TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD

Number 111, March 2014

Early Barn Repair in Central Vermont

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On the front cover, Michael Cuba lays out joint in hewn replacement timber for Samuel Abbott barn, Braintree, Vermont, stabilized and under repair in background. Photo Jim Dorn. On the back cover, Seth Kelley roughs out mortise on replacement sill girder, using Millers Falls boring machine. Photo Michael Cuba.

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TIMBER FRAMING (ISSN 1061-9860) is published quarterly by the Timber Framers Guild. Subscription $45 annually or by membership in the Guild. Periodicals postage paid at Becket, MA, and additional mailing offices. POSTMASTER: Send address changes to Timber Framers Guild, PO Box 60, Becket, MA 01223.

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

1985

TOPICS

On Timber Framing, 1992

[Ed Levin, a founder of the Guild and a frequent and valued contributor to this journal, died last August at 66. Following a sojourn in St. Petersburg with other Guild members helping to build a boathouse on the Neva for a charitable institution, he wrote the article "Russian Reflections" for TF 26, December 1992, from which these passages are excerpted. —Editor.]

TIMBER framers generally concern themselves with the how, what, who, where and when of their craft, omitting the why. But the revival of timber framing and the history of the Guild make incomplete sense without an examination of motive and purpose. In its short history, the Guild has established an admirable record of service, both in collective projects—Habitat, the 'Inimin forest, Guelph, St. Petersburg—and individual or company-based efforts for local communities. Why this irrepressible urge to work in the public domain?

In the daily grind of shop and office it's possible to fend off such musings. But when in the course of a single summer I found myself, first under a full moon at ten-thirty at night with a hundred other guys shingling a roof, then again two months later in full moonlight with vodka glass in hand, toasting Russian teenagers from the deck of a new log building in St. Petersburg, well then it was time to ask some interesting questions.

The roots of the Russian trip go back two decades to the early days of the American timber framing revival and the founding of the first boat-building apprentice shop in Bath, Maine, in 1972. The intervening years have seen considerable growth of timber framing leading to the birth of the Guild in 1985, and a succession of three additional Maine apprentice shops (in Bath, Rockport and Nobleboro) with attendant evolution of the philosophy and practice of hands-on education. It now seems almost inevitable that these two independent developments were destined to meet and mingle, but who could have predicted that it would happen on the banks of the Neva?

My interest in the possibility of an apprentice program in timber framing led me to invite Apprenticeshop founder and guiding spirit Lance Lee to speak to us at the Guelph Conference in June. Hearing from Lance of the struggles of his Atlantic Challenge Foundation Russian affiliate Shtandart and their need for a building led naturally to Guild participation in a scheduled August trip to St. Petersburg. The Guild's directors saw the venture as an obvious opportunity for public service and quickly gave their approval and financial support. An appeal went out to the membership on very short notice and the response was astonishing and gratifying, both in cash donations and volunteers. In less than a month we put together a fund of $8,400 and a crew of 15, most of whom were also veterans of Guelph. . . .

The evidence of crisis in American family life is compelling: high divorce rates, broken homes, single parents, child support delinquency, domestic violence, child abuse. Imagine then the critical situation in Russia, where the moral, economic and spiritual underpinnings of the family have been under direct and continuous attack for the last seventy years. Perhaps the most horrifying result is the staggering number of homeless children. In St. Petersburg, a city of five million, there are an estimated 25,000 homeless kids, living in alleys, basements, bus stations, on the street. This is the situation the people of Shtandart confront daily amidst the crumbling economy, government and social structure of the former Soviet Union.

WE haven't been in Russia ten minutes and we are already in trouble, caught between demands for dollars from the porters who moved our baggage and our host's insistence on paying the customary fee in rubles. Eventually tempers are soothed and a compromise reached, but it is an experience that will recur many times in different settings. . . .

Russian hosts cater to their guests' every whim, and we learn that we must take care what we ask for, since our friends will move heaven and earth to provide it. It is the custom here for the host to present gifts to the guest and our own generosity sometimes creates awkward situations. The people of Shtandart scrupulously avoid questionable financial transactions, and despite warnings and the best of intentions we repeatedly get ourselves in hot water.

The headquarters of Shtandart and the home of Blue Crow orphanage are in a four-story building on Liteiniy Prospect, a major avenue downtown. Shtandart got the building after it was abandoned by the previous owners, and it shows. Trudging up worn steps in the dingy stairwell, we exchange covert glances, sharing unspoken thoughts of Roxbury, Watts, the South Bronx. As our hosts take us through the building, proudly describing past and future improvements, we must seem a stolid and unresponsive audience.

Framers who have led tours over plywood subfloors and around studs laced with Romex while intoning, "This is the kitchen, the dining room's over here, this passage leads to the bedroom suite," are familiar with the layman's inability to extrapolate from work in progress to finished product, to visualize transformation. How poignant to have the tables turned! It takes a while to catch on, but slowly the old tenement insinuates itself into our hearts and when we leave it is beginning to feel like home. The cramped quarters, the peeling paint vanish behind the new posters and wallpaper and the warmth and love of the people of Shtandart.

SEEN through a wide-angle lens, modern timber framing is a coincidence of our place in the cyclical history of architecture—the alternation of classic and gothic, renaissance and baroque, neoclassic and romantic, modern and postmodern. From the framer's point of view, the relevant aspect of these cycles is the swing from exposed to subordinate structure and back. When timber framing came to America in the 17th century as a late medieval survivor, the frame was the dominant feature of domestic architecture. "He who warms as he ought to the spirit of these old houses must revel in the well-nigh barbaric massiveness of their framing," observed J. Frederick Kelly in his indispensable work, *The Early Domestic Architecture of Connecticut*. In the 18th century, the fashion for increasingly classical decoration buried timbers behind plaster and paneling. In the second quarter of the 19th century balloon framing appeared and flourished, with its advantages of speed, adaptability and unobtrusiveness. Timber framing survived in diminished form up to that great watershed, the Civil War, after which it fell off rapidly and had pretty much disappeared from domestic architecture by the turn of the century.

The joined frame may have the staying power to survive long periods of decorated taste, but it certainly could never have become established during such times. Thus the timber frame revival took root at the seemingly fortuitous conjunction of a taste for expressed structure ("form follows function"), nostalgia for the past, and a general renewal of handicraft. Once again the frame was predominant, the ruling notion. We sold and built timber frames, and people somehow made houses out of them and lived in them. In those heady early days, marketing consisted chiefly of listening for the regular ring of the phone, design was largely of the back-of-the-envelope variety, and project management was pretty much nonexistent.

Now the pendulum has swung in another direction. We design, sell and, to an increasing extent, manage the building of houses. The emphasis is on integration of the frame into the design scheme, taste and scarcity combine to reduce the size and number of timbers, and framing may once again have begun to retreat, this time behind drywall, infill, stain and paint. Many of us are ill prepared for these changes.

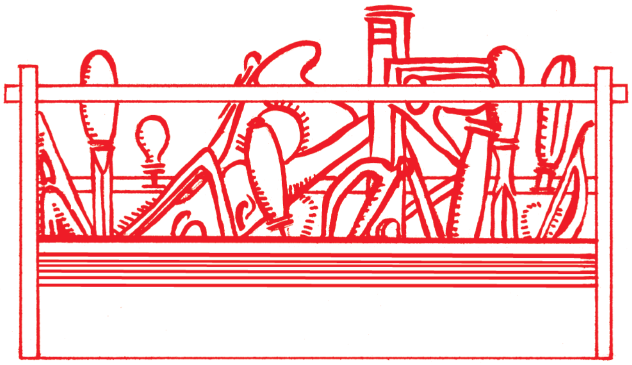
SO much for the frame, but what of the framer? The same principles of cultural selection that govern the cyclical history of taste have broader and deeper applications to the direction of material culture. Here again the Civil War can be seen as a cultural divide, marking the passing of the old apprentice system. As the 19th century drew to a close, the role of the trained "mechanic" (read smith, joiner, carpenter, mason) was increasingly taken up by the factory worker, as mechanization and early mass production supplanted the individual tradesman and the culture from which he sprang. One casualty of this change was the relative esteem in which the building trades were held, and carpentry ceased to be an attractive career for the upper echelons of the working population.

The early American carpenter could not aspire to the heights attained by his medieval predecessors, but he could still lay claim to one of the finest traditions of domestic architecture. As material and spiritual successors to these men, the viability of our work rests largely on the hope that we are not swept away by the historical tide, that timber framers and the fruits of their labor can continue to be held in high regard, that tomorrow's timber-framed houses will set the standard for residential architecture. Today's Guild offers encouraging evidence. But if the effect of our work is strong in proportion to our numbers, it is still minuscule in absolute terms. So, for the present, timber framers continue to be a breed of displaced persons, out of the mainstream, trying to play by a different set of rules and facing an uncertain future. The industrial and postindustrial revolutions seem to have bred a conviction that material culture is irrelevant, that the content and craftsmanship of the cloth on our backs, the furniture we sit on, the walls that surround us, even the food we eat can be willfully substituted, synthetic for natural, machined for handmade. As timber framers we are a kind of endangered species that will live or die in the test of this dire proposition. . . .

WE may have gone to Russia with a touch of missionary zeal, a paternalistic ambition to help those less fortunate than ourselves. But we return convinced that we got as good as we gave, that we have much to learn from and share with our old official enemies. While Russia must endure an economic drought, aren't we inundated by a material flood, with its own disastrous consequences? The Russians have no patent on moral inversion.

So, ironically, the dark Russian story sheds light on our own social and material history. Every circle hinges on its center. A prosperous America revolving around a bankrupt moral or material culture is a self-contradiction. We naturally seek to invest our work with meaning and social relevance. We come at the goal from opposite directions along the same circular track. —Ed Levin

TOOLS



TRACK SAW FOR TIMBERS

BEFORE cutting my first timber frame, I was convinced that the *biggest* circular saw was the essential power tool. So I purchased the popular Makita 16¼-in. saw (5402NA). After lugging this 32-lb. saw around and struggling to get straight cuts with it, I soon realized what you really need is the *smallest* saw that will get the job done.

Since then, I added two saws to my arsenal—a 10¼-in. Makita (5104) and a 6¼-in. Mafell track saw (KSS-400)—and divested myself of the biggest Makita. I thought I had all bases covered until I recently saw a new 9¼-in. Mafell track saw, the KSS-80 Ec/370.

The name of this saw is a mouthful. Mafell uses *KSS* to designate a saw and track combination. The *80* refers to the depth of cut in millimeters (about 3¼ in.) when on the track. *Ec* means the saw has a motor with electronic speed control and *370* is the length of cut on the track (again in millimeters, equal to about 14½ in.). The saw feels quite light (16 lbs.) for its size and very well balanced, even when assembled with its guide track. The controls are comfortable and well positioned and the machine evinces quality engineering (Figs. 1, 4 and 5).

Setting the blade depth When you first see the blade depth mechanism on a Mafell saw, you may wonder why all circular saws aren't designed this way. My 6¼in. Mafell has a top-mounted lever that raises and lowers the blade on two vertical shafts, along with a separate lever to lock the depth. The KSS-80 uses similar shafts, but combines the depth and locking levers into one, and it's even easier to adjust than its smaller sibling. Simply squeeze a button on the side of the lever to lift or lower, then release to lock (Figs. 1 and 5).

Mafell supplies two adjacent depth scales (both metric) on the saw, one showing blade depth when the saw is mounted on the guide track and the other when the saw is off-track. It's easy enough to print and tape an imperial conversion chart on the top of the saw for those of us who can't divide by 25.4 in our heads.

When the saw is mounted in the guide track, the maximum cutting depth is 3¼ in. Removing the saw from the track increases the depth to 3½ in. (Fig. 3).

The guide track The saw ships with a 32-in. track that can guide a cut up to 14½ in. long. Mounting the saw to the track couldn't be easier—just align the two channels in the saw base to the track, push a short distance on the track and the saw locks into place.

Cutting with the guide is a pleasure. The red plastic edge (Fig. 2) can be placed on the cut line and the saw moves smoothly along the track. The red-edge alignment works with bevel cuts too, even up to the saw's maximum tilt of 60 degrees. An integrated elastic cord aids the return of the saw along the track after the cut (cord end-fittings seen in Figs. 1 and 2).

The track guide is equipped with a sturdy and accurate miter gauge. The cut-side of the track has a fixed stud that should be positioned against vertical face of the timber before cutting. The opposite side of the track has an adjustable stud that slides along a rail and locks in place with the turn of a thumb screw. The scale goes from 0 to 60 degrees in one direction and 0 to 50 in the other, with detents at 0, 22.5 and 45 (Figs. 1 and 2).

Making cuts The Mafell KSS-80 cuts so easily through white pine timbers that you don't hear any motor strain at all (this is initially disconcerting). I also tested the saw by cutting through 3x12 slabs of cherry and birch, which the KSS-80 handled easily. The 19-amp Cuprex motor has an adjustable speed setting. I cranked it up to max and left it there.

The saw comes with an alternate-top-bevel 12-tooth blade, which looks odd (Fig. 3) but cuts almost effortlessly in soft pine, at the cost of some tear-out. Cutting 8x8 timbers to length is quite simple when using the track guide set at 0. If you've got a square timber, marking is not even necessary. For out-of-square timbers, holding the track on a drawn line is easy, provided the fixed track stud is held against the timber. The track remains aligned even without setting the miter gauge, using a minimal amount of pressure.

Cutting joinery This mid-sized saw works well for cutting timbers to length and roughing out tenons (although another ½ in. of cutting depth would be optimal for working with actual 8x8s). But what the KSS-80 really excels at is cutting braces.

The angle settings on the guide track can make reasonably fast work of the nose and tenon-end miters, though cuts from both sides are necessary with typical 4-in. brace stock. (I still prefer to do these cuts in single passes on a 12-in. miter saw.) But after that, no saw finishes off a brace faster or easier than this new Mafell.

