treated) 2x4 sleepers. One bedroom has an experimental cob (straw-clay) floor. Random-width pine boards cover the ceilings. All told, the house has about 1850 sq. ft. of net usable space, where two adults and two young children currently reside. Always trying to lessen our impact, I will use the second floor for my workshop. As I use no power tools in my work, primarily country woodcrafts including chairs and bowls, fine sawdust and machinery noise are not primary issues. I believe I can lessen my footprint by increasing my handprint.

**Outbuildings and future buildings** A chicken house, a sheep house and most of a cruck-framed smithy have gone up since the building of the house, and from the beginning we planned on having a barn large enough for a milk cow or two, a pair of working oxen and a half dozen or so sheep. We will start work this summer following the plans for a 27x36-ft. three-bay English barn with a hipped roof to match the main house, another traditional building. Additional planned timber-framed buildings include an 8x8-ft. open-sided building for a cob bake oven and a woodshed. The woodshed design remains elusive. Each passing winter I change my mind about how best to store firewood.

—KEVIN KIWAK  
*Kevin Kiwak (kevinkiwak@sprintmail.com) and family homestead and produce handcrafts in Massachusetts' southern Berkshires. He also instructs green woodworking classes at the Heartwood School.*



**9** Plank-and-muntin wall, in a 17th-century English farmhouse style. Ship's knee is one of only three knee braces in house (other braces at full wall height).

**10** Sawn lath over interior studding preparatory to lime plaster. Note gargantuan maple grown brace spanning corner.

**11** Paved hallway uses stone from the property laid over crushed rock on the slab. Other finish floors are hardwood milled from property.





# Making Riven Pins

**P**INS hold our craft together. They distinguish our frames from other types of post-and-beam construction. Not all pins—and many workers call them *pegs*—are created equal, and some may do more work than others depending on their location. Ideally, frames should be designed as much as possible to avoid tension joinery in which pins have to resist loads in shear.

In a well-designed frame, we use pins mainly to draw joints tight and hold them together during assembly (comealongs are thus seldom required) as well as to keep them tight after erection as the timbers shrink. This can be accomplished through drawboring—offsetting the pin holes in the tenon and the mortise a calculated amount such that the joint is drawn tight as the driven pin transfixes the tenon, a technique requiring a tapered pin, or one tapered for part of its length. (See “A Boring Essay,” in TF 67, also collected in the Guild’s newest book, *Timber Framing Fundamentals*, pp. 207–9.)

A thorough discussion of the relative merits of riven (split) pins shaved to an octagon, lathe-turned cylindrical pins, and octagonal pins sawn on a table saw is beyond the scope of this article, but it’s fair to say that the advantage of riven pins over turned or sawn pins is that the grain of the riven pin is predominantly continuous for the length of the pin, not necessarily the case with the others.

Continuous grain helps shear capacity, which translates into flexibility without breaking while a pin is driven. Riven pins are also less likely to split if they are struck imperfectly. I would guess, however, that most timber framers use turned pins. If the pins aren’t required to do much work, turned pins are sufficient and less expensive than paying for the labor to rive and shave pins.

Pins are split out from a clear log round (or billet) by quartering, then riving 4-pin blanks, then further riving individual squares and, finally, shaping with a drawknife. Favored species in our area of New England include white oak and black locust (both good for rot resistance), red oak and hickory. These are all very straight-grained woods (certainly over the short lengths that pins require) and will split easily and true in the absence of knots or twisted grain. Other possible species are white ash, Osage orange, yellow birch and hard maple (the last for interior use only). Whatever the species, splitting true is best assured by obtaining a round from the branchless butt (lower end) of a tree. Since log butts usually have a bit of flare, loggers or sawyers may be willing to sell off a foot or so to have the log fit better on the saw carriage. Of course, you can also buy a long, clear log a foot or more in diameter and cut it into short lengths for a decade’s worth of pins.

The billets should be sawn square to the axis of the log and 12 to 14 in. long. The outer few inches are usually waste (with their sapwood, bark and susceptibility to uneven splitting), but even with the remainder you could get about 100 1-in. pins from a 12-in.-dia. round. Pins should be 4 in. or so longer than the deepest framing timber anticipated, since the point will taper and you’ll want that extending out past the face after driving.

The blanks will split out better if the log is green; the finished pins themselves should be semidry when the frame is assembled so the frame’s green timbers can shrink around them. Usually enough time elapses for pins to dry between the making (say in winter while watching soap operas) and the frame assembly. End-seal the log butts if they’re going to sit for awhile. Quarters, if they have dried out before shaving, can be “reconstituted” by soaking, as can square blanks. Red oak works well even if dry, so if the stock must sit around for awhile, that would be the species of choice. White oak and locust are a little more difficult to work when dry, and all the other woods mentioned get much more difficult, so they

should be shaped green. Make pins immediately after felling if using white ash, as that species, with very little free water, starts to split on its own very quickly, making riving difficult. When making pins from green material, aim to make them slightly oversized compared to dry ones (but no more than  $\frac{1}{2}$  in.) such that they snug up a little sooner along their length in a test hole.

**Layout** To rive the squares that will be split and shaved into pins, lay out a grid on the end of the log using a framing square or other gauge (Fig. 1). Draw crossing perpendicular lines through the pith of the log, even if off center, to quarter it. (An ink pencil works well on a wet surface such as might be presented by a green billet. Ink pencils, available from [skinboats.com](http://skinboats.com) and [leevalleytools.com](http://leevalleytools.com), are also good for scribing wet timbers.) Then draw lines parallel to these outward at regular intervals to make a grid of squares; each of these blanks will yield (theoretically) four pins. The size of these square blanks should be  $\frac{1}{8}$  in. less than twice the diameter of a pin. In other words, to make four 1-in. pins, lay out a grid of  $1\frac{1}{8}$ -in. squares. The pins resulting will be slightly less ( $\frac{1}{16}$  in.) than 1 in. across the flats, but slightly more across the corners. For other sizes, use  $1\frac{5}{8}$ -in. squares for  $\frac{7}{8}$ -in. pins,  $1\frac{1}{2}$ -in. for  $\frac{13}{16}$ -in. pins, etc. The  $1\frac{1}{2}$ -in. module is handy since the tongue of a framing square fits the grid (Fig. 1); for other sizes make up a template to draw lines parallel to your original lines though the pith. If  $\frac{1}{16}$  seems an odd size, we do see it a lot in old buildings, and there is a substantial difference in heft between it and a  $\frac{3}{4}$ -in. pin.

It’s of interest at the outset to assess the growth rings of the log as well. Relatively speaking, fast-grown ring-porous hardwoods such as oak and ash are generally stronger than slow-grown examples of the same species, since the rate of growth is reflected in the amount of denser latewood put on each year. In these species, wider growth rings, as seen in parts of Fig. 2, mean stronger pins. (See R. Bruce Hoadley, *Understanding Wood*, 1980, p. 131.)

**Riving** Put the log on a solid surface or raised block—you’ll smack it pretty hard in the next step. Place the froe, the classic, ancient riving tool, on a line through the pith and split the log in half. Don’t try to enter the log all at once; start on the outside edge with the froe on a slight angle (Fig. 3). Pound it on the tip to get it started and then level it out as you pound it down near the handle into the end of the log (Fig. 4). The split should start before the froe is all the way into the log (a good sign) and simply torquing the handle often gives enough leverage to open up the piece (Fig. 5). If the log is wider than the froe, remove the froe before going too far and go to the opposite corner and start again. If the log is too stubborn or wide to get a good split started, try splitting off some of the outer circumference, or use a splitting maul or wedge (or a *glut*) to get the split started, as with firewood. A good straight-grained billet 14 in. long, however, should be split easily by a proper froe with gradually tapered sides (see discussion below). If the log fights back and doesn’t want to split, it probably has unseen knots or twisted grain and really doesn’t want to become pins.

Once the billet is split for the first time, the work, now with shorter cuts, should get easier. Take the two halves and split them in half (following the line nearest the pith) to make quarter-logs (Figs. 6, 7) and then begin splitting out groups of blanks (Fig. 8).

While the four blanks immediately surrounding the pith may be unusable because of knots and crooked grain formed early in the tree’s life, you should now see straight grain in the rest of the quartered billet. If you don’t, you may not want to waste further time on this billet.