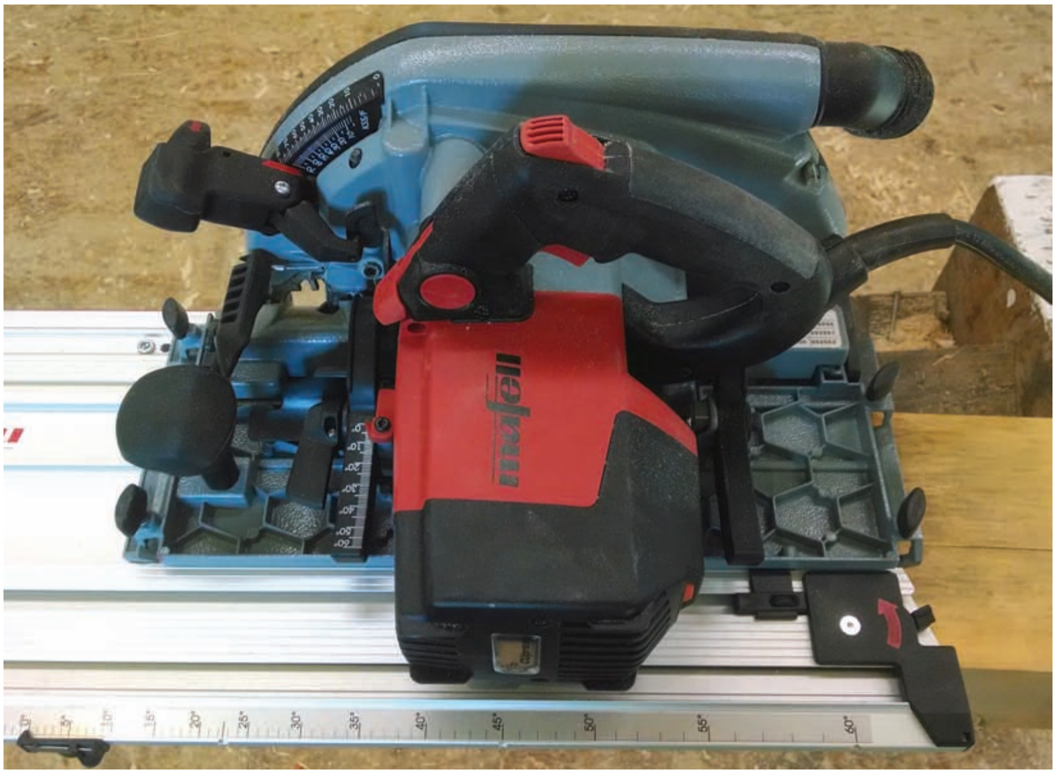
Cutting the brace shoulder is a matter of setting the shoulder depth and cutting another miter along the track. After the brace is secured (I use a bench vise) the saw can be removed from the track and the depth reset to tenon depth (or as nearly as possible) to make the ripcut along the tenon cheek while bearing on the end of the brace. Making this ripcut generates much waste, and I appreciated how easy it was to sight the inside edge of the blade because of the red pointers on the saw base, open sight lines and good dust extraction. (When using another saw to make the same cut, I would have to hesitate and blow the line off several times to see it, but not once with the Mafell.)

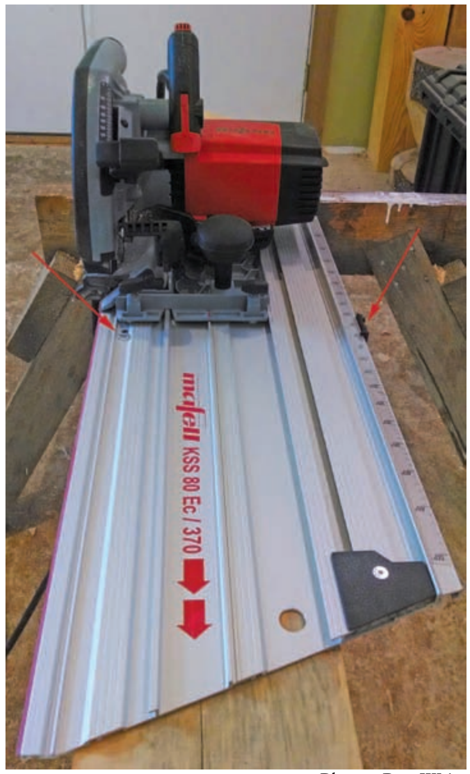
Dust extraction A dust extraction port is mounted to the upper part of the blade housing and includes a fitting with a Velcro strap to hold a vacuum hose in place (Figs. 1 and 3). Even without a vac, the saw ejects most dust through the port, which can be rotated to direct the stream away from you. By attaching a vacuum, extraction is almost 100 percent.

Other features The saw has a clever, safe way of lifting the blade guard before the cut, necessary when entering plunge and bevel cuts. A lever near the left-hand grip can be easily pulled by your thumb, without removing your hand from the grip (Figs. 1 and 2).

Bevel cuts can be set with a single lever, next to a legible scale (Fig. 4). The saw has an integrated riving knife that moves up and down with the blade, allowing the blade to be plunged into a timber from above without removing the knife (Fig. 3).

A 13-ft. power cord is supplied with a three-prong US plug. The standard package includes a full-length, double-rodded rip fence with metric measurements, which mounts to the cast and ribbed saw base and is secured by four thumbscrews. Mafell offers guide tracks of several different lengths, from 2.6 ft. to 10.2 ft., and fittings to attach two sections of track together. My evaluation package included two optional blades that Mafell produces for this saw—a 24-tooth and a 56-tooth, both ground alternate top bevel.





Photos Ben Weiss

1 Saw releases from track via single lever, lower right. Auto-return fitting just forward. Depth-setting lever at upper left frees by squeezing button, locks at new position upon release. Blade guard retractor just beneath. Fence-rod housings with twin thumbscrews at ends of cast base.

2 Two studs, one fixed, one adjustable (arrows), in underside of track bear on workpiece edge to establish cutting angle.

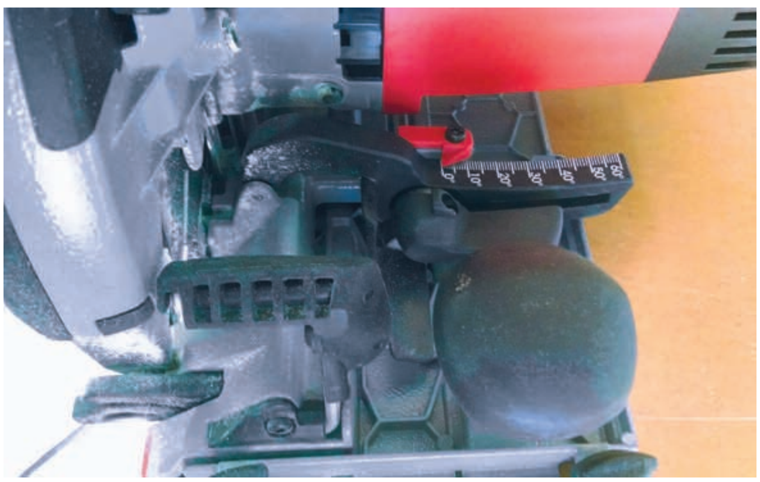
To remove a blade, you rotate a safety mechanism and pull a lever in the left-hand handle to lock the spindle, then loosen the bolt with the included Allen wrench that mounts at the rear of the blade housing (Figs. 1 and 3). I found the 24-tooth blade the best for Eastern white pine. It cut almost as freely as the 12-tooth and left a cleaner cut. The 56-tooth blade produced cuts only slightly cleaner again, and may not be worth the extra money for framing work.

Summary The Mafell KSS-80 is very well made, light for its size, balanced and powerful. The guide track is handy and easy to attach and detach. The saw's dust collection is effective and its mechanism for depth-setting unrivaled. For an American framer, a drawback is that the depth of cut is ½ in. shy of 4 in., however, and for most users the saw should ship with the 24-tooth blade instead of the 12-tooth. And at $1,572, this new saw is not cheap (nothing from Mafell is)—but if I were to start from scratch and buy only one timber-framing circular saw, the KSS-80 would be the one.

—Ben Weiss

Ben Weiss (zoomtext@gmail.com) is an owner-builder in Dorset, Vermont. He reviewed mortising machines in TF 91.

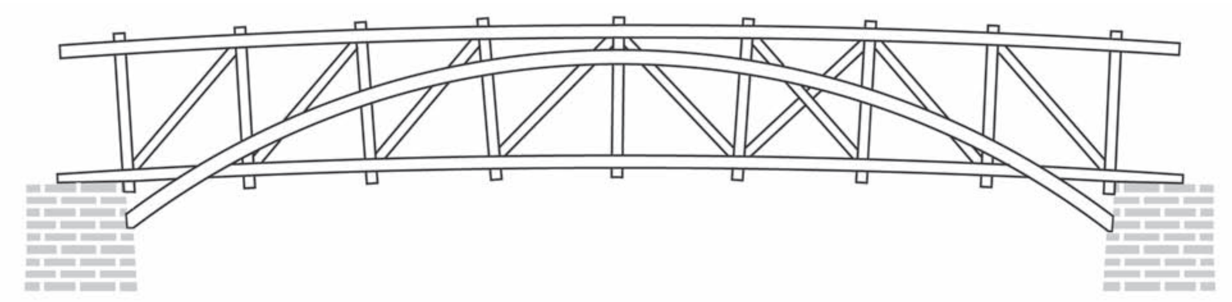
3 In-track depth of cut is 3¼ in. Riving knife descends with blade to keep kerf open behind blade. Dust chute rotates and accepts hose.



4 Bevel lock and scale behind knob, guard-retracting lever to left.

5 Squeeze-operated depth-setting lever and scales off and on track.

A Geometrical Perspective on the Burr Truss Covered Bridge



Drawings Laurie Smith

IS the Burr truss a configuration that superimposes one or more arches on a multiple-kingpost truss, as Katie Hill proposed in the Timber Frame Engineering Council's symposium section of the Guild's 2013 conference program? Or is it the reverse, or neither? "The combination of arch and truss—two structural systems that behave in fundamentally different ways—has led to endless theorizing by designers and builders on the respective roles of arch and truss and on how the load is distributed between them," she reflected. "Structural engineering remains—even with all our fancy analytical software—as much an art as a science."

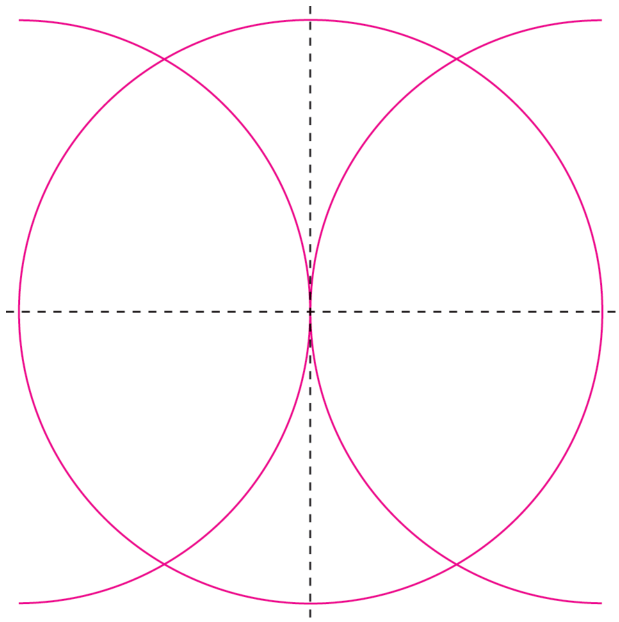
When Theodore Burr took out US Patent No. 2769x in 1817 on his "Truss Bridge," geometry was the state-of-the-art design methodology, and fancy analytical software didn't exist. In the 200 years between then and now, the spatial language of geometry has been superseded by the numerical language of mathematics: the art superseded by the science. Numerical analysis might tell us something about the Burr's structural behavior but nothing about the *geometrical* origin of the design. Geometrical analysis might throw useful light on the thinking that informed Burr's design.

The 1817 patent drawing replicated above strongly suggests the multiple kingposts are all radial to an undefined point somewhere below the bridge. The centerpoint of the arch, an arc of a circle, is likewise somewhere below. Also to be discovered is whether these two points are independent or a common point. The circle defining the arch would seem to be the element of the design to seek first. Indeed the bridge design evolves incrementally from this initial circle, using simple compass-and-straightedge geometry. The following drawings show the step-by-step development of the design.

Drawing 1 shows the circle drawn from an axis formed by vertical and horizontal perpendiculars, which simultaneously define the circle's North, South, East and West poles. Half-circles drawn to the same radius from the W and E poles intersect the full circle in four places.

Drawing 2 shows two horizontals drawn through the four intersections of circle and half-circles and a tangent drawn across the top of the circle and half-circles.

The tangent and top horizontal establish the alignments of the plate (upper chord) and sill (lower chord) respectively for the multiple-kingpost sector of the bridge.



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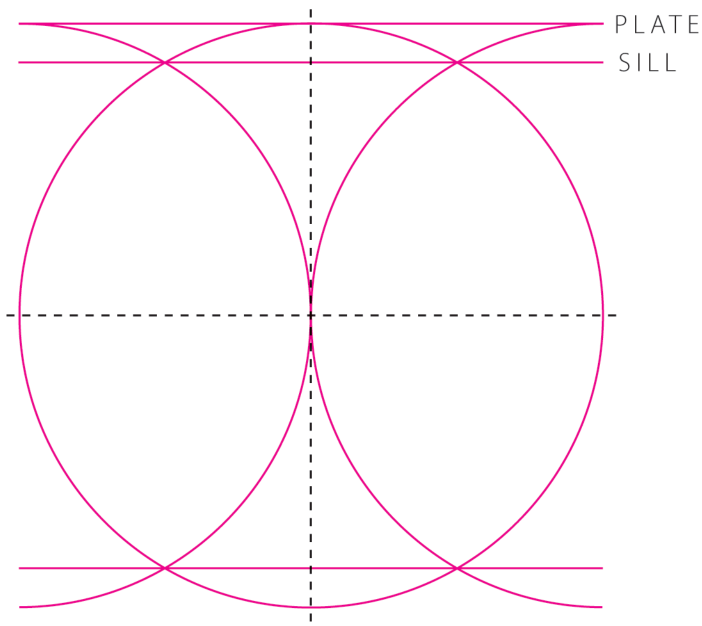
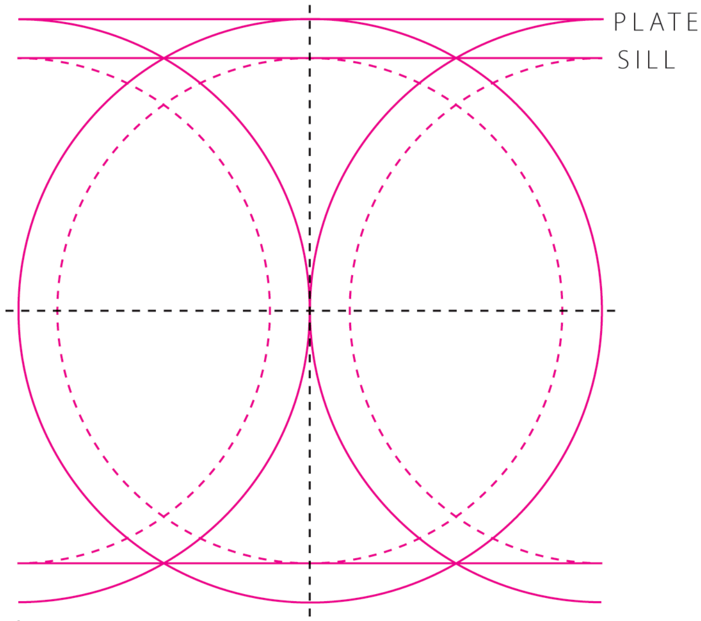


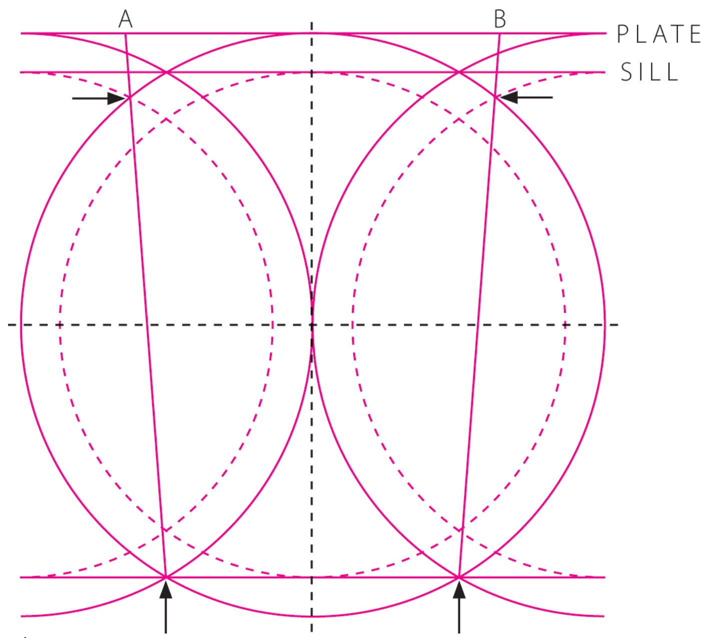
2

Drawing 3 shows an inner circle (in dashed line) drawn from the intersection of the perpendiculars so that it kisses the horizontals drawn in the previous drawing. Two dashed half-circles are drawn to the same radius from the W and E poles. The dashed circles generate further points of intersection that are used in the next stage of the design.