Photos Will Beemer except where noted

1 Pin grid laid out on end of billet with framing square. Each square yields four  $\frac{1}{16}$ -in. pins. Ink pencil leaves dark green lines on wet surface.

2 High proportion of dense latewood to porous springwood in annual rings means high strength in ring-porous hardwoods. Low or equal proportion, seen in rings running through middle of sample, means low strength.

3, 4 Drive froe into billet beginning at mid-line through pith. Tilt froe forward for first blow, then drive down level at heel. Froe may travel a bit from blow. Heavy maul takes abuse.

5 Pry halves apart. Best leverage near top.

6, 7 Split halves into quarters. Note how log splits again down the pith. Froe has traveled from blow to bottom of billet half.

8 Split off four-pin blanks from quarters. Sometimes blanks split off merely by dropping log section and froe together onto block.







9



10



11



12

Jack A. Sobon

9 Splitting squares from the blanks.

10 Two useful froes with forged full tapers and a less useful one, at right, with short ground bevel.

11 Bench hook adapted for pin shaping, stop at back of tapered V-groove.

12 Two shaving horse styles, Continental dumbhead (at top) and English bodger's bench. English-style grooved yoke offers advantages for pin-shaving.

**Splitting out blanks and pins** Place the froe on the line nearest the center of each remaining piece and work outward to split out the four-pin blanks of the grid. Start in the middle of each piece because the split then is more likely to run straight down; if you start close to an edge, the split may want to travel the path of least resistance and drift outward. Point the cutting edge of the froe slightly away from the bark side since that is another path of least resistance. Once the split has started using the maul, set it down and torque the handle of the froe to complete the split. If necessary, steer the split by pulling on the top of the handle in the direction you want the split to go.

Take the square blanks and quarter them in turn (a smaller froe or an axe helps here) to make roughly square pins (Fig. 9). These squares are larger in area than a corresponding-size round hole, such that when the corners are shaved down and tapered to size the pin should still fit snugly. A few ridges left with the drawknife are desirable to key the pin once it's driven.

**Froes and mallets** A word about froes: a good one for splitting out pins must have consistent taper for its entire depth; the cross-section of the blade should be a V. Some new ones available today

are simply made from flat stock with a short bevel ground along one edge (Fig. 10). After being driven to a certain depth, such would-be froes don't continue to drive apart the workpiece properly, so they should be avoided. Antique froes have the long taper, as do new ones made by Ray Iles and Barr Quarton.

The mallet (or maul) takes considerable abuse from striking the froe. I have a 5-lb., cast-iron-head Garland mallet with replaceable rawhide faces that works well, but Dave Bowman, of Worthington, Massachusetts, the demonstrator in the photos, uses a beech maul (Figs. 3 and 7) that has lasted practically forever—reportedly 22 years and tens of thousands of pins. Dave's explanation is that the maul is made from rootstock, which has very dense, interlocked grain.

**Shaving pins** To shape the squares into usable pins, take them to a shaving horse, to be worked into octagons with a drawknife (bevel down), or to a modified bench hook, to be worked with slick and handplane. The bench hook shown has lengthwise stopped and tapered V-grooves in its surface to elevate one end of the pin for convenient rotation (Fig. 11).

Instead of working the square pins to octagons, some workers use a sort of die, a heavy steel plate drilled out with the desired pin





13 Lightly trimming square newly riven pin.

14 Long taper achieved while squaring. An eighth over most of pin length is adequate.



15 Turning peg to shave down 90-degree corners to flats.

16 Octagonal shape mostly accomplished. Corners of finished peg and tapered flats grip well in peg-hole.



size, or a short pipe of the desired inside diameter and with one end sharpened, to drive the squares through. The sharp edge of the hole shaves the square to round but doesn't provide a taper. The pipe has the advantage of guiding the pin as it is shaved, the next square forcing the finished pin out the bottom.

There are two types of shaving horse: the English (or *bodger's bench*), with a yoke to hold the work, and the Continental (or *dumbhead*), with a solid head open to the sides (Fig. 12). The Continental horse is better for long pieces that can be inserted from the side. For shorter stock like pins, the English is preferable, since it holds better via the notch incised and centered in the yoke. (A notch might help under a dumbhead but would still be not centered.) Greenwoodworking.com/ShavingHorsePlans offers plans online, together with discussion of the two styles.

Drill holes in the bench seat or working surface to match the diameters of the pins to make. If the distance from the sloping work surface to the seat is about the same as the desired length of the taper, then this gauge will serve to check both diameter and length of the finished pin.

Start by squaring the pin if necessary (at this stage, the section might be a parallelogram), with the drawknife edge bevel down for

best control. Evaluate the pin for any splitting taper; the narrower end obviously should be at the tip of the finished pin. Work the tip end first, finishing it before turning the pin around to work on the driven end. Place just enough of the driven end under the clamp of the shaving horse to hold, and carefully shave the faces square (Fig. 13).

Take only a few passes and at the same time introduce a slight taper ( $\frac{1}{8}$  in. or so) over the entire accessible length (Fig. 14). Then rotate the pin successively and take off the corners, first passes starting up near the clamp head and second passes starting about halfway down the pin. That should be all it takes. Don't shave off too much: the resulting flat surfaces should all be about the same width. In other words, approximate an octagon (Figs. 15, 16).

The 135-degree corners left on the pin are good for gripping the pin hole, and with a proper taper the flats will also wedge into the sides of the hole when driven home, so don't overdo it trying to get the pin round. Keep trying it in the test hole: the pin should just go snug in the hole as the tip nears the seat of the horse below. In any test hole, the pin should go snug at about the point along its length where the tenon would ultimately be in the assembled joint.





17

The next step is to make a heavy square taper on the last 1½ in. of the tip end, reducing the tip to a blunt end about ¼- to ⅜-in. square so that it can get started easily in the offset drawbore hole. Ideally this short taper should be slightly concave to help guide the tip through the offset of the drawbore, so turn the drawknife edge bevel up to shave it (Fig. 17). Once the pin is driven, the short taper will extend beyond the far face of the timber and the cross-section of the pin will appear to fill the pin hole.

Finally, flip the pin around and dress up the driven end, which has been marred by the clamp.

**Testing** The pin shouldn't be able to enter the test hole, but rather just cover it, with a bit of the hole showing at the flats. When finished it should be slightly smaller than the pin hole when measured from flat to opposite flat and slightly greater than the hole when measured across the corners (Fig. 18).

Having a slightly undersized pin is better than having one oversized, since the latter could split the timber, and it's the drawbore that holds the joint together more than the snug fit of the pin. A good pin will show fair lines, reasonable consistency in the flats and not too great a reduction in section where it will emerge from the joint after being driven tight (Fig. 19).

The operation of riving and shaving tapered pins takes some practice. After a few dozen or so, however, consistent results are likely. Twenty pins an hour, including splitting out the blanks, is a good goal (Fig. 20). A sharp drawknife is essential, of course. The quality of the blank is key to saving wasted effort. Reject blanks that have knots, splits or twisted grain. Rejected pins can be used to keep your dogs occupied so they don't get to your good ones. And all those curly shavings make great fire starter.

—WILL BEEMER



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17 Shaving short taper at pin end for easier entry to drawbore.

18 Proper relationship of big end of finished pin to test hole.

19 Finished pin, nearly octagonal, with continuous gentle taper and short entry taper.

20 Dave Bowman holding about an hour's worth of riven oak pins from an experienced hand.



19



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Photos Andres Uus, Joosep Metslang, Will Gusakov

1 Small 19th-century barn-dwelling at farm museum, Saaremaa Island, Estonia. Doors to threshing floor on right; entrance to dwelling on left.

## Traditional Log Building in Estonia

ESTONIA is the northernmost of the three independent nations that make up the Baltic region of Northern Europe and, with a population of 1.29 million, one of the smallest states in Europe. The people are Finnic and their official language, Estonian, is closely related to Finnish and Hungarian. The territory of modern Estonia covers about 17,000 sq. mi. (slightly smaller than Vermont and New Hampshire combined), half of it covered by forest. The north and west of Estonia are bounded by the Baltic Sea, the east by Russia and the south by Latvia.