3

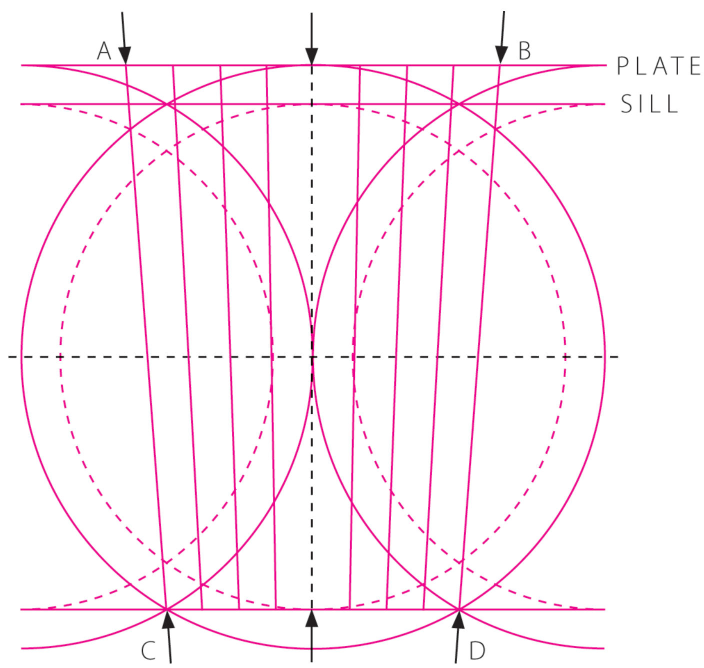
Drawing 4 shows two alignments drawn between the points of intersection marked by black arrows on the left and right of the drawing. These alignments start at the intersection of the solid-line full circle and half-circles at the foot of the drawing but pass through the intersections of the solid-line full circle and dashed line half-circles at the head of the drawing. This results in lines that diverge at the head of the drawing to give the outer kingpost angles between the plate (upper chord) and sill (lower chord) at A and B. The inner faces of the masonry buttresses beneath the sill (not shown) also follow this alignment.



4

Drawing 5 shows the plate line AB and foot line CD each divided into eight equal sectors which are linked to form kingpost angles between the plate (upper chord) and sill (lower chord).

Division into eight is attained by divider division of the full lines into halves (which is predetermined by the dashed black vertical perpendicular), divider division of the half-lines into quarters and divider division of the quarters into eighths. Divider division eliminates the need for ruler measurement and is a simpler and more accurate method of setting out.



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Drawing 6 shows the final stage of the design (the full circle is reduced so that the drawing's length fits the page). The outer lines AC and BD are extended downward to meet at a common point on the vertical perpendicular. Two arcs of circle are drawn in black dashed lines from this point, the first passing through the plate line (upper chord) at A and B, the second through the sill line (lower chord) at its centerpoint on the vertical perpendicular, the points marked by black arrows. The two arcs determine the parallel shallow curves of the bridge sill and plate.

As in the construction of a building, where scaffolding is an essential but temporary structure, much of the geometry shown acts as scaffolding that is superfluous after serving its purpose. The bridge occupies the upper sector of the construction between points A and B and between the parallel dashed arcs.

Drawing 7 is doubled in scale with the bridge superimposed on the geometrical construction so that the intimacy of the two is clear. The bridge is also shown separately for comparison. It can be seen that the masonry buttressing at either side of the bridge follows the angles of the outer kingposts and that the bracing in the center of the bridge connects the main circle's W and E poles to its N pole. While we know intuitively that the vertical perpendicular is at 90 degrees to the drawing's base line, a protractor tells us that the adjacent radials are at 86, 87, 88, and 89 degrees on the perpendicular's left and the same angles in reverse order on the perpendicular's right.

Drawing 8 shows the roadway as an arrowed black line, the arches as magenta lines, and their relationship in masonry and timber bridges.

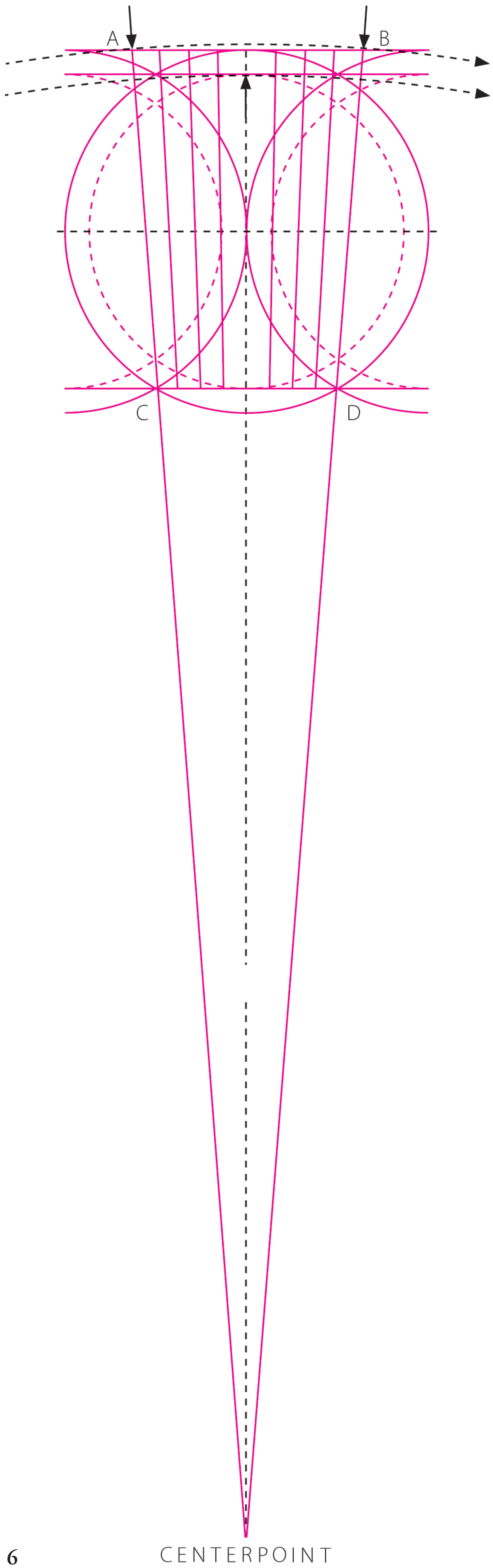
A third view There appear to be two major design opinions about the Burr truss: it is predominantly a multiple-kingpost truss supported by an arch or, conversely, it is an arch strengthened by a multiple-kingpost truss. I hold a third view, that the bridge is a unified design where every component arises from the same geometrical matrix and is therefore in spatial harmony.

Where did the idea of the Burr truss come from? In my view it is a linear timber frame evolution from solid masonry bridges, keeping in mind that the underside arch of a masonry bridge (the intrados) was built on carpentered centering, and the roadway was supported on the necessary depth of masonry above the intrados. If the precedent was already there, the innovative aspect of the Burr truss was to consider the arch and roadway as two separate linear elements that could be formed from timber. More important, in the absence of masonry, the roadway and arch could be placed in a different relationship to each other. Drawing 8 shows the roadway of the Burr truss as far below the apex of the arch as the masonry arch is below its roadway.

As Drawing 7 shows, the linear elements of timber structures mesh perfectly with compass-and-straightedge geometrical design methods. The only issue is scale, translating a drawing to a full-scale structure. If the Burr truss bridge in Drawing 7 is 100 ft. in length (some were longer) the initial circle would be 144 ft. in dia. at full scale. At 1:12 scale this circle would be 12 ft. in dia., or 6 ft. at 1:24 scale and 3 ft. at 1:48 scale, the last a scale that could be drawn comfortably on a 4-ft.-square table with a beam compass or trammel set to an 18-in. radius. With the radius established, the geometrical development is simple and straightforward.

—Laurie Smith

Laurie Smith (lauriesmith@uku.co.uk) is an artist and graphic designer living in Devon, UK, who has made a specialty of geometric building analysis. His "Useful Geometries for Carpenters" appeared in TF 95 and is collected in Timber Framing Fundamentals.



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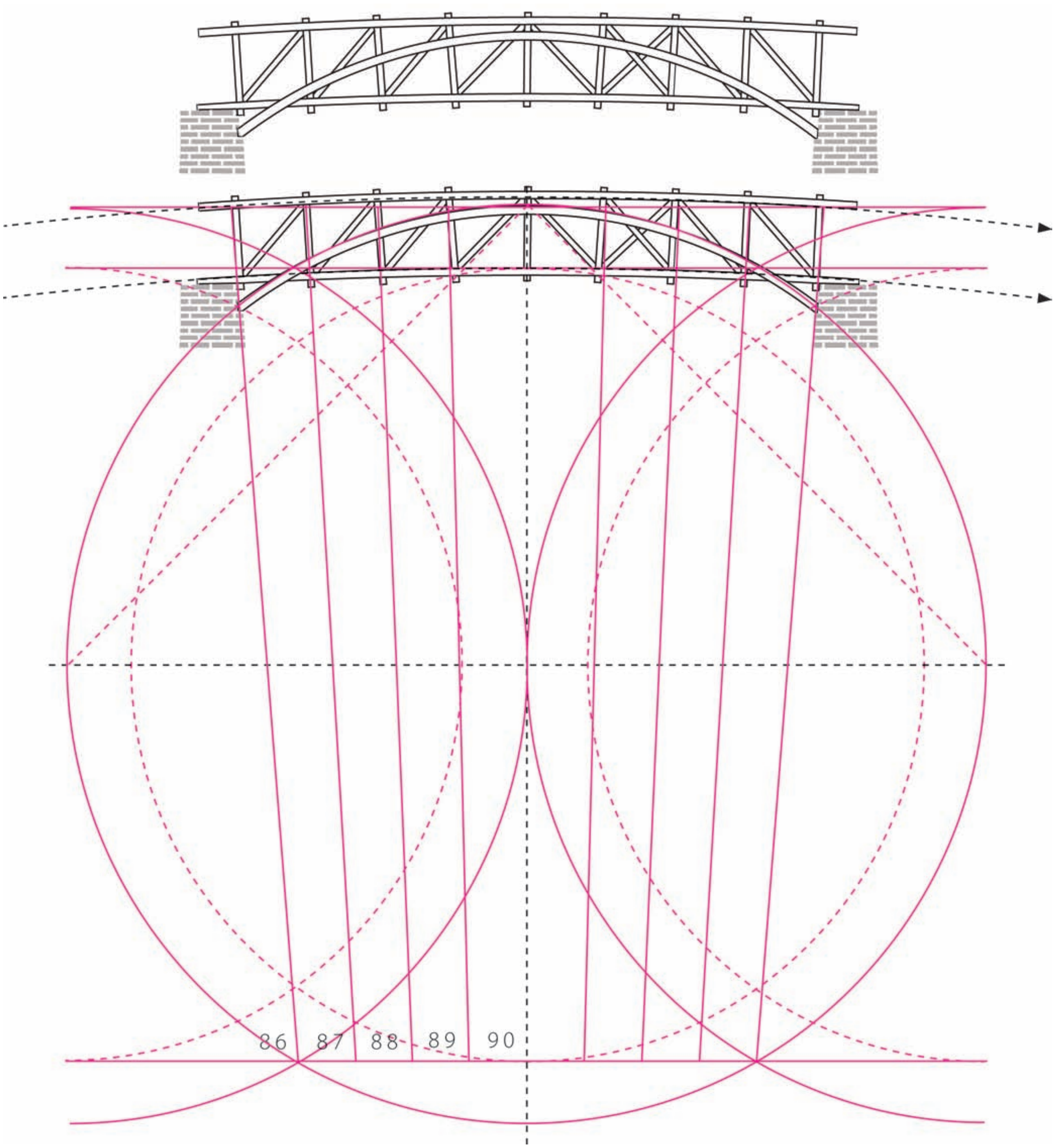

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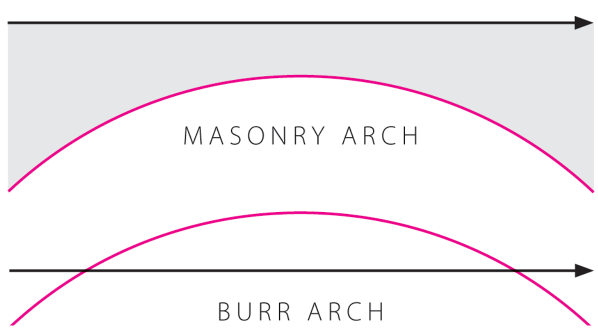

8

Lost in Translation: Early Square Rule Framing in Central Vermont

THE origin and development of the square rule layout method has long been a subject of speculation, about the beginnings of the technology and its migration. What must it have been like to have been a competent joiner of the scribe rule method, a contact sport, and to make the transition to the square rule, with its imaginary frame? How was the practice disseminated? We have this rather brief and esoteric account of the method, titled "The Square Rule," published in Edward Shaw's *Civil Architecture* (1831):

> This principle is considered more simple than the Scribe Rule [described just previously], as it can be applied in many cases with less help and more convenience.
>
> In order to make a good frame of any considerable magnitude, it should be the first care of the master-workman (after examining the plan of the frame with care) to make out a proper schedule of the various sizes of the timber. Set down their appropriate marks on the schedule, and when you have finished Nos. 1, 2, &c., check them on that schedule. It is of importance that all mortises, tenons, pin-holes, &c. should be struck with a patron [pattern]. All the timber should be lined to its proper size, and the mortises faced to the same. Care should be taken in applying the patron; for striking, it should be governed by the appropriate lines. This method has the preference in detached framing: the timber admitting of being framed in different places, and not tried together until its raising.

There appear to be no accounts of the method in any major publication within a few decades of the square rule's early use in the last years of the 18th century. Accounts of the technology may have spread like the telephone game, resulting in varying degrees of clarity about the concept and how it was to be applied.