Estonian territory has been governed by powerful neighbors throughout most of the last 800 years, starting with the Germans in the 13th century and followed in succession by Danes, Swedes and Russians. Estonians largely lived in rural areas under feudal serfdom through the 18th century. The country gained independence in 1918 but was caught in the vortex of World War II. It was invaded and annexed by the Soviet Union in 1940, occupied by Nazi Germany 1941–44 and then remained a Soviet Socialist Republic until 1991, when it regained independence. Today Estonia is a member of the European Union and a so-called Baltic Tiger, known for its prosperity and progressive social policy.

Historically, Estonian architectural heritage can be divided into two different branches: local (vernacular) and European (international). Vernacular farm architecture of local origin is without ornament or decoration, simple formally and in its division of rooms, traditional and quite stable over time until the middle of the 19th century (Fig. 1). Urban, manor house and church architecture of European origin, which appeared here beginning in the mid-13th century, has been more open to change and more individualistic. In this discussion, we cover only the traditional buildings of vernacular rural architecture, built prevailingly of logs (but also of clay and quarried stone) and notably plain and modest.

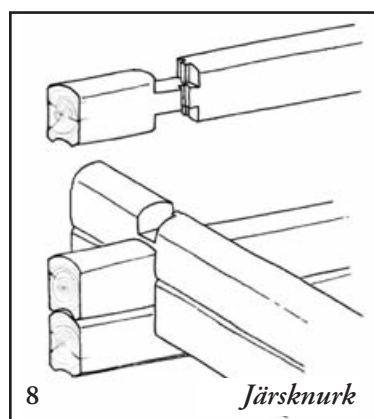
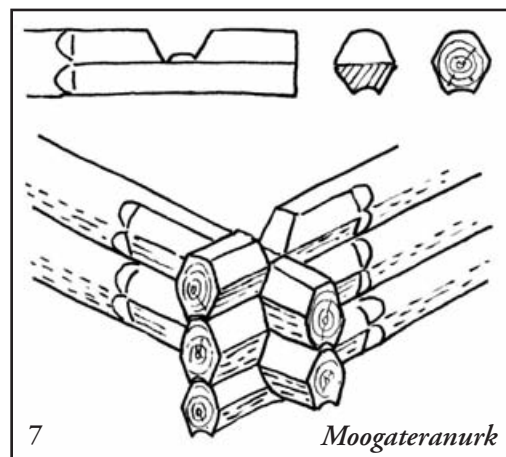
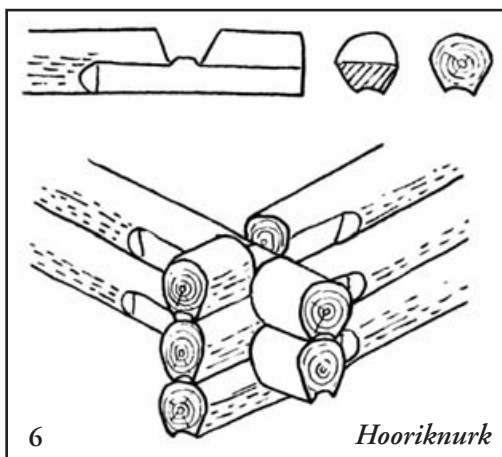
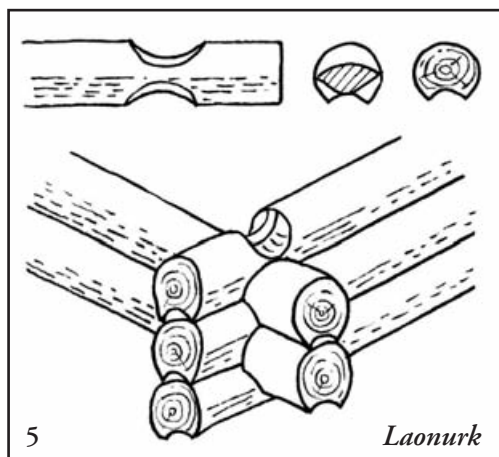
Native Estonians were locked into a serf-and-manor system well into the 19th century. The general population was not allowed to own land or buildings and forced to rent from the lord of the local manor. Rent contracts were signed only for few years and dependent on the landlords' judgment. In addition, one had to labor grievously for the manor (two men six days a week for an 11-acre

property was not unrepresentative at the end of the 18th century) and the tax burden, the portion of grain the peasant had to turn over to the manor from his own allocated land, increased in proportion to the tenant's prosperity. Obviously, under this feudal system peasants had little incentive to develop or improve the buildings they occupied. At the same time, modern, often gorgeous houses of stone and local wood were built in the towns and centers of power for the aristocracy (mostly German) and aldermen, merchants, artisans and other bourgeoisie.

Matters changed in the middle of the 19th century when peasants gained the right to own farmland and buildings. This change brought about a golden age of rural vernacular building for the next century, which saw the brisk development of building techniques and architectural styles. This golden era ended in Estonia by the 1950s, when Soviet occupation and central control quashed the local building style. Still, large quantities of log houses 100–130 years old persist in rural Estonia today and, since independence in 1991, numerous companies have been established that revived the craft of traditional building.

**Traditional building** Historians believe that the first log buildings (*ristpalkmaja*) in the Estonian region were built at least 2000 years ago and presume that Estonians learned their building skills from the Baltic tribes; the Estonian words for axe (*kirves*) and wall (*sein*) originate in Baltic languages rather than in the dominant Finno-Ugric. In vernacular peasant architecture, both dwelling houses and outbuildings typically were built of round logs until the middle of the 19th century, while hewn logs were used for manors and public houses. Axes were the sole tools employed in the construction of log buildings until the 1860s, when crosscut saws won a place in the carpenter's toolkit. Norway spruce (*Picea abies*) and Scots pine (*Pinus sylvestris*), both indigenous to Estonia, were the traditional species of choice for log builders, a preference that continues today. Historically, woodsmen cut and brought timbers to the jobsite in midwinter during the old moon (December to February), peeled and stored them for spring, and the building was cut and raised during the same summer.





2 Deteriorated wall with keys and grooved door jamb for short tenons.

3 Modern log scribing in process. Note wedged kerfs in unseen surfaces to control checking.

4 Next log laid out for corner notch and full-scribe cut. Tradition notches corner first to bring next log closer for lengthwise scribe.

5 *Laonurk* (round corner), was earliest, here in locking form.

6 *Hooriknurk* (saddle) followed, cut two lower faces.

7, 7b *Moogateranurk* (locking), cut four faces plus draft stop.

8, 9 *Järsknurk* (straight lap), popular in 19th century, here locking.

10 *Puhasnurk* (dovetail), usually for hewn logs, often sheathed.

Foundations were generally primitive, with walls supported by piers of quarried stone, infilled with loose stone, rubble, clay or sand. Often outbuilding foundations were not infilled at all. After the second part of the 19th century, lime mortar use became widespread even in rural areas, and henceforth the quality of the foundations increased and the lifespan of the buildings lengthened. Birch bark served as a barrier against damp between the first log and the stone foundation.

Dowels or keys placed at intervals along the logs helped bind larger walls. To keep walls in plane at door and window openings, plank jambs (*tender*) were grooved into log ends at the openings. Side jambs typically cut 5 percent short allowed wall logs to shrink and settle (Fig. 2).

Log diameters varied with building type. For houses and barns it was generally 7 to 10 in. In the traditional full-scribe procedure, not always used today, the corner joint (neck) was scribed first and

then, once the logs were in proximity, the bottom of the upper log was grooved and scribed to fit the lower (Figs. 3, 4).

**Joinery** Estonian carpenters employed a wide range of lapping joints to bind the corners of their buildings (Figs. 5–11). Though the topic warrants fuller treatment, here we show the most nearly typical corner joints, in order of historical development. (*Nurk* means corner, *tapp* means notch.) With widespread use of the crosscut saw in the mid-19th century, the *järsknurk* (“steep corner”) joint, faster to build, became the most popular for buildings with log walls exposed to the exterior. In the town milieu, and in rural areas beginning in the 20th century, the *kalasabatapp* (“fishtail notch”) became the preferred corner joint (*puhasnurk*). This notch was generally used for logs hewn flat on their vertical faces, to accept sheathing or plaster; it was more rarely used on round-log buildings, with logs hewn flat near their ends to allow for a clean joint.

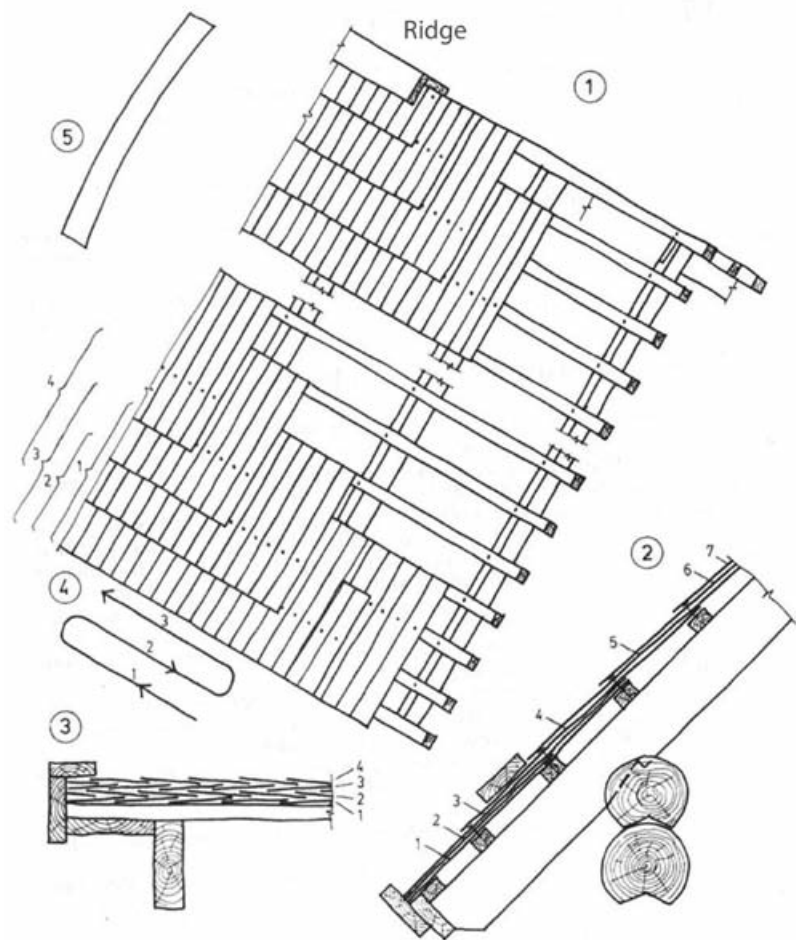




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From T. Masso, *Palkmajad*. Tallinn, 1991



15

12 Lashed purlin poles provided support for traditional thatch.

13 Coauthor Andres Uus shingles roof of wooden bridge at Lemmaku, Estonia, in 2102 (see *Scantlings* 174). Note untapered, curved shingles, method of laying starter courses, edge laps of shingles alternating direction in successive courses.

14 Diagram showing further details of method, triple coverage generally, quadruple coverage at second course. View 3 taken at edge of roof looking straight up rake. See also Fig. 19.

15 Andres demonstrates short grain of curved shingle, exaggerating to obtain splits. Laid correctly, the shingle's grain thus directs flowing water down and outward.

**Roofs** In farmstead architecture the hipped roof prevailed, typically in regular form with a pitch of 45 degrees. Round rafters about 6 in. in dia. carried round purlins lashed down by willow switches or spruce roots, on which the roof covering was fixed (Fig. 12). Until the end of the 19th century, thatch was the most common roof covering in rural areas. Typical thickness of a thatched roof was around 10 in., with an expected lifetime of 50 years. Straw from winter rye, the staple cereal crop, was the most common material.

With the arrival of the threshing machine (which rendered rye straw useless as thatch), and better availability of nails in the early 20th century, wooden shingles replaced thatch. In 1890, 80 to 90 percent of rural buildings were thatched, but by 1930 the percentage had reversed in favor of wooden shingles.

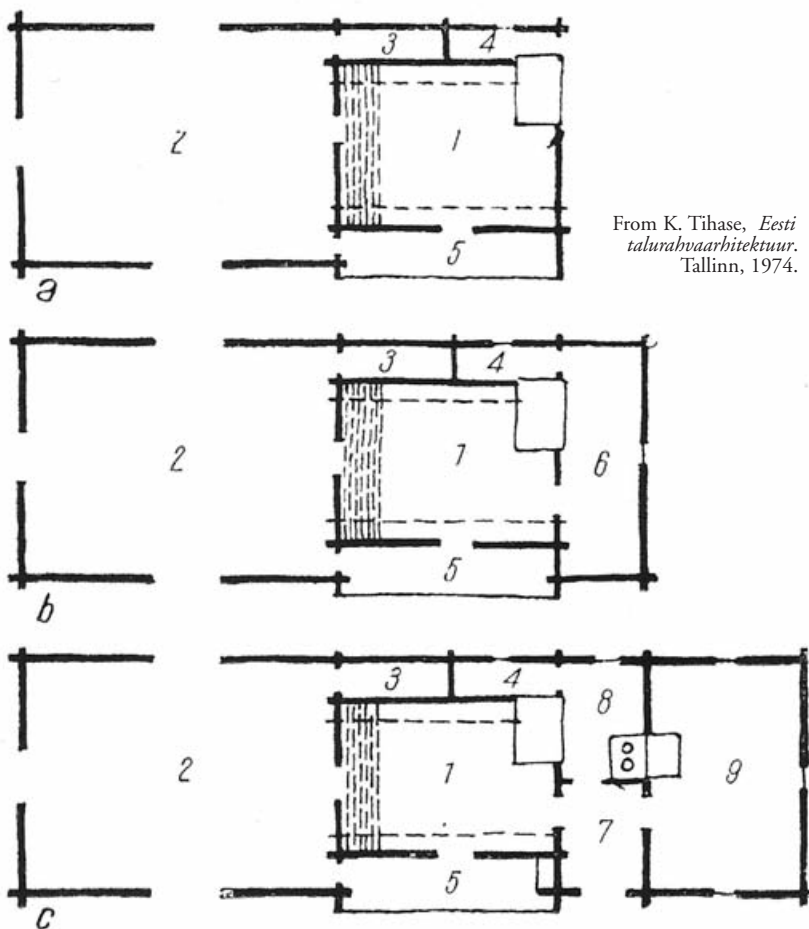
There are four distinct traditional types of wooden shingles in Estonia: *pilbas*, split from a block by hand, 2–3 mm thick; *sindel*, sawed from a block and rabbeted one edge to fit over the next

shingle; *kimm*, taper-sawed from a block; and *laast*, cut from a block by special machine, 4–5 mm thick, not tapered.

The machine-cut *laast* is the most common, produced by a special reciprocating cranked arm in the mill that yields a shingle curved in its length presenting short grain to the wide face. Laid convex side up and firmly nailed, the shingle clamps down the course beneath and on its lowest third exposes shedding grain to the weather (Figs. 13–15). Shingles were laid exposed to obtain triple coverage, with an expected 30-year lifetime. Norway spruce and aspen (*Populus tremula*) were the most commonly used species. In towns roofers used wood planking and stone as roof coverings.

Until the middle of the 19th century, closely spaced small logs, sometimes hewn on the underside, framed ceilings. From the mid-19th century onward, wooden boarding, known as a Polish ceiling, covered the underside of the joists. Moss, sand, clay or soil piled on top of the ceiling served as insulation.

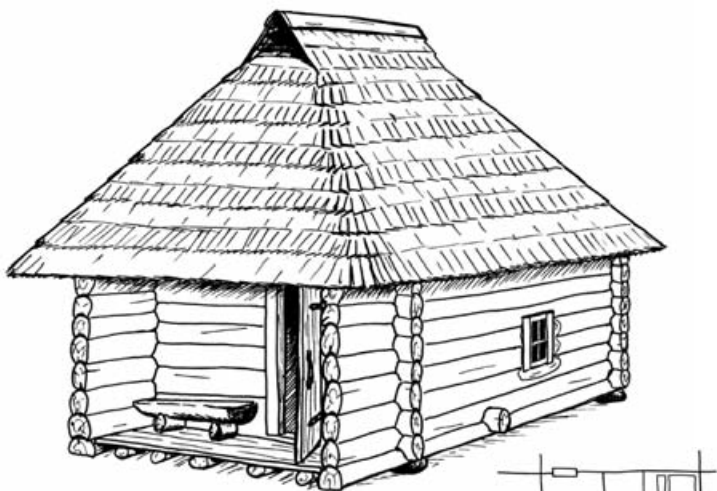




From K. Tihase, *Eesti talurahvaarhitektuur*. Tallinn, 1974.