In central Vermont, where I have worked for some years with Seth Kelley at Knobb Hill Joinery, there are many early examples of the square rule method (Fig. 1). Over the past few years I have also had the opportunity to explore structures beyond Vermont and New England. The diversity and regional specificity of joinery styles has proven to be far greater than I had ever imagined, and the degree of predictability in the joinery styles of central Vermont is something that I may have mistaken for granted. The upside of predictability is that we develop expectations of joinery style and arrangement, and then deviations from the standard inventory really stand out. We are always excited to see a new joint or variation. In some examples it seems that new thinking or logic is being applied by clearly skilled framers.

"The History of Washington County," in the *Vermont Historical Gazetteer* of 1882 (Abby Maria Hemenway, Vermont Watchman and State Journal Press) carries an account of Bucklin Slayton, an early resident of Calais, Vermont, who was born in Brookfield, Massachusetts, on April 20, 1783, and moved to Calais in 1790 with his father, Jesse, a farmer and cabinet maker. Noting that its information comes from a "Genealogical and Biographical Sketch of the Slayton Family, 1873," the *Gazetteer* wrote thus of Bucklin (page 138):

> He was a master carpenter, and planned and set out many of the frame dwelling-houses and stores of Montpelier and Calais. He was the first man, according to common report, who set out buildings by square rule. Previous to that time buildings had been built by scribe rule. Whether he was the originator of the square rule or not, is not known beyond a doubt by the writer, but it would seem there were few, if any, who set out by square rule at that time, for in 1827 and '29 he was sent for to set out the factories in Nashua, N.H., and when asked how long a building he could set out, he said if they would furnish the lumber, he could set out a building that would reach from Nashua to Boston.

With naive enthusiasm I planned to discover what were sure to be the first square-ruled structures in the country, right in my own backyard. Soon after, I curbed my enthusiasm with more discoveries of individuals purported to be inventors of the square rule, in communities throughout New England and beyond. Nevertheless, Seth and I were both excited to have a name to pursue and a body of work to discover.

Fitch barn We were eager to explore Calais in hopes of being able to attribute a structure to Slayton and to identify the hallmarks of his work. While examining a large barn on the hill above the sawmill at Kent's Corner, an exceptionally beautiful hamlet in Calais, we finally found what we were looking for. The Fitch barn, a bank barn measuring on the frame just over 46 ft. across the gable end and a little over 80 ft. along the eaves walls (Fig. 3), was constructed in 1855 and had originally belonged to the Robinson family, who owned and operated the sawmill below.

To our surprise, we discovered that the core of the 1855 bank barn was in fact a much earlier (ca. 1805) English threshing barn that had been expanded by 16 ft. along the gable and 39 ft. along the eaves (Fig. 2). The original barn contained several features that we have seen variations of around Calais, Montpelier and Marshfield but rarely outside of the region (Fig. 4).

In addition to boarding grooves along the ties and plates, the gable rafters also featured these grooves (rare) and the interior rafters had plumb-cut abutments at the plate steplaps (seen several times in the immediate area). The rafters were supplemented at the mow bay by massive braces lapped across to distribute the roof load toward the drive and gable bents, visible in Fig. 2.

All of these attributes in one barn, combined with sash-sawn 3x5 yellow birch braces and nailers, suggested a fairly early date for the area, and it seemed obvious that the barn must be scribe ruled. There were no housings, nothing to indicate a reference face, so we continued exploring for some time before we noticed that the barn was in fact square ruled. We searched high and low for marriage marks of some sort to lead us back to a scribe rule theory. None were to be found, not even on the shoulders of empty mortises.

As we measured the braces, the mortises and the timbers, it became clear that the barn was built with all of the uniformity of a square-ruled structure, with the one odd difference that there were no gains (reductions from the original surface) to be found. The spruce timbers were simply hewn to perfection.

The interchangeability of braces and consistent shoulder lengths of the girts were just as you would expect to see for any square-ruled structure. Of course, I immediately decided that this proto-mill-ruled building, built long before accurate mills and four-siders, must be the work of the fabled Bucklin Slayton.

Google Earth

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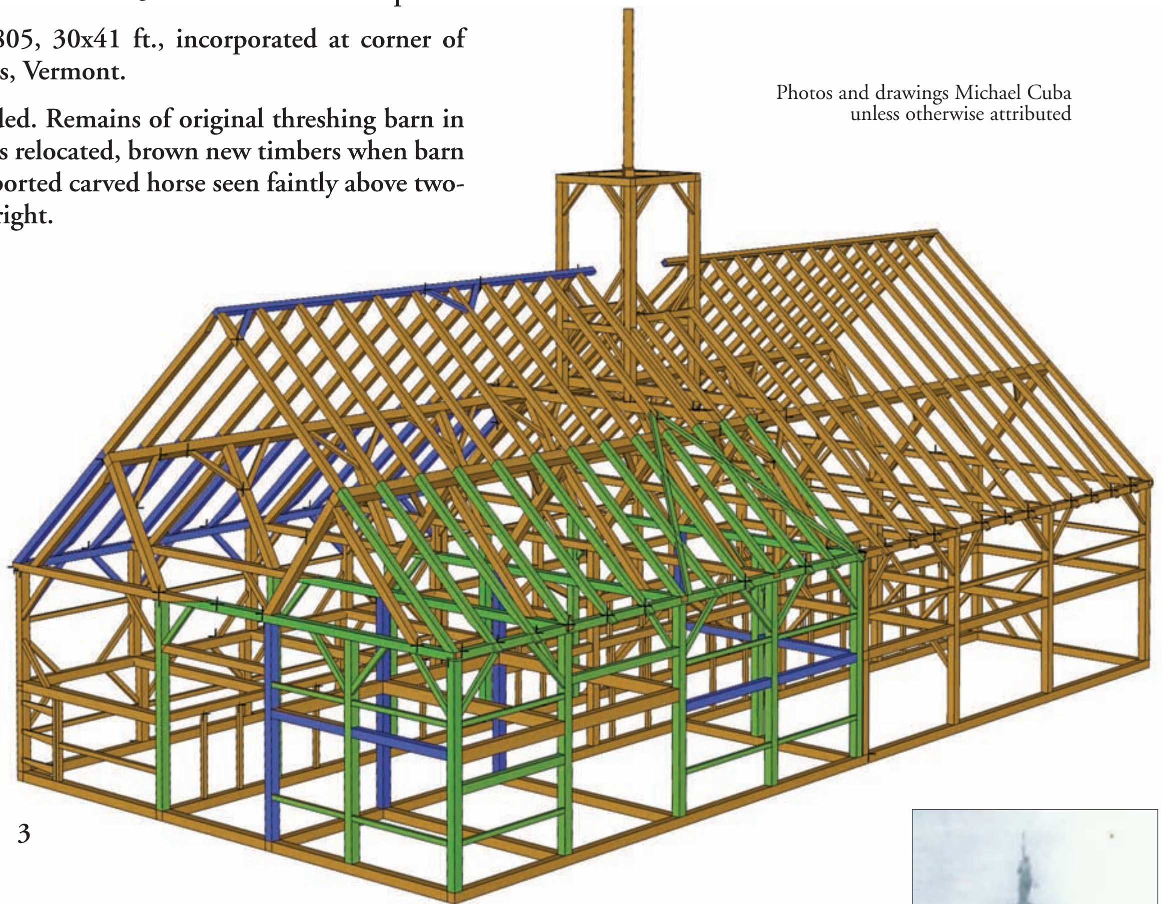
1 Central Vermont location of three barns discussed. Fourth structure, Samuel Abbott barn, stands in Braintree about 30 miles south of Montpelier.

2 English threshing barn, ca. 1805, 30x41 ft., incorporated at corner of 40x80-ft. Fitch barn, 1855, Calais, Vermont.

3 Fitch barn rendering, color coded. Remains of original threshing barn in green. Blue shows original timbers relocated, brown new timbers when barn was expanded in 1855. Mast supported carved horse seen faintly above two-stage cupola in old photo below right.

Photos and drawings Michael Cuba unless otherwise attributed



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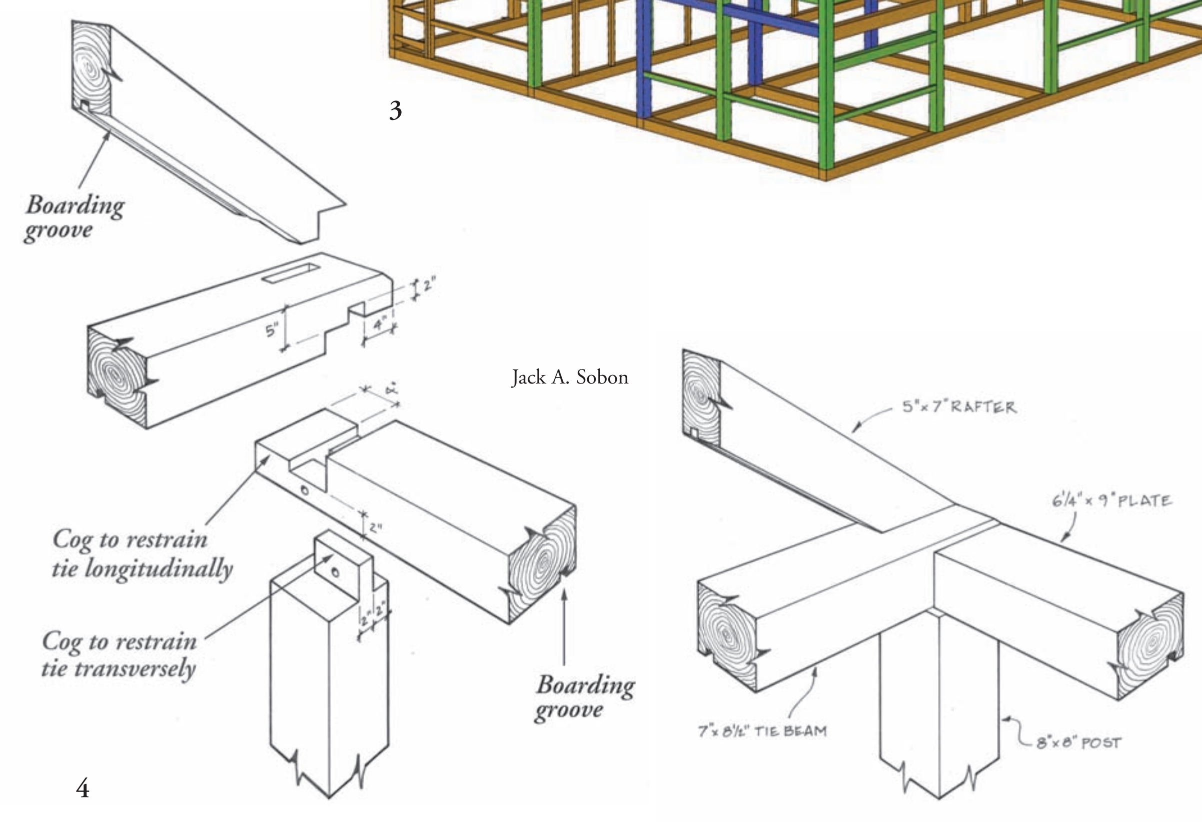
4 Below, Fitch barn tying joint, exploded and assembled views. In departure from lapped dovetail-to-plate joint, tie beam is cogged over projecting post tenon. Plate also restrains tie longitudinally via end cog. Note overhanging boarding groove in gable rafter.



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Jack A. Sobon

Fitch Family photo

Slayton barns About a year later, we were invited to examine a pair of English threshing barns on the property of the original Slayton homestead. The barns abutted gable to gable to form a 30x80-ft. building, elevated to accommodate a basement level below the main floor. In the *History of the Slayton Family* (1898), the early structures on the property were attributed to Jesse Slayton, and the remaining structures to Jera W. Slayton (born 1804). What is unclear from the account is whether *built* means merely commissioned or actually built by their hands, so we can only guess at dates.

The two structures were in terrible condition but we were able to determine that the older of the two barns was almost identical in plan to the threshing barn at the core of the Robinson-Fitch barn three miles down the road. The rafters were birdsmouthed instead of step-lapped but featured the same roof-plane long bracing scheme at the hay mow (Fig. 5).

The tie-at-plate arrangement was similar in that the tie beam half-lapped over the plate and used a cog joint at the gable (Fig. 6), but the Slayton cog registered in the side of the tie instead of the underside. The barn also featured tapered posts with teazle tenons into the tie beams (Fig. 7).

When we first entered the Slayton barn, it seemed a variation on the theme of the Robinson-Fitch barn. The brace legs were close to uniform and all of the numbers that we pulled seemed to fall at regular increments, yet Seth discovered marriage marks in this barn, hard to see at first but consistent throughout. I believe the older Slayton barn and the Robinson-Fitch barn were likely built by the same hand, presumably Slayton's, though we have no documentary evidence. They show an evolution of thought and style transitioning from the scribe rule to the square rule. Certainly the builder of the Robinson-Fitch barn, on the geographic and historic evidence likely Bucklin Slayton, had a clear understanding of the concept of the square rule.

Abbott barn The Samuel Bass French Abbott barn (ca. 1825), in Braintree, Vermont, we found during restoration to be square ruled and yet not simplified in its layout. It could well be argued that the square ruling only complicated the whole design. Although all of the principal timbers in the frame were hewn to roughly 8x9, each post seemed to have its own unique square ruling or ideal-timber-within, and might be square-ruled differently from one side of the post to the other. To make matters worse, different net sections were chosen for the foot and top of the same post. The situation was then further complicated by middle girts laid out with 2-in. shoulders and 2-in. tenons ("2, 2"), upper and lower braces laid out at 1½, 1½ ("schnaf, schnaf") and, finally, upper and lower girts with (bizarre) 1½-in. shoulders and 2-in. tenons (Fig. 8). Perhaps this was all very prudent from someone's point of view, but such a scheme leaves variables to keep track of and readily lends itself to mistakes (although the only mistakes we found in a partial dismantling were one post 3 in. too short and one misplaced mortise). The design of the Abbott barn suggested that it was a relatively early barn in our region for the transitions from the scribe rule to the square rule and from the English tying joint to the dropped tie. The drive bents of the barn have dropped tie beams while the gable tie beams land on top of the posts with the plates tenoning into their sides.

The relatively small tenons at the ends of the plate made for weak connections and proved to be the path of least resistance when the accompanying braces were put into compression. The combination added up to one of the least stable and unnecessarily complicated frames that we have worked on (Fig. 13). We can only imagine that the telephone game was at play in this barn's conception. It shows the learning curve in applying a new concept without established guidelines (Figs. 9–12). Note, however, that while the joinery layout was convoluted, the craftsmanship of the hewing and joinery made clear that the barn was not built by novices.


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Seth Kelley

5 At left, Slayton barn roof framing, first quarter 19th century, Calais, Vermont. Long brace let in to tops of rafters similarly to Fitch barn in same town.

6 Plate cogs into side of Slayton tie beam with overhang framing support notched in just adjacent. Principal rafter seated at right.