16 Stages of ground-plan development of original barn-dwelling: (a) early 19th century, (b) mid-19th century, (c) mid-20th century. 1, *rehetuba*, threshing room; 2, *rehealune*, threshing floor; 3, *aganik*, threshed grain storage; 4, pantry; 5, *ulualune*, shelter; 6, *kamber*, room; 7, *esik*, entry; 8, *köök*, kitchen; 9, *elutuba*, living room.

17 Below, *suitsusaun* or smoke-sauna, typically about 10x16 ft., with bench, stove room and antechamber inside (plan view sketch).



From A. Uus and R. Lõbu, *Soovitud käsitööna palkmaja ehituseks*. Ristipalo (Põlvamaa), 2007

The resulting attic space sometimes stored hay or other materials; it was never finished. Ground floors were also very simple until the middle of the 19th century, typically stamped clay, soil or stones. With the golden age of building, wooden floors came into use, the oldest made of riven boards over dry sand. Sawn and planed floorboards came into use at the beginning of the 20th century. The practice of sheathing walls with boarding (typically horizontal) then expanded in rural areas when the dovetail notch

(*kalasabatapp*), which yields flush, sheathable corners, came into wide use. In general, decorative details, relatively simple, appeared only minimally, for rafter tails or to garnish posts, for example.

**Rehielamu** Among the typical classic buildings of Estonian vernacular architecture, the barn-dwelling (*rehielamu*, from *rehi*, threshing barn, and *elamu*, dwelling) is one of the oldest and most important (Fig. 1). A multipurpose building and one of the largest rural buildings of traditional Europe, the barn-dwelling sheltered the household and provided space for drying and threshing grain, carrying out different kinds of farm work and housing domestic animals in winter.

The barn-dwelling developed in Estonia early in the second millennium AD, shortly after the cultivation of winter rye and the attendant agrarian lifestyle became widespread. Early on it was a smoky two-room building with a threshing floor and a threshing room with open stone hearth, or *kerisahi* (Fig. 16a). Later, the dominant dwelling type, it consisted of three parts: *rehetuba* (1), threshing room; *rehealune* (2), threshing floor; and *kamber* (6), unheated room for personal belongings (Fig. 16b).

Typically 19x19 ft. and 11 ft. 6 in. high, the threshing room was located within the walls of the building. During the rest of the year, it housed the farm family, but with the autumn harvest (August to October) the family moved outside and grain was dried there, hung on wooden bars fixed 6 ft. 6 in. off the floor.

The *rehealune* was reached through wide doors in both eaves walls, allowing grain to be loaded into the building easily and good airflow to winnow chaff during threshing. Walls of all rooms were unfinished logs, the floors packed soil. Until the mid-19th century, threshing rooms, with their low interior doorways and high thresholds to minimize the flow of cold air into the room, typically lacked windows; with exterior doors closed, the only light came from a small opening, shuttered or covered with a swine bladder.

In the back corner of the *rehetuba*, the threshing room, was the quarry-stone open hearth without chimney, where the cooking was done. Numerous stones sat on the hearth to retain heat. Smoke from the fires left via the entrance of the threshing room. Richer farms had storehouses into which the family moved during the summer, and cooking was done in outdoor summer kitchens.

Ultimately the barn-dwelling form expanded to include a year-round living space separate from the grain-drying room, and chimneys were built to vent the open fireplaces (Fig. 16c). It wasn't until the abolition of serfdom in the mid-19th century, however, that the life and housing culture began to change for Estonian peasants. The most significant modernization in farm architecture of that period was a dwelling house detached from the threshing barn. Glass windows and porches (verandas) came into fashion, and dwelling houses began to look like the houses we see nowadays.

**Suitsusaun** The second classic structure in the Estonian building tradition is the sauna, which best preserves the old practices of architecture as well as traditional customs and beliefs. The typical sauna was built away from other buildings, if possible near a body of water. When establishing a new farm, the sauna was often the first building to be put up, to live in while the barn-dwelling was built. Saunas varied in size, corresponding to household size and wealth. The sauna, like other vernacular structures, preserved ancient building traditions for a long time. Saunas were still built without foundations until the 20th century.

The *suitsusaun* or smoke-sauna (*suitsu*, smoke) is one of the oldest types, still popular today and retaining much cultural significance. Traditionally the only place on a farmstead with hot water, the sauna was the place of recreation, bathing, healing, childbirth and many rituals and rites. A smoke-sauna is a small, low building, about 10x16 ft., with one or two rooms (Fig. 17).





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18 Firebox in a *suitsusaun*. Note water cauldron and lack of chimney. Flames rise through stones. Soot has only just begun to accumulate; eventually entire interior of sauna will be black. Smoke is evacuated before guests enter.

19 New *suitsusaun* in Mooste, Põlvamaa with hewn corners and *laast* shingle pattern. Note alternating-course edge laps.

20 Round log wall fit-up at yard of Tender Ehitus in Tudu. Note grooves for window and door jambs. Topmost log in position for new scribe. Compression straps take up shrinkage.

21 Logs sawn two sides with *järsknurk* (straight lap) corners. Hand-bored holes underway for dowel joints.



21

The identifying feature is that it's heated by an open firebox without a chimney. Many large stones are piled right on top of the firebox, heated directly by the flames; smoke rises into the room. A cauldron nests in the pile of stones on top of the firebox (Fig. 18). Water is dipped out onto the surrounding hot stones to make steam. A fire must burn for at least 3 to 4 hours until the stones have stored up enough heat for the entire duration of the sauna. When the fire has burned long enough and the flames have died to coals, the firebox is closed and a window or door opened to let the smoke clear before guests enter.

In Estonia, taking a sauna can easily last an entire evening (or an entire night), with incredibly hot sessions in the sauna punctuated by plunges in the nearby icy pond or river, and cold beers. Even today many traditions persist in smoke-saunas, from beating oneself with birch switches (to exfoliate and increase blood flow) to placing aromatic and healing herbs in the cauldron of water on top of the fire. Nowadays relatively few smoke-saunas stand in the north and west of Estonia, but they are ubiquitous on the farms of the southeast, including many newly built (Fig. 19).

**State of the industry** In the decades since independence from the former Soviet Union, Estonians have come to value their traditional building, natural lifestyle and environment. Renovation of old log houses, the use of traditional details and building new log houses in the traditional manner have become more and more popular (Figs. 20, 21). In the 1990s, about 300 companies sprang up to build traditional houses. Many of them also exported to the rest of Europe, taking advantage of cheap domestic labor and materials. As Estonian wealth and living standards have grown, these comparative advantages have shrunk and many traditional-building start-ups have closed, but many others survive and continue to revive and develop the craft of traditional log building in Estonia.

—PIRET AND ANDRES UUS

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# When Good Timbers Go Bad

UNPREDICTED timber behaviors and associated remedial efforts have taken a small but disproportionately interesting part in my 30 years of designing, building, selling and repairing heavy timber structures. In each instance recounted below, close friends played a role and, as with any activity involving humans, the errant timbers were only part of the story. Coping with untoward events and client relations also told a tale.

The most dramatic occurred in a wonderful greatroom (Fig. 1) framed with four strikingly large curved *taiko* beams, so called because of their resemblance to the famous Japanese drum of the same name, seen in section. (Taiko beams are sawn on their plumb sides and left round on top and bottom edges, somewhat as a drum in elevation has two flat surfaces transecting curves.) These arched beams straightened as they dried, significantly and strongly enough to induce failures both in some of the large members themselves and in some very-high-capacity connections.

The room's timber structure, a superb expression of our craft, was complicated by an unconventional shape and the interactions among members. The room widened from 18 to nearly 26 ft. over a length of 30 ft. 6 in. The four transverse taiko beams varied in length, therefore, from about 20 to 26 ft., in 2-ft. increments, and supported a large continuous ridge beam on posts, the ridge terminating in the end-wall masonry mass. The eaves were level, as was the ridge, so the two roof pitches necessarily varied, from less than 6½:12 at the window end to a bit more than 9:12 above the shortest taiko. As a result of the continual change in pitch, the two roof surfaces were not planar.

The curved beams showed signs of settling soon after the building was finished. The kingposts up to the supported ridge broke free of the taikos and hung from the continuous ridge—but only after shearing the 1-in. pegs at the kingpost bottom tenons. The initial upward arcs in the four beams varied from 3 to more than 6 in. at the midspan.

R. Bruce Hoadley, in his standard work *Understanding Wood* (1980), describes how reaction wood in naturally bent timber shrinks longitudinally far more than straight-grained wood. This differential shrinkage means that softwood curves straighten as their compression wood on the outside of curves shrinks. Hardwood curves, conversely, curl tighter as their tension wood on the inside of the curves shrinks.

The Port Orford cedar (softwood) beams in this room continued to straighten as the outside of their curves, their upper surfaces, shrank, until they broke over the knee braces and one of the chimney posts. Reaction wood is also known for brash tension failures, making for horrific-looking breaks. The failures in the beams in this room were indeed alarming and initiated two years of investigation and negotiation over responsibility and repair.

Those four 1200-lb. (dry weight) gorillas in the room, shoving things around as they respond to their own powerful internal forces—how strong were they? It would have taken about 50,000 lbs. to induce the same centerline deflection as the taiko beams underwent, a good indicator of how much force their deformation imparted to the internal structure. The maximum design load that I would expect the connected kingpost to have applied, for comparison, is less than a tenth of that.

At the braced bents, the straightening taikos pushed down on the knees enough to thrust the posts more than an inch off the ends of the beams' 3-in.-thick through-tenons, shearing three 1¼-in. pegs in the process (Fig. 2).

At the end-wall bent, two interior posts along the fireplace provided such solid, purely vertical support that the taiko lifted the

outer corners of the room as it straightened. The end-wall beam finally snapped over the interior post (Fig. 3) at one end, but not before it had also initiated a shear failure in the post above the housing at the other end.

Once the experienced timber framers who had so carefully constructed the magnificent room had absorbed their initial shock at the damage to the timbers and connections, they set out to establish what had happened and how best to repair the damage. Part of establishing cause, of course, was the issue of how to allocate remedial costs. Insurance companies, lawyers, owner's representatives and engineers weighed in. Mother Nature, the prime mover in the events, sent only the distorted timbers and damaged joints to the meetings, completely unconcerned about the entire thing. This is, of course, the issue: while it may be Mother Nature's "fault," it is beyond difficult to hold her responsible for impacts. (Try sending her a bill for tsunami rebuilding.) The technical legal concept of *latent defect* was introduced but did not unduly dominate the discussion.

In the end, all the non-fault parties behaved well and shared responsibility for the repair work. The investigation work began with a thorough inspection and careful survey of the frame's configuration. We measured moisture content, to confirm our hopes that the movement had (most likely) run its course. We measured ridge elevations, eaves spread and post-to-post distances at their bases and at the brace mortises. These measurements indicated that the posts had not just spread, but had even bowed out under the brace thrust—this in 10x10 posts.

All parties negotiated the remedial work with realistic expectations and goals. Clearly, the roof was not falling down, despite the structural retreat of the taiko beams. The large ridge beam could "handle" the load without unacceptable deflections, even absent any support from the taiko beams. Some apparently structural issues, albeit dramatic, were almost entirely aesthetic.

We set the goals to make the repairs as effective and unobtrusive as possible within reasonable limits of buildability, and to assure that the repairs need be made only once. This latter goal raised one of the tougher questions: should we render the large knee braces ineffective, to prevent further damage if the taikos continued to shove them down and out? This would have meant cutting away the bearing area at one end of the braces, a drastic enough reworking that we elected not to do it.

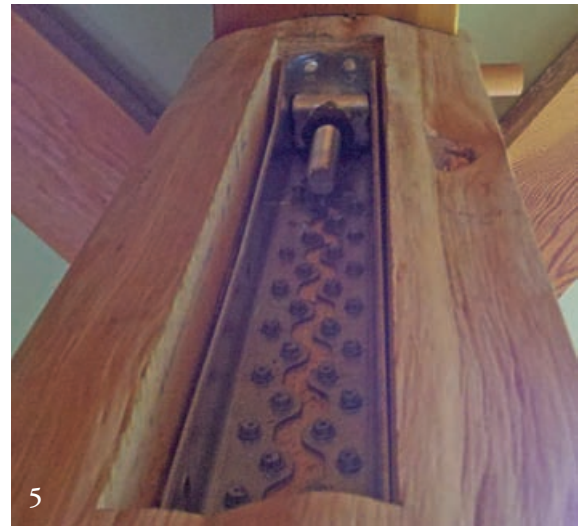
The three damaged taikos were drawn back together cross-grain and clamped with hardware. The badly broken end-wall taiko needed through bolts and 2½-in. timber washers to match (Fig. 4). The interior bent break was repaired from above with lag screws and washers, with counterbores filled by 1-in. pins. While the taikos no longer are pristine, they are clearly stabilized and going no farther in the future.

The tension failure in the post-taiko connection was the most concerning structural issue. To restore capacity, the framers added Simpson HDU14 Holdowns at the two broken ends of the taikos. A 1-in.-dia. rod passes through the post out to a nut over a washer about 6 in. square on the outer face. This hardware, normally applied vertically, lies horizontal here, concealed from below in the top of the taiko (Fig. 5).

The repair work included retaining earlier shims between kingpost and taiko to serve as ready indicators of any future relative deflection. If the shims become load bearing, the ridge beam will again be bearing on the taikos (Fig. 6).

This tale has a happy ending. The owner is certain that the damage has been repaired and will not recur, and the framers used





Photos Chris Madigan and Ben Brungraber

1 View from balcony of open roof framing over isocles trapezoid-plan great-room. Rafters change pitch constantly over length of room. Fractured tie beam at far end.

2 Fractured Douglas fir post and withdrawn curved cedar beam, following shrinkage in top of beam.

3 Detail of fractured curved Port Orford cedar end-wall beam before repair.

4 Detail of fractured beam repaired with Acme-thread bolts, cast-iron ogee washers and double nuts.

5 Simpson Holdown hardware for sills and posts adapted to tying joint. Long bolt passes out through wall post.

6 Shims fitted at withdrawn tenon in earlier repair left as telltales to monitor possible further movement.



the work to fill in a weeklong gap in their winter schedule. I learned a lot about the power of timbers and about negotiating construction concerns. I also learned some things about natural curves.

If natural curves are used as simple spans, they will merely sag, not induce internal forces. The taiko room is one very rare example of how redundant structures—those with multiple load paths—can misbehave in ways that simpler (or *determinant*, in engineer-speak) structures will not do. The bigger they are, the harder they shove. These beams, immense in the scale of the space, generated forces capable of inducing significant damage.

Building with dry curves could prevent a lot of this unpredicted

behavior. The curves in those softwood taikos might have been not so dramatic by letting them dry first, less impressive when built into the frame, but they would have stayed put. The Japanese practice of cutting and wedging *sewari* (“backsplint”), deep kerfs in the unseen surfaces of large beams, and then letting the latter dry, is clearly a great idea.

In the case of a curved softwood timber to be placed curve up, the deep kerfs would be cut into the reaction wood face. The kerfing procedure would thus not only focus the checking, but also permit faster drying of the crucial reaction wood zone by introducing air deep into the beam.





7



8

Ben Brungbauer

CAREFULLY wrought glulam curves in truss bottom chords, in another elegant greatroom, led to a second curved-beam-anxiety-inducer. I had old friends on all sides of this project—the client-builder, the designer of the curved bottom chord assemblies and the fabricator who did an exquisite job, not just grain-matching the ripped and reglued timbers, but even through-knot-matching them. These timbers were simply the most elegant expression of the glue-laminating art that I have seen (Fig. 7).

The project was going well until the on-site framers began cutting joinery in the glulams at the eaves connections. In many instances, the laminae had flared into brooms (Fig. 8). I have seen some pretty alarming timber behaviors, but a quick look via email at the ends of these beautifully fabricated timbers had me on a boat on my way to the site, without delay.

I was inspecting the timbers within hours, and found them to be just as alarming in person. The  $\frac{3}{4}$ -in. Douglas fir laminae, each about 20 ft. long, had been bent into curves of about 16-ft. radius for gluing—not a particularly harsh or stressful curvature to achieve. (This was soon borne out by just how little clamping force it took to reintroduce the curves during repair.)