7 Tapered post (bottom) and pinned blind teazle tenon at modified English tying joint in Slayton barn. Tie beam, left, passes over plate, right. Principal rafter at top.

8 Samuel Abbott barn, ca. 1825, Braintree, Vermont, under repair. Erratic mortise layouts on replicated gable post.

9 Restored Abbott barn frame, 26 x 36 ft., post tops held level.

10 Drive bay dropped tie, Abbott barn. Tenon end severed from tie by too-deep, too-close joist pocket.

11 Faulty gable tie-to-plate level connection, Abbott barn. Failure to cut housing in plate or to support tie on convenient post shoulder left tie hanging on short tenon above beam midline.

Photos 10 and 11 Seth Kelley

12 Unnecessarily deep gains of original Abbott framing replicated on new timber.

13 Failed gable tie-to-plate joint in Abbott frame restrained transversely by straps and comealong. Structural staging supports triple beam carrying screwjack under gable tie at far end and second screwjack on near-end cantilever to collect plate load.

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Gould barn The David Gould barn (ca. 1807) in Montpelier, standing just four miles west of the Slayton homestead, was easily the most fascinating example of square rule interpretation that we saw (Fig. 14). Property records suggested that the original English threshing barn had been built around the time of David Gould's marriage to Polly Carry in July of 1807. Seth and I worked on the restoration of the Gould barn on and off almost a year, speculating about what the builders had been thinking, planning or trying to do. Unlike the Robinson-Fitch barn, the Gould barn clearly had been square ruled. The reductions or gains were consistently large, often well over an inch deep (in fact leaving very little continuous wood grain at two- and three-way connections, Fig. 15). What first caught our attention was the absence of tie braces (except for the one brace that was upside down, not shouldered, nailed into place and missing a tenon, Fig. 16).

Initially we assumed that tie braces once existed but were lost during the building's transformation into a bank barn after the Civil War, a huge oversight and yet the barn was still standing without their lateral support. When we began our work, the stone foundation supporting an eaves wall was failing and much of the added basement post work had rotted, leaving over a foot of variation in the elevations of the post feet, as seen in Fig. 14. To make matters worse, both of the wall plates were completely rotten and fractured in several places (Fig. 17). Gaps between the inside face of the wall plates and the plumb abutments of the birdsmouthed rafters indicated a great deal of movement (Fig. 18). The rotted ends of the tie beams must have allowed the broken plate and eaves walls to spread, we thought. How else to explain all of the gaps at the girt shoulders along the gable walls?

Eventually, we realized that there may have been an error or two in the calculations and layout. The more time we spent staring at the barn, the more mistakes became apparent. Referencing on the intermediate posts in the drive bents switched from one side to the other (apparently the two posts had been made identical instead of mirror imaged). The same mistake was repeated on the tie braces at the intermediate gable posts where the run is greater than the rise (4 ft. and 3 ft. 5 in. respectively). All eight braces had been cut the same. Only four could be correctly installed; the four remaining braces were identical to the four in place except that they had their tenons cut off and were butted and spiked since they could not fit their mortises.

Once we had begun to measure individual dismantled parts, we gained more clarity about what might have happened. With the deterioration of the plates, ties and the replacement sills, it was difficult to determine whether the gaps at the girt shoulders were a result of movement or caused by original miscalculation. Minor mistakes in the eaves walls evidently had been corrected when the walls were assembled on the ground for raising. All of the girts were well shouldered. Mistakes in the height of a set of lower and middle girt mortises in the mow bay remained evident. The other noticeable aberrations along the eaves walls were post tops reduced on both reference and nonreference faces, creating a slight battering of the posts to the outside of the frame.

The majority of errors were in the transverse direction. Most notable, each of the tie beams had been cut 4 in. short at 30 ft., the framers apparently failing to take into account the 2-in. projection of each plate at the walls to provide the boarding groove, perhaps being confused by the roof bevels cut on the outside upper plate corners. We surmised this mistake had not been realized until raising day, and the choice had been made to keep moving somehow. Further, the lap dovetails had been cleft from the tie beam ends and nailed back into place at opposite ends (Fig. 19).

One result of the mistakes with the tie beams was that only the rafters landing on the ties supported the ridge beam and took the outward thrust of the roof load. The remaining rafters, while joined at the ridge, landed 2 in. short of the inside face of the plate, resting on their level cuts but with their plumb cuts not making contact with the plate. Oddly, this may have been a saving grace of the other cumulative errors. With the gaps at the plumb cuts, the rafters at the plate did not thrust outward on the plates. That and the tight double-boarding may explain how the barn was able to survive. Of course, we replaced many members to give the barn a new life, but we preserved certain oddities such as the canting of the upper girts in the eaves walls, which would have shouldered well over horizontal spans but originally fell short in their canted orientation (Figs. 20 and 21).

Lost in translation We realized by the end of our experience with the barn that the carpenters were really quite skilled as woodworkers. The hewing and chisel work were extremely well executed. As with the Abbott barn, these carpenters were not novices. Ultimately we found few exceptions to the regularity of the layout. Perhaps some of the broader concepts of the square rule, such as interchangeability of parts, were lost in translation. Or the use of gains may have been applied a bit too liberally, as shown by the case of one of the plate posts in the hay mow where unnecessary heavy

14 Gould barn, 30 x 41 ft., ca. 1807, Montpelier, Vermont, before repairs. Framing mostly spruce.

15 Deep housings leave little material flanking tenons at two-way and three-way joints.

16 Upside-down nailed brace with single tenonectomy, sole tie brace found in barn. (Wide strap to sill added during stabilization.)

17 Original plate decayed and fractured. Note roof-pitch outer bevel and tie beams cut inches short of the mark, unable to cover plate.

18 Large gaps at plumb cuts of birdsmouthed common rafters falsely suggested spreading walls rather than erroneous construction.

19 Tie beam with severed half-dovetail reattached reversed (photo doctored for clarity). Note orphaned boarding groove in lower part.

reductions were made with an adze above and below each mortise. Fundamentally the carpenters were close to the point of the new method. A few mistakes repeated consistently prevented them from reaching the intended configuration of the frame.

It's difficult to envision what it must have been like for those who first attempted square ruling. It would have been quite a transition indeed to move from a familiar way of building where each timber is set into place surface to surface, to a system dependent on accurate calculations and the correct visualization of an imaginary timber within. The development, adaptation, interpretation and migration of the square rule method continue to be a source of wonder that keeps us excited to dig through barns and attics in search of the next discovery. —Michael J. Cuba

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20 All common rafters (new and old) now fully rest on plates.

21 Restored frame on post–Civil War raised foundation with bank.

Confessions of a Timber Frame Salesman

It all begins with sales. Everything else—brilliant people, extraordinary management, sophisticated reporting systems—amounts to nothing if you do not have work. —Charles B. Thomsen, FAIA

Give them a vision of Oz, show them the direction, and convince them you can create the Yellow Brick Road. The rest is civil engineering. —Dirk Susharme

THIS essay is not about marketing, advertising, closing the deal, sales techniques, strategies or how-to much of anything. This essay is mostly about listening and responding. If we cannot communicate, we have no art, no skill and no work, as Chuck Thomsen observes.

When we mention that we are in sales, a familiar response is to assume that our job is to convince people to do things they do not want to do. People regard sales and salespeople as distasteful. First and foremost, however, we are professionals. We have to learn a great deal of technical information. We have to have the insight of a good psychologist, the sensitivity of a parent, the taste of a designer, the knowledge of an engineer, the presentation skills of an orator. We must be storytellers with common sense and good judgment and the listening and observational skills of a good detective. We have our work cut out for us.

Why do we need all these skills?

We have paradoxical challenges in building relationships of trust with our clients. We have to sustain a sense of urgency while our work may feel mostly like tedious effort. We must tell our story quickly but in such a way that our client feels as though we have all day, and believe that this relationship is meaningful beyond the house to be built.

Remember that we all sell and negotiate all the time. We try to change the price of the car or appliance at the dealer's, we want to convince you of (sell) our point of view, we finally finish the carpentry of the house to make it more convincing. Parents and kids constantly banter over food, toys, leisure and duties, which is negotiation. Selling and negotiation are part of everyday life. Perhaps remembering this fact comforts us in our trade.

In the timber frame business, most of us are passionate and personal, we do understand the skill in successfully connecting pieces of wood together, and we perceive how the connections relate to the entire frame. We know how the frame expresses the building and vice versa. Our personal experience is useless unless our clients understand what we see as well.

And what we see must be what they want. The moment we discuss design, we must clearly consider sustainability, energy efficiency and resources. These considerations bring a wide variety of materials and questions to the conversation: enclosure systems, operational features (low-maintenance materials and energy-delivery systems, low-water-usage plumbing) and healthy nontoxic finishes, for example. And these impact style and design. Are we communicating this sufficiently with our client?

Time and money must be carefully woven through the process, beginning in an initial meeting or phone call. Especially in these days of highly informed buyers, we absolutely must balance scope of work, construction budget and process schedule. It will be up to us to tackle the problem of designing to a budget. It happens too often that design gets out of hand and substantially over budget. Is the problem a matter of listening by the designer, or of articulating needs by the client? Generally the client has little experience with the language of a design and construction budget. Meanwhile, a third-party designer's focus and commitment normally will be to the client rather than to the framer.

Most overages are in specifications and finishes. One can double the price of a house simply through choice of finishes: $7,000 copper slipper tubs, $2,500 faucets, $40,000 stone fireplaces, $1,000 interior doors, $5,000 cedar garage doors, $1,000-per-square slate roofing and so on. These specifications and more need to be managed in the design phase.

We should be capable of advising on these elements. We speak for the timber framer, only one of about 40 major suppliers in a building project, but the one clients see as key to their house. The main competitor for the owner's time and money is the endless list of materials for the walls, roof, floors, kitchen, bath, great room, home office, library and landscaping.

Building a house is an unrealistic process with everyone wanting predictability without enough information. Questions such as how much it will cost, when there is no design, and how long it will take, without understanding the site, are common. The many institutions involved are not coordinated, either: banks, title and insurance companies, zoning, transportation and building authorities, health departments, utilities. One institution needs detailed information in time to allow another to move forward. How often do we hear of a breakdown in communication and sequence?

Building a house is further complicated by a parade of small independent tradespeople, all with personal reasons for being who they are and where they are. They report, largely, to themselves; and if it's deer hunting season, well then. . . .

Selling requires communication and communication includes listening. This is a vast subject critical to our business. Misunderstandings and assumptions get us into trouble. We all want to be able to say what we do, do what we say and have our clients know what to expect. This implies clarity, agreement and understanding.

Information comes in many forms. As consultants, we impart most information via verbal and nonverbal communications alike. Language is the audible side of the coin. Posture, clothing, setting and expression are part of the nonverbal.

Language shapes and reflects our attitudes. Listening and asking questions as elements of the consultative sales process (see blog.hubspot.com/clients/bid/172099/The-Consultative-Sales-Process-6-Principles) bear careful consideration. We hear probably 125–250 words a minute, yet think much more quickly. That's why we often have to resist interrupting the speaker—we have already begun to comment mentally on the speaker's words.

According to Edgar Dale's *Audiovisual Methods in Teaching* (1969), we remember 10 percent of what we read, 20 percent of what we hear (if we are listening), 30 percent of what we see and 50 percent of what we see and hear.

Language is a system of auditory and visual symbols of communication. Structural rules (grammar) help us combine them into coherent sentences so we can understand each other. It's possible, however, to make a sentence that meets the rules of grammar but does not make sense, such as "The blue idea jumped over the moon."

This is where we salespeople come in.

Words are not things or ideas. Remember that definitions and meanings of words are within people, the listeners. Our understanding of what a word means is highly influenced by our education, social experience, family and culture. Even our regional accent can influence what we hear. For example, "I took that heel straight on" might be heard by a Northerner when a Southerner speaks of going up a hill. A football aficionado hears and sees the word yard very differently from a landscaper. There are something like 250,000 words in the English language. Most of us operate on about 20,000 (some say 50,000) and that is confusing enough.

Construction jargon (Is the deck the first floor or outside? In a building, what is a *Frog*?) and design jargon (What is a vignette?). What do we do with homophones such as prints and prince, or homographs like leaves (of a tree) and leaves (the room)? No wonder our language is difficult. (A Frog, by the way, is a finished room over a garage.)

Languages are living things: they change with time and place. How we said something in the '60s could be quite different today. One reassuring beauty of the language is that it also has the words to clarify the differences. But language must be deliberate (much to my 13-year-old daughter's dismay). We must work hard to make sure our listening client hears what we intend.

Timber frames are full of risk of the unknown. Timber framing is a known entity to substantially fewer people than 10 percent of the population ("What kind of log house is that now?"), and uncommon—about 2500 new timber-framed houses out of 800,000 houses built in the US in 2012, a ratio of 1 in 320!

Being a niche business within a larger industry that has a negative reputation presents a risk to the client. Angie's List, "The Money Pit," NBC's "How to Avoid Homebuyers Heartache," builders who leave their clients holding the bag, countless books on construction litigation (don't forget to get the lien waiver signed)—all these form the reputation of the building industry. Our supplying only a part of the house adds more risk for the client.

Will something more compelling come along, the client may wonder? Will timber framing become obsolete (again)? We framers know that light-frame building systems have been around only since the latter part of the 19th century and timber framing has been around for thousands of years, but the client may not know that. If the client does not understand that prefabrication of the frame or even panelized construction need not imply trailer parks or modular home parks, or that on-site construction is not the only definition of custom building, we may lose the proposition that we can meet the desires of the client.

Risk in this context is lack of trust or belief in the product, service or salesperson. How much risk is the client willing to take? To find out, ask the client's entrepreneurial experience and opinions of gambling, for instance, or extreme or dangerous sports. The answers may reveal their tolerance for risk. Estimating and acknowledging the risk tolerance of the client is one of the jobs of the salesperson and requires communication. For the client, the rewards obviously have to outweigh the risks, and all the risks have to be dealt with. It is our job to explain to clients that working with us substantially reduces risk.

The characteristics of nonverbal language are not usually taught. Such communication generally occurs in combination with the verbal, arising from watching, listening and interpreting, and from within, including how we feel that day and our general attitude (worth being aware of). How we present to our client includes involuntary gestures and expressions as well as a tone of voice, and the presentation is in a particular environment and its qualities. The listener takes all of this in. Generally, a listener believes the nonverbal before the verbal.

In all our communications, we need to be mindful of our client's particular position. All clients have basic concerns for safety, security, health, value and quality, but we have to distinguish priorities. The prospective house might be in an especially remote locale, so the client might be notably concerned about fire and theft (safety and security). If the family has two children in college, the client may be even more than usually sensitive to cost (value).

What clients *want* to know naturally comes from their perspective. What clients *need* to know, however, comes from the salesperson's. The client will ultimately need to know everything, but not early in the relationship. A viable solution to the question at hand suffices. If there is too much information in an interview, it will not be heard, let alone remembered. (We remember 20 percent of what we hear.) A person uninitiated in building will understand only a limited amount of information from a meeting. Avoid overstimulation. If there is an abundance of critical information, provide it in another form to take away, such as a book or catalogue, and supply sources where to get additional information including libraries, websites, trade associations and so on.

It is useless to ask questions and not listen carefully to the answers. Wait several seconds after the client responds before speaking again: you will be amazed at the information that pops into your head during this time. Listen 80 percent of the time; talk 20 percent of the time.

So, where does this leave us?

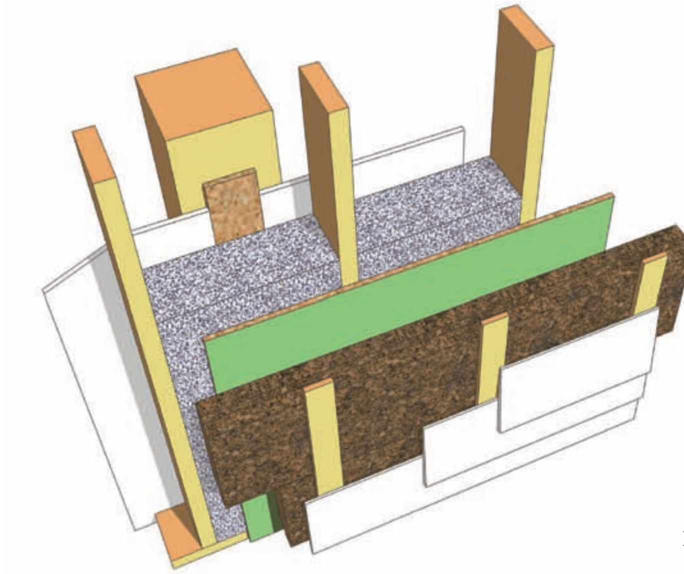
It takes the psychologist in us to begin to understand the wants of our client, the parent to provide the comfort in a scary design-and-build adventure, the inner designer to relate a timber frame to their design, the engineer to know the structure will hold up. We provide inspirational presentations, absorbing stories, sensible solutions and the right services. If it doesn't work, what then? "Success," Winston Churchill said, "is going from failure to failure with no loss of enthusiasm." —Stewart Elliott

Stewart Elliott (selliottt2@gmail.com) started a construction company in 1970 to restore 18th-century houses and build new timber frames. He is the author of The Timber Frame Raising *(1979)*, The Timber Frame Planning Book *(1978) and* The Timber Framing Book *(1977)*.

Stewart Elliott

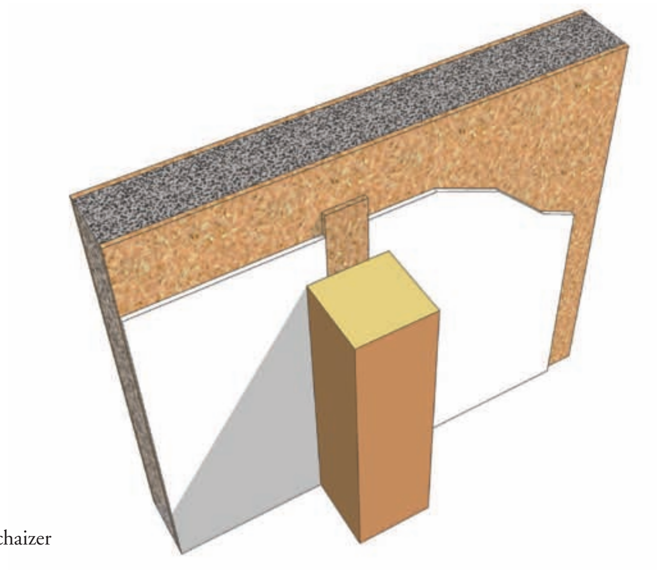
One in 320 US new houses in 2012 was timber framed.

New Enclosures for Timber Frames?



Renderings Andrea Warchaizer

1 Cork boardstock over conventionally framed wall with cavity insulation, Zip System sheathing (fully taped), cork, high-performance housewrap, vertical strapping, clapboards. Vapor barriers, tapes and housewrap not shown.



2 Neopor (expanded polystyrene with graphite) foam-core structural panel, seen from inside.

THE Burlington 2013 Guild conference last August in Vermont was host to a number of presentations on enclosure systems for timber frames. While foam-core structural insulated panels (SIPs) continue to capture a large market share for timber frame enclosures, they are not the only choice. Options abound; the key is to identify the criteria for choosing one system over another. On-site assembly versus off-site panelization, DIY vs. contracted, choice of insulation material and wall assembly, codes and standards to which the building is meant to conform—all inform the choice of enclosure system.

Building or renovating your own house is a great opportunity for experimentation without subjecting clients to the possible pitfalls. Alex Wilson, long a writer on efficient buildings and founder and editor of BuildingGreen.com, and high-performance-building contractor Eli Gould (Ironwood Brand), are using a number of newly available materials in the renovation of Wilson's 19th-century farmhouse in Dummerston, Vermont. The foundation and sub-slab are insulated with *Foamglas*, a cellular glass rigid boardstock insulation. With an R-value of 3.4 per inch, it's less insulative than extruded polystyrene (XPS, R-value 5.0), a common foundation insulation material in the Northeast, but several properties made it appealing for use below grade: high compressive strength, moisture and fire resistance and, most important, especially in a changing climate, imperviousness to wood-boring insects including termites. The cost as compared to XPS is significantly higher but, according to Wilson, the increased benefits warranted the increased cost.

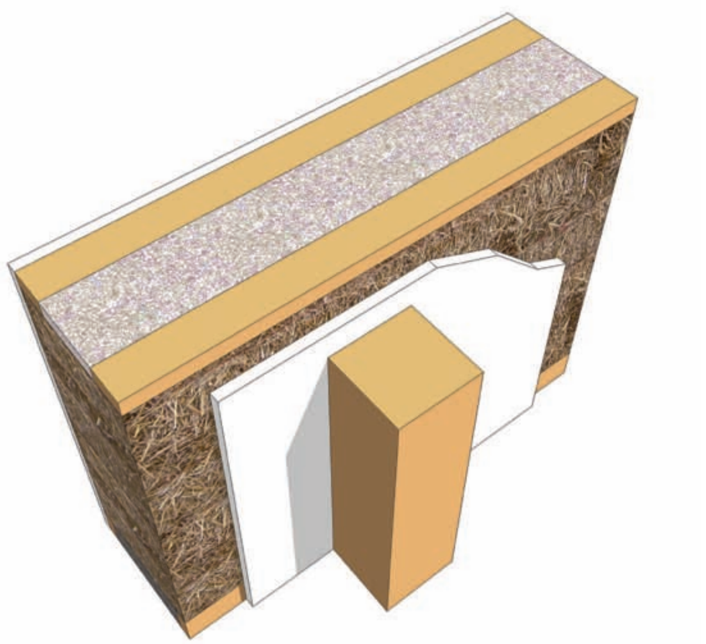
The above-grade exterior of the Dummerston house is insulated with *Thermacork*, an expanded cork boardstock insulation produced by Portuguese manufacturer Amorim Isolamentos (Fig. 1). Cork, a renewable resource (cork bark can be harvested from the cork oak, *Quercus suber*, every nine years), has an R-value of 3.6 per inch and is typically used as an exterior insulation layer. It's somewhat moisture-permeable and more fire-resistant than extruded or expanded polystyrene. Cork has been used as insulation in Europe for years and is now making its way to North America. According to BuildingGreen, once distribution channels are in place, the cost to achieve a similar R-value is likely to be double that of XPS.

Also newly available is the option of *Neopor* as the foam core in structural insulated panels (Fig. 2). Neopor is an expanded polystyrene with graphite added; R-value is 4.5–4.9 per inch, depending on density. Many panel manufacturers have added Neopor to the list of available insulation options.

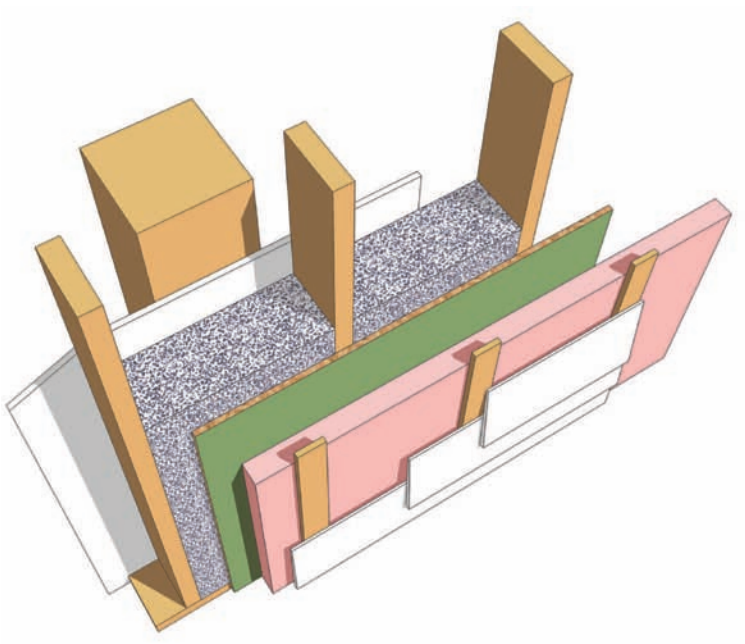
Tim Krahn of Building Alternatives (buildalt.com) presented a newly available straw bale SIP at the Timber Frame Engineering Council symposium. The panel (called *NatureBuilt*) uses the US "two-string" bale (about 14x18 in.) as the core, with plaster interior and exterior skins (Fig. 3). The wall panel is rated at R-35 and the company's website asserts that installed cost compares favorably with conventional construction, with improved performance. While straw bale is not new as an enclosure option for timber-framed structures, the production of a straw bale SIP is. This could be of great benefit to those who do not have access to a crew for on-site assembly of a straw bale enclosure, or for other reasons prefer to have the enclosure system prefabricated off site.

Off-site fabrication, with the attendant savings of time and elimination of on-site waste, is a major argument for enclosing timber framed structures with SIPs. The foam-core SIP, however, is not the only option for a panelized prefabricated enclosure. Jonathan Orpin, of New Energy Works, and Chris Carbone, of Bensonwood, each presented details of their companies' panelized enclosure systems, both prefabricated off site and relying primarily on cellulose instead of foam insulation. New Energy Works' *Matrix Wall* is meant to improve on the practice of wrapping the timber frame with stud walls while maintaining the familiarity and mechanical accessibility of a stick-framed system (Fig. 4). The wall system comprises a panelized stud wall insulated with cellulose, wrapped on site with rigid insulation, strapping and exterior siding. The Matrix Wall has an R-value upwards of R-25, varying with studwall and foam sheathing thicknesses. The Bensonwood *Open Built Plus* (OB+) wall incorporates interior wall finish, a chase for wiring and other services, 9½-in. I-studs with cavities insulated with cellulose, exterior sheathing and even, at times, the exterior siding system (Fig. 5). The typical OB+ wall has an R-value of 35 and is nearly airtight.

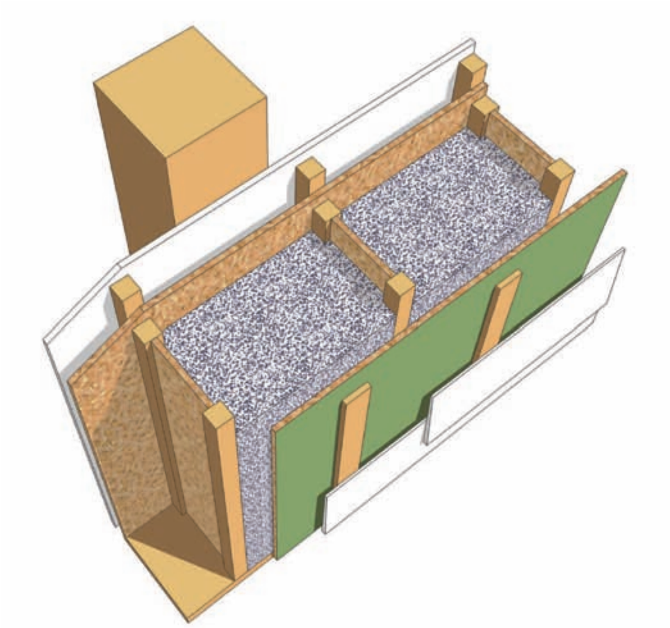
Supplying the exterior walls allows these companies to have greater control over the design and installation of the enclosure and



3 NatureBuilt panel. Interior skin 1-in. cement-lime plaster, core 14-in. compressed straw bale, exterior skin 1-in. cement-lime plaster. Bottom plate 3½-in. mineral batt insulation between edgewise 2x4s, top plate 1½-in EPS foam between flatwise 2x4s.



4 New Energy Works Matrix Wall. Panelized stick-framed wall insulated with cellulose, exterior sheathing, rigid insulation, strapping, exterior siding. Vapor barriers, tapes, housewrap not shown.



5 Bensonwood OB+ wall panel. Interior finish, services chase, panelized stick-framed wall insulated with cellulose, exterior sheathing, strapping, exterior siding. Vapor barriers, tapes, clips, fasteners and housewrap not shown.

6 New Frameworks system with cellulose insulated 2x6 wall to outside of 14-in. strawbale wall, omits wall timbers.

directs a greater percentage of overall building costs to the timber frame company. Garland Mill Timberframes, meanwhile, takes such diversification to another level, providing full design and general contracting services in addition to providing timbers cut on their own water-powered sawmill. Garland Mill's Tom and Ben Southworth presented examples of houses built to Passive House (see passivehouse.us) and super-insulation standards. Both standards set performance benchmarks rather than require specific insulation or assembly materials. In the case of Passive House, the more institutional standard, the finished building must be insulated and airtight to a specified degree and use no more than a prescribed amount of energy. Wall systems are built on site with careful attention to detailing, in particular creating a tight shell with as few insulation breaks as possible.

With the level of insulation required, homes built to Passive House and other high-performance standards usually end up with thick exterior walls: 12 to 14 in. is not uncommon. In the case of the Garland example, the designers chose to have the exterior wall take on a fully structural role, eliminating the perimeter timber frame. Likewise, Ace McArleton of New Frameworks Natural Design Build, who has built many timber-framed houses with straw bale enclosures, presented a new straw bale wall system that relies on a 2x6 loadbearing wall built to the outside of the strawbale wall instead of a timber-framed wall built to the inside (Fig. 6). Interior posts support a timber-framed floor system and roof. According to McArleton, this system saves about half the construction cost of their standard timber frame–straw bale enclosure combination. —Andrea Warchaizer

Andrea Warchaizer (springpt@sover.net) designs timber-framed houses at Springpoint, Inc., in Sandown, New Hampshire. She wrote "Enclosure Systems for the Timber Frame" in TF 99, collected in Timber Frame Fundamentals.

Documentation and Assessment Methods for Timber Structures

OVER the past few decades new documentation and material assessment techniques and technologies have been introduced into the field of historic preservation, including computer-based photorectification, infrared thermography (IRT), stress-wave timing and resistance or microdrilling. While slow to catch on in private practice in large part due to initial cost, technological development has brought costs down to a point where their use appears to be gaining traction. These technologies and techniques offer those who work with historic timber-frame structures improved efficiency, increased retention of historic fabric and more informed assessments.