I wish that I could confidently say whether this episode was a problem of materials, methods or fabrication by a crew that had done many successful layups and used West System epoxy correctly. There was no particular sign of sawdust on the failure planes (at the glue lines, in all instances), which would have indicated contamination, a classic cause of glue failure. My lingering concern is that cutting long mortises and bearing-face tapers for the rafters into the glulams released internal and residual stresses within the

individual laminae, or within the assembled layers, that caused the laminae to separate. In the end, simply regluing the laminae and installing frequent high-strength, double-threaded lag screws sufficed. The repaired timbers in their trusses flew within the week and remain looking good.

SOLID, straight-grained timbers were the bad actors in a third curved-timber tale. Timber framers have been working curves from straight timber since we have had axes. But the resulting large cross-grain areas of the timber can be problematic (Figs. 9, 10). Even in our diminished forests, we can still get timbers wide enough to bandsaw some pretty radical curves—but that does not make the practice a Good Idea. It's said that the builder is left hoping that "the check clears, before the check appears."

These members do not do well in compression and even worse in tension. If the curve is pronounced enough, there may be no zone of continuous grain along the full member length, which means that the tension capacity is, really, a question of shear transfer from side to side of the fibers along the member length. Even in cases with some region of full-length continuous grain, the member ends—where the critical tension joinery of a truss must be cut—will have the greatest proportion of cross grain.

Generally, I consider these sawn curves nonstructural components, suited only for "trimmer framing." I only wish that I had been able to cleave to this protocol throughout my design career. I have allowed some milder examples to be loaded in tension. In such cases I ask for a layout of the sawn shape on the original timber billet to help assess grain continuity and in laying out joinery to maximize grab.

So, how to "fix" failed timbers? Lots of light lag screws through the shear planes was the straightforward method here (it even works, sometimes). I have avoided using glue, when possible, being unconvinced that any added capacity is worth the mess and expense. Adding a tension rod directly between chord ends is a time-honored scheme. Using this method, one needs to recognize that the curves may be loaded in some compression. The curved timbers could go from shearing to buckling if one is not attentive when tightening the added rods.

My counsel is to avoid sawing curves from straight timbers, except as a last resort, and to treat them like malicious beasts if you must resort to them.

MY final tale of woe features a large, straight, once-green timber that chose to twist and check profoundly (and directly above the master bed) in a spectacular, large new residential barn dedicated to a remarkable art collection. I had spent some time trying to talk the owner's reps into using recycled timbers for the frame to reduce moisture release into the building during the first several years, all to protect the art. The added money and time seemed too much for them. In retrospect that choice has come to seem lamentable.

The big timber in question was a 12x16 Douglas fir plate, 40 ft. long, spliced to its mate (for a total length of 76 ft.) at the midpoint of the center span. The timber had already showed signs of a cantankerous nature during construction, to the point that I took a photo of it to serve as a baseline for future behavior.

Over several years, other large timbers in this barn twisted enough to blow out housings. Each time we went back to repair those eyesores, we would look up at the big 36-footer as it continued to twist and check. By the time the patron had reached the tolerance threshold, the combined check and twist had put the originally flush timber and post faces nearly 2 in. out of plane. All agreed that *something* needed to be done.

Proceeding with care, and not taking irreversible steps before thorough communication with the owner, we first applied a heavy homemade clamp of two stout pieces of oak pulled together by



nuts on two threaded rods. We hoped to learn how much we could expect to close the check and with how much force, and what the owner would think of the reduced check. The relationship between the torque applied to a thread and the clamping force induced can be complicated (friction, for instance, plays a role), but we estimated that our rig applied a clamping force of 15,000 pounds—and not, frankly, with a huge influence on the check.

We left the clamp in place for several months. Unforeseen benefits accrued during this period in the eyes and mind of the patron. First, it was clear that nearly anything we did would look better than this kludged clamp rig. Second, getting rid of the twist in the beam was clearly demonstrated to fall in the not-happening category. Finally, it occurred to all that the most crucial aspect was that this distortion was going to be checked (sorry) where it was. This made possible an important attribute of our remedial efforts: we could express the repair efforts, rather than trying to conceal them (with countersunk bolts, for instance).

Because I love the way it works and looks, I had saved a clamping pin (what builders used to squeeze things together before the Industrial Revolution made threads so available) from an 1826 Burr truss rebuild, a heavy square bolt with square head, diamond bearing plates and a prominent outside wedge to tighten the assembly. We sent images of it to the owner linked to an artistic bed's-eye view from directly below the troublesome beam, and aware that among the very fun art in the barn is a sculpture including an axe embedded in a timber. I am surprised at how readily the analogy and pitch were made and accepted.

Back we went, staging in hand, to install three permanent, artistically and historically inspired clamping pins (Fig. 11). With the through-holes drilled, we were able to use a 12-ton hydraulic ram to confirm the clamping force we would be applying. The agreement with our torque-determined forces in the homemade screw clamp was satisfactory and illuminating. The patinated hardware installed quite easily and the wedges, in fact, proved to be entirely capable of inducing every bit as much clamping force as had the hydraulic ram.

HERE are a couple of lessons I learned (or relearned) in these disparate examples of timber misbehavior. I gained only more respect for the power, and unpredictability, of exposed heavy timbers. Trying to *close* checks is not worth the enormous effort—and you will generally only make another face look worse. Fixing fractured timbers and regluing delaminated timbers, on the other hand, really are worth the effort, and remarkable improvements are realistically achievable. I still prefer glue-laminating for curved timbers that will bear significant loads, but I am not reluctant to reinforce them in advance with copious light lags across the glue and shear planes.

More than this woodworking lesson, though, I am reminded of some guidelines in dealing with humans in general, and clients in particular, when confronting untoward events. Communication, timely and thorough, is the experience devoutly to be wished for. Listening to your clients, particularly for their hopes for the future, is crucial. In all the examples I discussed in this article, the owners were united principally in wishing not to leave a mess that would only get worse. They preferred to look ahead to a better, if still imperfect, world.

—BEN BRUNGRABER

7 Gluelines, could they be seen, would appear in the wide face.

8 Delamination followed onsite cutting of joinery.

9 Sawn curves lack full-length continuous grain. Possible exacerbation of split here by differential shrinkage of spline and timber.

10 Detail of short-grain split in splined chord segment.

11 Visibly pleased author having fastened wedged clamping pins through checked and twisted 12x16 Douglas fir timber.



Ben Brungraber, above, and Dennis Marcom, below





# It Takes Three to Yield One



Susan Hammond

**T**HE historic Bartonville covered bridge across the Williams River in southeastern Vermont, built in 1870 and at 151 ft. one of the longest single-span covered bridges in the United States, was destroyed by flooding in August 2011 when the west abutment was scoured away from under the bridge in the aftermath of Hurricane Irene (Figs. 1, 2). The resulting 8-mile road detour made prompt replacement imperative, but the fact that the Bartonville had been a covered bridge was an issue. Local residents wanted a similar timber bridge to replace it and recognized that added cost would be a factor.

The replacement effort had to commence immediately, starting with the construction of new abutments to accommodate whatever superstructure was ultimately approved. Eckman Engineering, LLC, of Portsmouth, New Hampshire, began a geotechnical exploration in short order as well as the design of new abutments based on estimated loads for several types of superstructure. A covered bridge built of timber would be the heaviest and require the longest supporting length of abutment.

The Town of Rockingham, Vermont, which owned the destroyed bridge, and with which I had worked before, invited our firm, CHA Consulting, to provide design services for the replacement superstructure. We were under contract within a month. The first task was to prepare construction cost estimates for a plain-vanilla bridge to compare with the cost of a covered bridge using traditional materials and details. The initial estimates demonstrated that a traditional covered bridge would cost about 10 percent more than a conventional bridge. A combination of insurance and Federal Emergency Management Agency disaster damage reimbursement funds would cover the cost of a conventional (least expensive) replacement. The community was prepared to pay the difference.

The replacement bridge utilizes the same Town lattice truss design (named after Ithiel Town, who patented the configuration in 1820) as the original bridge. Observing historic preservation principles, the single level of top-chord elements as well as the trim details of portals and windows closely simulate those of the earlier bridge. Further, the unusual double-intersection top lateral system configuration, rather than the typical X with a single intersection at midpanel, was retained. We intentionally specified glue-laminated floor beams instead of solid-sawn, to provide extra capacity and long service life, in keeping with provisions of the Secretary of the Interior's Standards for the Treatment of Historic Properties, when use of different materials (albeit still wood) is required. Unfortunately, the remains of the timber superstructure were suf-

ficiently damaged that in our view they were of no practical use in the replacement structure.

The new bridge is 17 ft. longer than the original structure to allow an increase in its hydraulic opening. The new superstructure (168 ft. at deck level and 178 ft. overall) is the longest Town lattice single-span covered bridge in the United States (if not the world).

In keeping with common practice in Vermont for bridges with timber decks, the bridge had been posted with a 16,000-lb. vehicular weight limit. The town intends to maintain the same load posting on the replacement bridge. Nevertheless, we used a 30-ton, two-axle vehicle (H30 in national bridge design codes) for the bridge's design load. This size vehicle will provide reserve capacity for unauthorized overweight vehicles and extend the life of the structure, as normal stresses will be significantly lower than design allowables.

Sizing of the elements of the highly indeterminate Town lattice trusses and the verification of stresses in the solid sawn members and wood trunnels represented significant challenges. These were overcome by developing a first-order three-dimensional finite element model of the six planes of truss components. BSDI, Ltd., of Coopersburg, Pennsylvania, and Bates Engineering, Inc., of Lakewood, Colorado, worked together to prepare the model and provide forces to us for use in our evaluation of member stresses.

The extra length of the bridge and a desire for ample reserve capacity had led to a truss height increase of 2 ft., which naturally added considerable strength and stiffness to the trusses, approaching 25 percent (Fig. 3). But the community desired retaining the same bridge opening to deter use by oversize vehicles. Thus at the bridge entrances that extra height is hidden behind the portals and not noticeable to lay people traveling through the bridge.

The increase in truss height and element sizes led to a corresponding increase in the horizontal spacing of the lattice, from 4 ft. to 4 ft. 6 in., measured center-to-center of the crossings. Primary bottom chord and top chord elements sections increased from 3x12 to 4x14. The upper bottom chord (also called the secondary bottom chord), visible at deck level (Fig. 3), was made of two pairs of 4x12s (for a total of four) flanking the lattice. The top chord of 4x14s is configured similarly.



1, 2 Facing page, the Williams River in Bartonsville (Rockingham), Vermont, still rising in exceptional rains following Hurricane Irene in 2011, and partial view of upper chord of destroyed Bartonsville covered bridge (1870), dropped in river by failed abutment.

3 Trusses 2 ft. higher and floor and tie-beam framing of new bridge, 17 ft. longer, mostly complete, on a work platform right beside its eventual position. Note double X-bracing at tie beams.

4 Bridge builder Jim Hollar clowns as bridge is moved to permanent bearings.

5 At right, details of upper chord, butted diagonal roof bracing and wedged ends of transverse X-bracing.

6 Far right, details of lower-chord X-bracing, turnbuckled tie rods and glulam floor beams in underpinnings of new bridge. Winter does not keep bridge builders from their appointed rounds.



Photos CHA

We increased the maximum length of chord laminae from 16 ft. to 40 ft. 6 in. to provide better load distribution. All lattice elements increased from 3x12 to 3x14 to accommodate the critical connections with the primary bottom chords, using four 2-in.-dia. traditional oak trunnels. Three 2-in.-dia. trunnels fasten all other truss element connections.

The design originally called for select structural Southern yellow pine for primary truss elements, to take advantage of its slightly higher bending strength than Douglas fir. Concern over the dimensional stability of such large pine elements during their drying, however, ultimately led us to accept Douglas fir.

Many original covered bridges supported by Town lattice trusses used floor beams spaced to match the lattice spacing, with the beams threaded through the lattice openings to allow support by both inner and outer pairs of lower bottom chord elements. In this case, the 8½x16½ section of the floor beams prevented that option and therefore they are only supported by the inner pair of chords (Figs. 3, 4). Accordingly, bending stress is higher than usual in the chords, as is shear stress in the affected trunnels.

Since almost all floors have been replaced in historic covered bridges, we felt that it was tolerable to include some improvements in the floor system. Reflecting the floor-design details of the nearby Hall covered bridge over the Saxtons River (built 1867, destroyed 1980, current replacement built 1982 by the renowned Milton Graton and sons), also a Town lattice design, gaps for drainage and ventilation are provided along the curbs, but with fills above the floor beams and bottom lateral system to prevent drainage from dripping directly on those critical elements.

Air spacing to avoid direct contact of siding and truss chords provides extra ventilation around the truss elements. Additionally, shiplap siding protects better against rainfall penetration compared with square-edged boarding.

The top lateral system comprises double intersecting elements connected to the tie beams with mortise and tenon connections held tight by opposing wedges. Knee braces are bolted through lattice intersections and connect to the tie beams in notches with bolts (Fig. 5).

At the abutments, bolster beams, glue-laminated from pre-treated lumber to promote complete preservative penetration, support the trusses. (Floor beams were made in a similar fashion.) The bolster beams are supported by glulam bearing blocks atop raised concrete strip pedestals. At the bottom of the bridge, transverse tie rods hold tight the lateral system of single intersection timbers (Fig. 6).

Metal roofing sheds snow loads much faster than wood shingles (the original covering of most covered bridges), thereby lessening long-term loading on the bridge. At the time of its destruction, the original Bartonsville bridge likewise carried a metal roof.

Bensonwood, of Walpole, New Hampshire, provided rough-sawn, pre-cut timber to the job for assembly and erection by the construction contractor, Cold River Bridges LLC, of Readsboro, Vermont. We specified wood preservative treatment for the 4-in. Douglas fir deck planking and the timber curbs. We did not specify it for the truss elements for a number of reasons.

First, Douglas fir elements must be incised to provide uniform retention of preservative treatment. US design codes specify a reduction in strength of 15 percent for incising—a critical loss of strength. Second, preservative treatment would have required an additional month to obtain materials, deemed too long given the urgency of the project. Finally, treatment would have added an extra \$40,000 to the cost of the project. We were not convinced that it was a necessary or cost-effective investment. Many historic covered bridges have survived for more than 150 years without preservative treatment.



The bridge will weigh approximately 130 tons when its timber attains stable moisture content (Figs. 7, 8). The title of this article arises because Cold River Bridges, after building the abutments, installed a Mabey pony truss superstructure to carry traffic temporarily. Then they built the new covered bridge atop a work- platform bridge placed alongside the temporary bridge—three bridges, then, to yield one. Construction of the \$1.2 million superstructure was completed and opened to traffic in January 2013. The work-platform bridge will be removed later in the year.

—PHIL PIERCE

*Phil Pierce, P.E. (phil@philsbridges.com), is an Associate and Senior Principal Engineer at CHA Consulting, Inc., Albany, New York, and has worked and consulted on over 100 historic covered bridges. He was selected by the Federal Highway Administration as principal investigator and primary author to prepare the FHWA's Covered Bridge Manual (2005). Phil has written several articles and a book chapter and made numerous presentations to national and international audiences about covered bridges.*



Photos CHA

7, 8 New Bartonville bridge, dedicated in January 2013 (despite sign), is 168 ft. long at deck level and 178 ft. overall. Double transverse X-bracing, below, repeats unusual detail of original.





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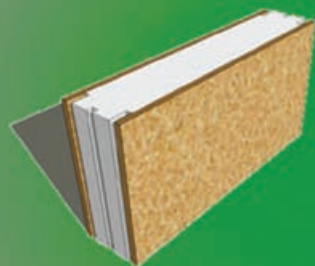
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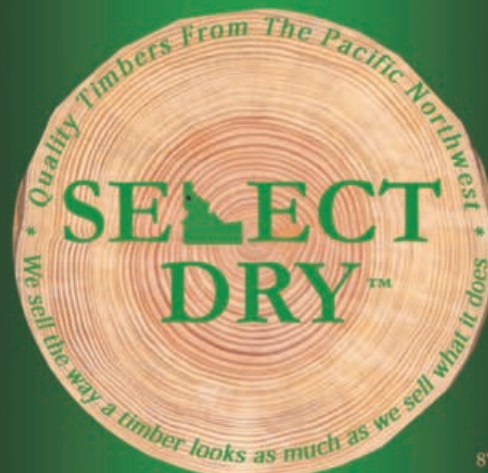
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