Photorectification Measured drawings are often among the first requirements when preservation, restoration or rehabilitation work is contemplated for historic timber structures. Such drawings assist in design, structural assessment, damage mapping, creation of construction drawings and academic research. The extent and accuracy of the measured drawings, however, vary widely. Until recently, accurate and highly detailed drawings such as those submitted to the Historic American Building Survey (HABS) were often considered too time consuming and expensive to undertake on a regular basis. With improved photorectification techniques and laser technology, such levels of documentation are becoming more cost efficient and are increasingly undertaken. While not warranted for all projects, this level of accuracy does allow a better understanding of a building's structural components and deficiencies, and also provides a solid base from which to conduct accurate condition assessments.

Photorectification uses optical means to remove both perspective and lens distortion from photographs, enabling measurements to be taken and line drawings to be produced directly from the image. Used for the creation of maps in World War II and employed by HABS for documentation as early as 1989, hardware and software advances have reduced the cost as well as the learning curve associated with this technique. Many older rectification techniques have been replaced by surveyors' total stations and AutoCAD-compatible software.

One recent set of projects conducted by the Department of Historic Preservation at the University of Mary Washington used photorectification to document and draw a series of Virginia barns in Warren, Stafford, Spotsylvania, Caroline and Orange counties. During the fall semesters of 2012 and 2013, students measured and drew a total of seven barns using a reflectorless total station which gathered *XYZ* coordinates for the structures being drawn. This device's laser is powerful enough to reflect directly off structures for distances up to 300m (984 ft.), thereby reducing preparation time and avoiding lift or scaffolding rentals to place reflectors.

The *XYZ* coordinates from the total station were exported directly into AutoCAD in the field using specialized software, allowing for real-time verification of measurements. Measurements for each barn were adequately taken by a team of four during a single day, with some barns requiring less time. The efficiency of such documentation arises from the fact that only key *XYZ* reference points on the building's elevations and projections need be obtained. The reference points are then used later to rectify (optically correct) digital images taken of the structure. This process compares favorably to traditional hand-measuring methods, which can often take weeks to complete depending on the size and complexity of the structure as well as the size and skill of the team assembled.

Once all necessary *XYZ* coordinates and field measurements are obtained, digital images of each elevation are imported into the AutoCAD file containing the field measurements. Using rectification software embedded within AutoCAD, the *XYZ* data points obtained in the field are aligned with their corresponding location on the digital image (Figs. 1 and 2). The digital image is then altered to remove any perspective distortion.

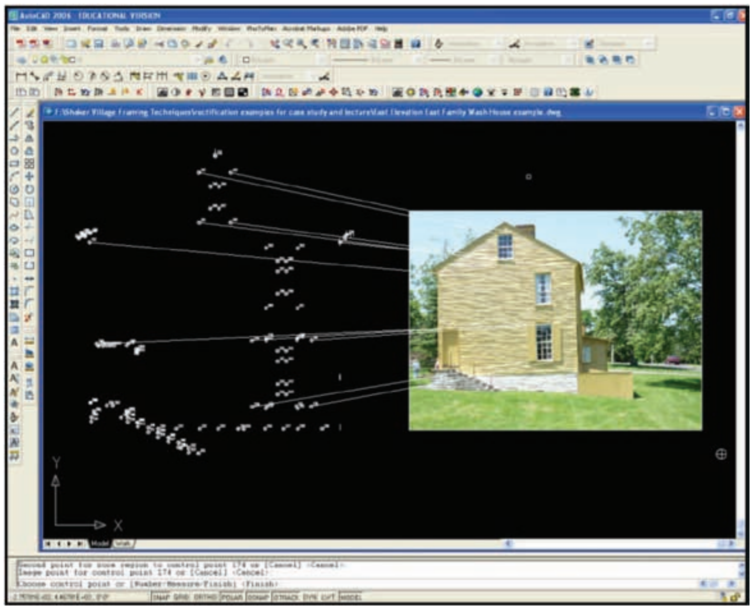
Lens distortion can be removed at the same time by using focal length settings previously calibrated by taking an image of a set of perpendicular grid lines at a known focal length. The digital image of the structure can then be altered to coincide with actual line trajectories.

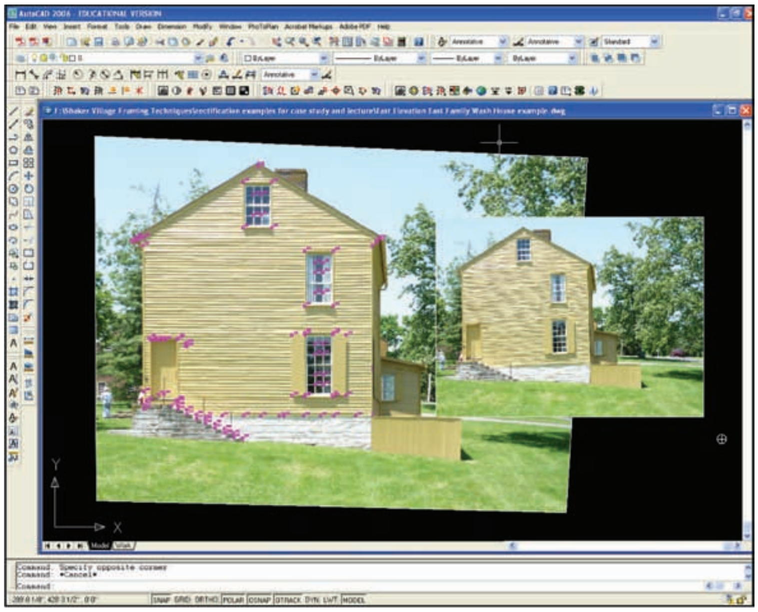
The final rectified image when scaled is often accurate to ¼ in. or better, with greater accuracy possible, and it can be traced easily to produce amazingly detailed line drawings. A rectified and scaled image is also beneficial in making certain building condition observations and assessments, something not always picked up by methods such as laser scanning or even possible to measure with more conventional techniques. Rectified images can be stored for creation of line drawings at a later time without having to worry about whether all measurements were taken in the field, thereby avoiding additional site visits.

Infrared thermography (IRT) Traditionally, the condition assessment of timber-framed structures has relied on a seasoned eye and a sharp tool. Even with the advent of new techniques and technologies, visual inspection and basic tools remain an integral first step to the evaluation of historic structures. Infrared thermography (IRT), a nondestructive assessment tool that measures temperature variations, is, however, quickly becoming a cost-effective complement. (FLIR Systems Inc., a prominent manufacturer of infrared cameras, has even developed an IRT "jacket" for iPhones, to be introduced later in 2014.) IRT can quickly identify areas of potential concern via temperature anomalies; distinctly colder temperature readings are often associated with the presence of moisture. Infrared images taken over time or as a video can also assist greatly in determining the location of moisture infiltration.

The technique can also be used to help identify the placement and relative size of concealed timber members by taking advantage of the different thermal transmission rates inherent within frame wall construction. Used in conjunction with photorectification techniques, such images can accurately convey the size, placement and even deflection associated with timber-framed structures, allowing for more accurate and less destructive evaluations (Figs. 3–5). The technology's short learning curve is another advantage, with only a basic understanding necessary for qualitative assessment and analysis.

Stress-wave timing Whereas observational data and IRT can identify the presence of moisture and symptoms of deterioration within timber-framed structures, further assessment is needed to confirm the extent of deterioration. Damage is often concealed within finished walls, making it difficult to quantify without destructive exploration. Such exploration is often time consuming, messy and expensive, and it can lead to the loss of additional material integrity, making it far from ideal.

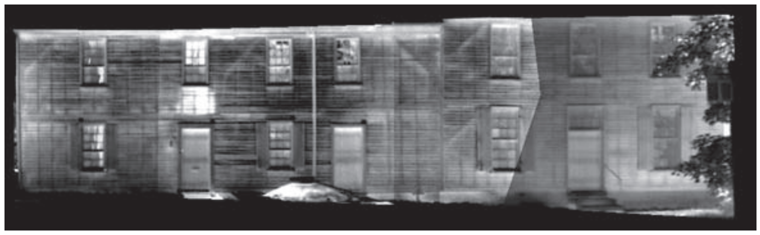


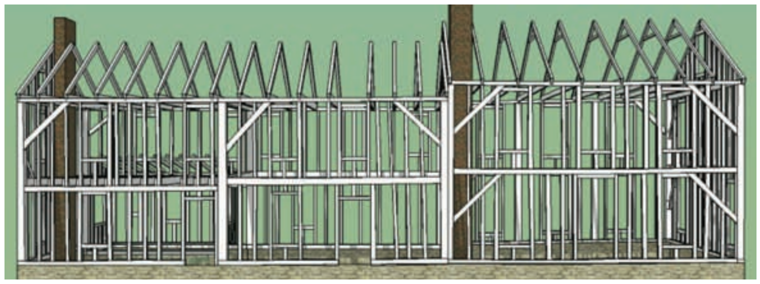


Illustrations Michael Spencer unless otherwise credited

1 Above, screenshot of *XYZ* data points gathered using total station, East Family Wash House at Shaker Village of Pleasant Hill, Kentucky, then referenced with corresponding locations on digital image of building, indicated by lines, imported into AutoCAD.

2 Above right, screenshot of image rectified by Kubit software's PhoToPlan program. Prerectified image (right) adjacent to rectified image (left). Magenta points now align with corresponding locations on the digital image, thereby removing any perspective distortion.





3 At right, top, composite digital image of East Family Wash House rectified and combined using points obtained through a total station and use of both TachyCAD and PhoToPlan software.

4 At right, middle, infrared images taken of same elevation during assessment, likewise combined and rectified, yielding a single, accurate image highlighting concealed framing.

5 At right, bottom, accurate 3-D model (shown 2-D) of framing developed in SketchUp from composite infrared image.

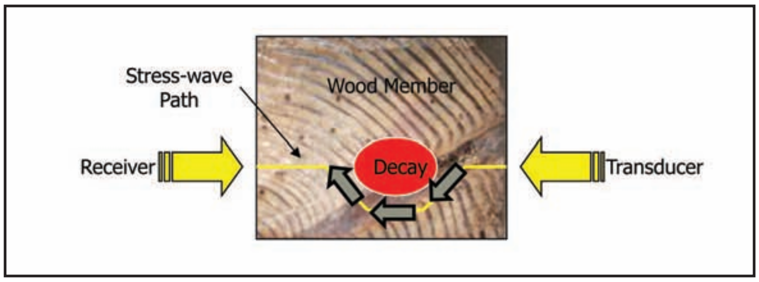
Stress-wave timing, a technique developed by the lumber industry for the evaluation of standing timber, is one minimally destructive technique that can help avoid problematic destructive evaluations. First applied to structures in the 1970s, the technique has seen increasing use within the field of historic preservation. Because of the early groundwork laid by researchers such as Roy Pellerin, Robert J. Ross and others at the USDA Forest Products Laboratory in Madison, Wisconsin, the applied concept of stress-wave timing is relatively easy to understand.

The technique works by connecting a timing device to a transducer and receiver placed directly opposite on parallel surfaces of the wood member under investigation (Fig. 6). Both transducer and receiver are firmly attached to the wood by spikes driven about ¼ in. deep and placed at about 45 degrees to the surface. The observer then strikes the transducer with a small hammer, starting the timer and inducing a stress wave that propagates through the wood member. The receiver senses the leading edge of the wave and stops the timer, providing an accurate measure of the time of flight of the stress wave. The stress wave can move quickly when wood is solid but slows when rotten material is encountered. Time

6 Microsecond timer used for stress-wave timing analysis. Transducer probe on right is struck with hammer, inducing stress wave to receiver probe. Device records wave flight time.

		Stress Wave Transmission Times (perpendicular to grain) @ 1'-0" Elevation on Posts		
	Moisture Content	Radial Direction (µs/ft.)	Tangential (µs/ft.)	Tangential (µs/ft.)
White oak sample	6%	236	240	240
Post 8	10.8%	318	328	256
Post 13	13.3%	234	418	216
Post 15	10.3%	**974**	**632**	**574**
Post 19	13.5%	426	285	219

Table 1 Adjusted stress-wave timing values of control white oak sample and four white oak posts analyzed at Bowman-Hite bank barn, Long Meadow, Warren County, Virginia. Transmission times, initially displayed by device as *µs* readings, have been converted to *µs*/ft. for easy comparison independent of member size. Compare readings for post 15 with control value as well as (sound) post 8. Posts 13 and 19 readings indicated possible deterioration but inspection using resistance drill confirmed them to be sound, with interior checks causing longer transmission times.



7 Stress wave passing along transverse plane of wood sample in mostly radial direction. Rotated 90 degrees clockwise in image and stress wave would be going in mostly tangential direction. Rot or decay slows stress wave, resulting in longer transmission times. Bend in wave represents diffraction in much-simplified form.

discrepancies between sound wood and rotten wood can be as high as 30 to 50 percent, with values over 50 percent often indicating severe decay.[1] Flight time of the stress wave is measured in microseconds (*µs*) and later converted to a flight time per foot.

The anisotropic nature of wood is important to take into consideration when stress-wave timing, as wood-grain direction and growth-ring orientation can affect transmission times. Typically in historic structures the timber's grain orientation allows for stress-wave timing tests to be conducted across the grain in both the radial and tangential directions. Shortest transmission times are found when testing in the radial direction, while the longest times are along the tangential direction at 45 degrees to the growth rings[2] (Figs. 7 and 8). Temperature and moisture content of the wood under investigation can also play a role and require the application of adjustment factors.

Testing using stress-wave timing is a good way to begin mapping deterioration within certain historic timber-framed structures. Barns, for instance, provide good opportunities for stress-wave timing as the process requires that the wood member be exposed on at least two opposite sides.

A test case The Bowman-Hite bank barn, owned by the National Park Service at Long Meadow in Warren County, Virginia, was initially assessed by stress-wave timing performed in 2011–2013 by the University of Mary Washington. While symptoms such as surface rot, termites and water staining could be identified by visual inspection, much else remained hidden below the surface of the barn's structural members. Each post except the four corner posts (precluded from investigation because two opposite sides were not accessible) would be evaluated using the stress-wave timing device. Preparation for field-testing the 16 accessible posts first required the identification of the wood species (white oak), in order to take initial readings off site from sound examples to establish baseline data. Results from this testing in microseconds were converted to *µs*/ft. values and established that readings for sound white oak in the radial direction should be approximately 236 *µs*/ft. and approximately 240 *µs*/ft. in the tangential direction. Variables such as travel distance, temperature and moisture content would be recorded regularly during the investigation. In the Bowman-Hite case, since most symptoms of deterioration such as water staining appeared within 4 ft. above the floor, three readings would be taken at both 1-ft. and 4-ft. heights for each post.

Unadjusted qualitative readings taken within a few hours identified seven posts with possible subsurface deterioration. Upon closer visual inspection, four of the seven posts were judged sound, with observable splits and checks having adversely affected the results of earlier testing. Three of the posts (13, 15 and 19) warranted further investigation as they displayed no such visible defects. After closer study using another minimally invasive technique, one post, 15, was confirmed to have a 57 percent loss of material integrity, supporting the stress-wave results. Posts 13 and 19 were later confirmed to be sound with unseen checks causing the longer stress-wave propagation times (Table 1).

Resistance drilling Resistance drilling is another minimally invasive method used to quantify deterioration in timber-framed structures. More recently developed than stress-wave timing, resistance drills have been used since the 1990s to investigate buildings. Though more time consuming than stress-wave timing, resistance drilling produces easily interpreted quantitative data that can be used to confirm stress-wave timing results. The tool is also effective in evaluating members where stress-wave timing cannot be used, for instance the four corner posts in the Bowman-Hite bank barn. In some instances, the process can be used to evaluate members concealed behind plaster or drywall as long as the location of the member has been determined by methods such as infrared thermography (IRT).

Easy to use, the resistance drill works like a traditional cordless drill with a housing containing the drill bit and a recording device situated on top (Fig. 9). When the trigger is pressed, the 3mm-dia. drill bit is sent through the piece of wood under investigation. As the bit moves through the wood, resistance it encounters is passed along to the calibrated stylus, which inscribes results in a 1:1 ratio on wax paper strips. Recent innovations also allow results to be captured digitally and downloaded to a computer to be analyzed. When sound wood is encountered, high resistance is conveyed on the wax paper strip, whereas when decay is encountered the resistance drops toward zero. Such results allow for the investigator to determine the degree of deterioration as well as its extent within a particular location in a wood member, making it a great tool for confirmation of suspected degradation.

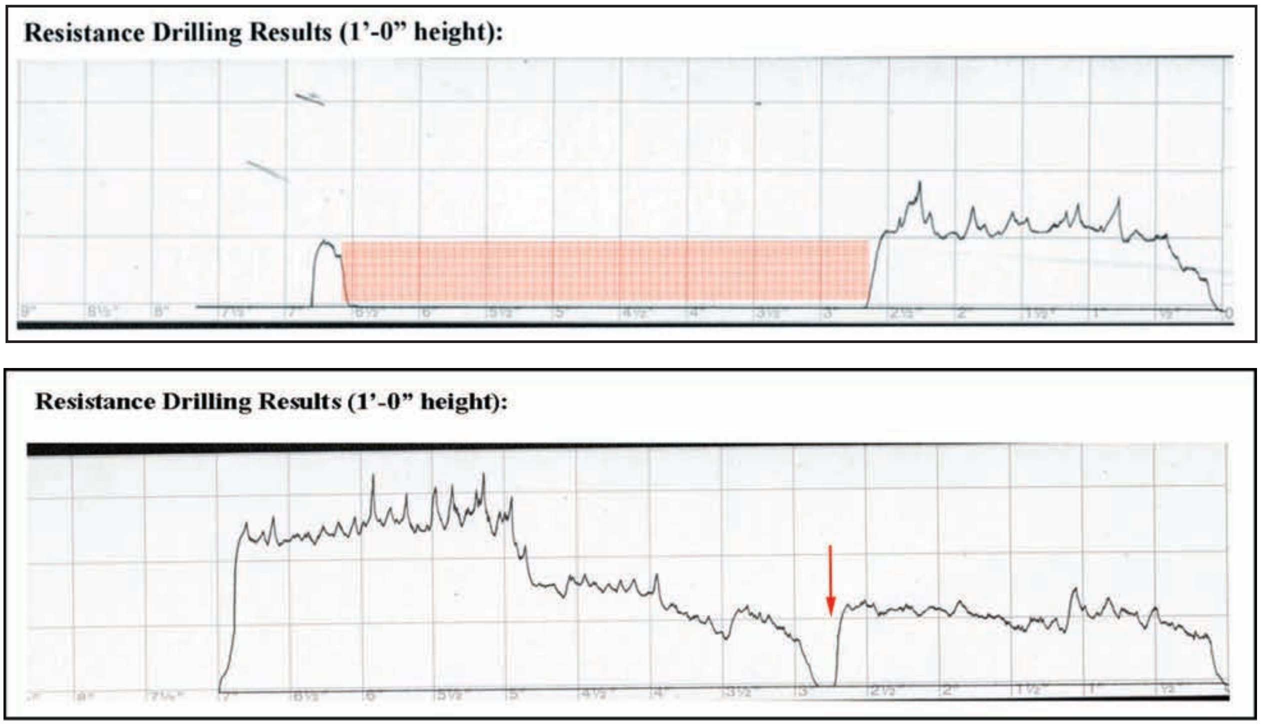
Tests performed at the Bowman-Hite bank barn utilized two drillings for each of the three posts identified by stress-wave timing as having possible deterioration. The drilling locations repeated the stress-wave timing locations. Each drilling measured the resistance along the radial direction of the post. Results of the resistance drilling conducted confirmed that only post 15 was deteriorated (Fig. 10).

[1]Ross et al., *Wood and Timber Condition Assessment Manual*, p. 17.
[2]Ibid., pp. 15–16.

8 Three planes to specify path of stress-wave through timber.

9 IML Resistograph being used by author to assess a joist at Union Church (ca. 1819) in Falmouth, Virginia.

Logan Metesh



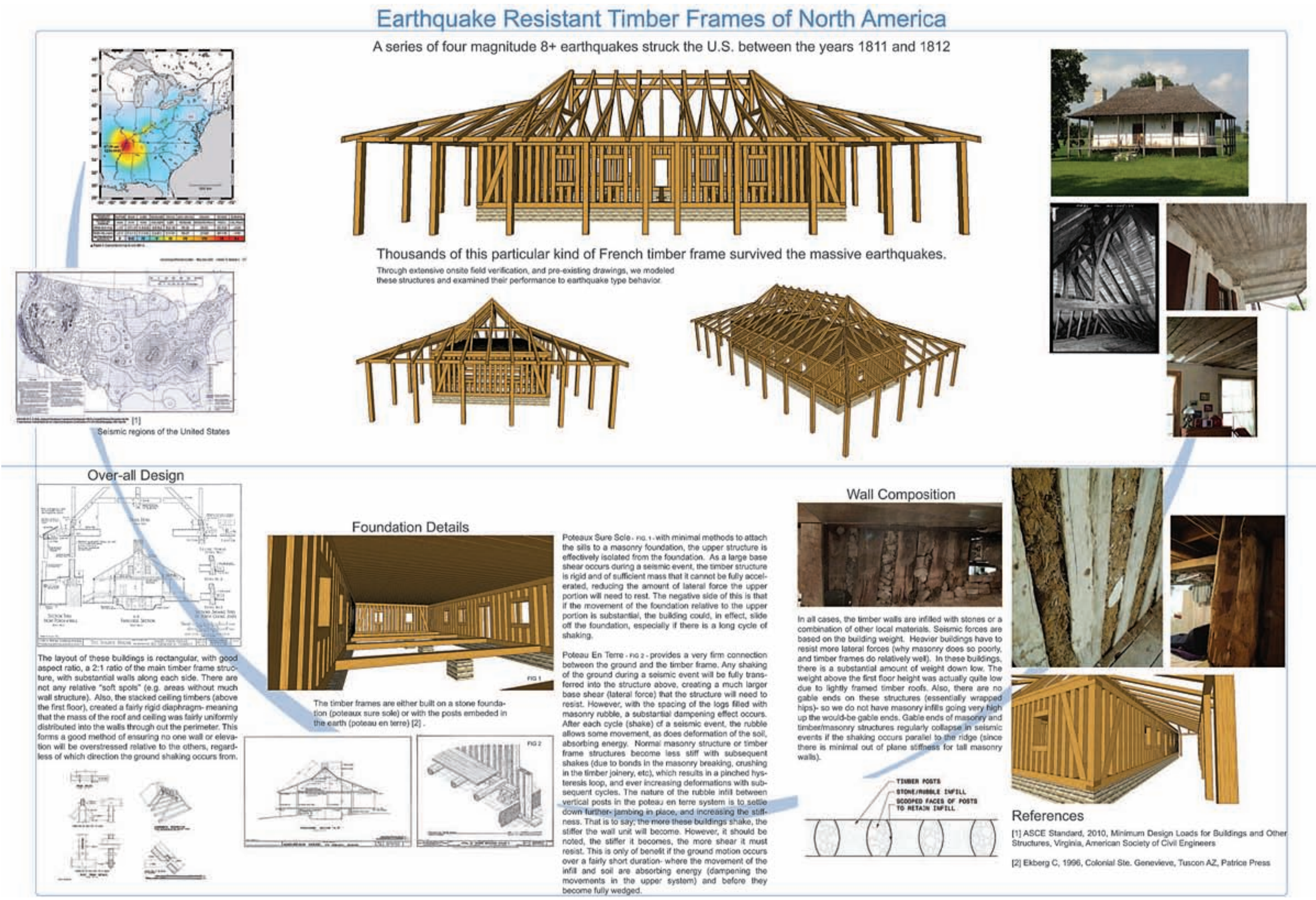
10 Resistance drill readings from Bowman-Hite post 15 (top) and post 19 (above) with each square equal to ½ in. Shaded red area on post 15 readout denotes extent and location of rot starting just ¼ in. under surface of post. Peaks in sound portion of wood (right side) denote denser latewood. Red arrow in post 19 reading indicates high stress-wave results despite majority of its wood being sound.

Results for posts 13 and 19 indicated invisible checks and splits had caused the higher stress-wave timing results.

While cost of equipment is still relatively high (upwards of $20,000 for the specialized hardware and $5000 for the specialized software omitting AutoCAD), and the accuracy generated may be considered overkill by some, their contribution to the preservation of historic timber-framed structures cannot be ignored. The efficient generation of accurate, actionable data—made possible by techniques such as photorectification, infrared thermography, stress-wave timing and resistance drilling—can assist in the retention of historic fabric and thus reduce the cost of replacement materials and labor in preservation, restoration and rehabilitation efforts. While much work is still necessary to fine-tune these techniques for use with historic timber-framed structures and in conjunction with the needs of the artisan, technological advances will continue to decrease cost, making the use of the tools ever more practical. —Michael Spencer

Michael Spencer (mspen1bi@umw.edu) is Assistant Professor in the Department of Historic Preservation at the University of Mary Washington in Fredericksburg, Virginia.

Earthquakes and Early Timber Frames



Rick Collins and Joe Miller

Posterboard displayed at conference on earthquake-resistant timber buildings held in Italy, November 2013.

FOR several years I have been studying the timber-framed homes, churches and outbuildings built by the French in Illinois from 1680 to 1820. Merchants and farmers along the Mississippi, Missouri, Ohio, Wabash, Wisconsin and Illinois rivers constructed thousands of these structures in the upper Midwest during the 1700s. The rivers destroyed many of them when four earthquakes racked the continent during the winter of 1811–1812, the largest known recent seismic events in North American history. On a whim I entered my research as a posterboard proposal to a conference last November about historic seismic-resistant timber frames of the Mediterranean, advertised in a mass email. The review committee accepted my proposal and I recruited Joe Miller to collaborate with me on the posterboard. Joe, originally from Indiana, had also been aware of the French, who built timber-framed settlements in Indiana as far back as the early 1700s. Together we worked on a posterboard that displayed how and why these French frames were so capable of surviving earthquakes. Four of the 18th-century earthquakes along the New Madrid (Missouri) fault line are estimated at 8.4 on the Richter scale. The area we focused on, St. Genevieve, Missouri, had estimated readings in the range of 6.

Our conference, Historic Earthquake Resistant Timber Frames of the Mediterranean, or HeaRT, included two days of presentations at the University of Calabria near Cosenza and a third day of field visits to existing timber-framed houses nearby. University professionals, architects and engineers came from Portugal, Japan, the Czech Republic, Germany, Switzerland, Albania, Greece, Syria and Turkey. The conference was sponsored by the International Council on Monuments and Sites (ICOMOS), the National Research Council of Italy Trees and Timber Institute, the Institute for Sustainability and Innovation in Structural Engineering (Portugal) and several universities in Turkey, Greece, Portugal and Italy. The organizers aim to hold a yearly conference on viable methods of building framed structures in earthquake zones worldwide.

I learned that timber frames were a key part of the expansion of the Mediterranean world, from early temples to houses and barns, easy to cut, pack and ship anywhere. The presentations offered an opportunity to see how the clearest path to longevity in structures does seem to be simplicity, and in framing a redundant system with minimized components.

We saw presentations of frames from Japan with brick infill, Portuguese X-braced frames with brick and stone infill, framed houses from Turkey, Greece and Albania, and an amazing Greek cathedral with timber elements supporting a vaulted stone-clad ceiling. Japanese engineers showed videos of experiments testing the integrity of infilled frame units on shaking tables, large platforms that simulate the movements of an earthquake. The Japanese lead the world in structural seismic research, with over 20 of these tables and research centers. They have been comparing differences in reinforced infill (fiberglass rods laid horizontally in the masonry) and unreinforced infill, as well as looking back to the building technology of ancient structures that have endured.

On our field trip to Mileto the last day of the conference, we examined an early-18th-century timber frame built immediately after a massive earthquake in the region (and when some of the first seismic building codes on record in the Western world were developed as a result). These framed buildings look exactly like the stone structures they stand next to—in fact there's no way to know they are framed unless you peel away the stone veneer on the outside or get past the lath and plaster on the interior. Built continuously in this town for almost 200 years into the late 19th century, they are numerous, though almost all are in disrepair. This method of construction, called *Casa Barracata* by the researchers rediscovering it, was designed and engineered by carpenters and masons during the reign of the Bourbon kings of France who controlled this part of Italy in the 17th century. The timber frame was built first, stone walls were applied as veneer on the exterior, stone or brick or both added as infill, and the interior walls lathed diagonally with split branches and finely finished with plaster. Suspended-kingpost wood trusses connected the buried wall posts.

The other well-documented major system of combining timber with masonry has horizontal timbers woven through the masonry walls at approximately 4-ft. intervals (see "Wooden Houses of Istanbul," TF 109). This style is the oldest known use of wood and timber in the Mediterranean world and has continued as an uninterrupted practice through the present day in rural areas.

Throughout the conference, I sensed the real possibility of a European return to timber framing with masonry infill after several centuries of masonry-only building. Strong influences driving the movement include concern for public safety. Timber buildings offer greater life safety than stone structures, and infilled timber frames are exponentially better in a seismic event. Economics, however, seems to be the major influence. Timber stands in historically timbered areas were replanted and have regrown in the last 75 years. Such regrowth, and the fact of depressed local economies, make obvious the use and thoughtful management of the timber to produce housing, jobs and general economic stimulation.

We got second place in the posterboard competition with our "Earthquake Resistant Timber Frames of North America." The French buildings from the 1600s and 1700s in the US Midwest show a natural and designed resistance to earthquakes, as do the many structures throughout the Mediterranean world that we learned about. We have much more to learn from those who have gone before us. —Rick Collins

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Nicola Ruggieri

Stone-infilled timber frame ruin, 18th century, Mileto, Italy.

PUBLISHED BY
THE TIMBER FRAMERS GUILD
PO BOX 60, BECKET, MA 01223