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Medieval Germanic Roofs

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CONTENTS

On the front cover, St. Stephan's Cathedral in Vienna. Crowds on pavement are probably tourists, some headed for cafés on the facing square. Photo © 2014 Bwag/Commons. On the back cover, comparative drawing of four medieval roof frame elevations and sections, discussed in article page 14. Drawing Philip S. C. Caston.

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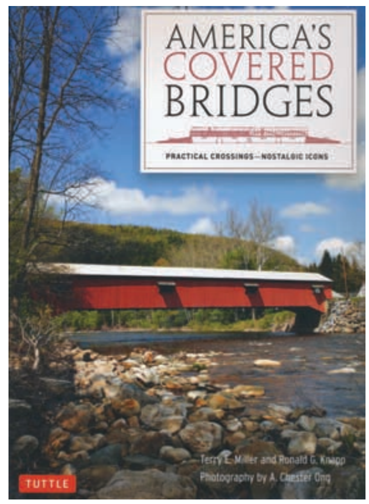
BOOKS

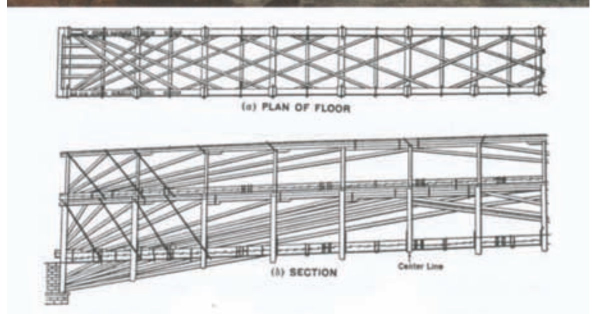
America's Covered Bridges

America's Covered Bridges: Practical Crossings—Nostalgic Icons, by Terry Miller and Ronald Knapp, with photographs by A. Chester Ong. Singapore: Tuttle Publishing, 2013. 9¼ x 12¼ in., 272 pages, 550 illustrations. Hardcover, $39.95.



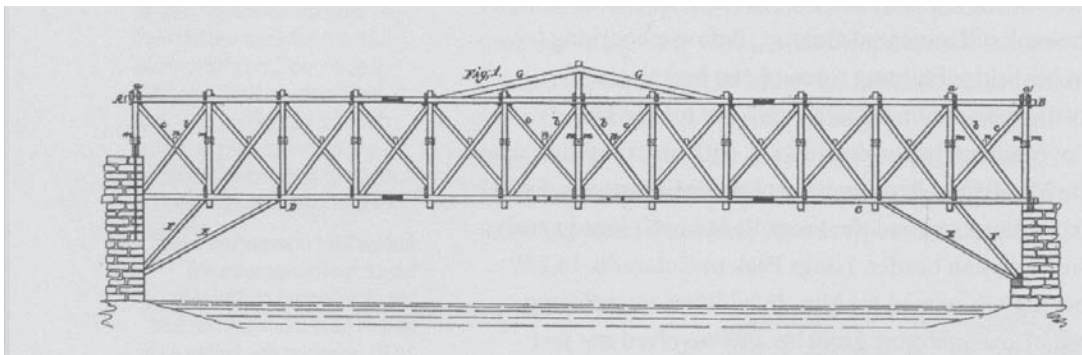
IF you would like to know a lot about covered wooden bridges, buying this book is probably the best forty bucks you could ever spend. Chester Ong's new photos alone are worth the price and place the bridges in their settings, showing us why they are so widely beloved, and indicate the geographical range of what survives, from New Brunswick and Quebec throughout the eastern half of the US and reaching to California, Oregon, Washington, Alaska and even Hawaii. The historic photos and drawings are already hard to find elsewhere, mostly illustrations of bridges under construction, on falsework or being dismantled, together with their patent applications and modes of failure in real time. This strength of the book grows out of the work of the late Richard Sanders Allen of Round Lake, New York, to whom Miller and Knapp give abundant credit.

The authors are neither bridge builders nor bridge engineers, but their research is so extensive and detailed that it is hard to find fault with the chapters on origins, evolution of truss forms and procedures of erection that occupy the first 117 pages. Any assertion they make is backed up by primary sources that they cite, rather than depending upon "what the old timer said" or "legend has it" or flights of their own speculation, as do so many other books on the topic. Terry Miller is an ethnomusicologist from Ohio who has been documenting wooden bridges since childhood and has examined perhaps 1000 spans. In this he rivals Joseph Conwill, that other great pilgrim and researcher of bridges, and the longtime editor of *Covered Bridge Topics*, whose knowledge and memory of North American covered bridges is so comprehensive that the late timber engineer David Fischetti once suggested "we should freeze his brain after he dies." (See Joseph



Above, Burr truss bridge under way at Beverley, West Virginia, 1873. At right, Hans Grubenmann bridge over the Rhine at Schaffhausen, Switzerland, 364 ft., 1758, with plan of floor timbers and partial elevation showing complex framing.

Below, detail of Stephen H. Long's 1836 patent drawing, with detail of Allen's Mill bridge, Miami County, Ohio, 224 ft., 1860, its Long truss recently cleaned.



All illustrations from *America's Covered Bridges: Practical Crossings–Nostalgic Icons*

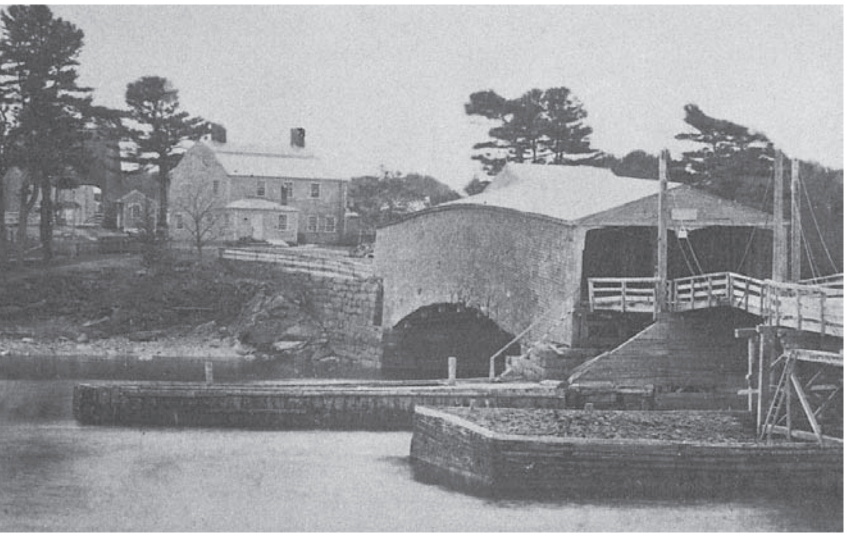
Conwill's discussions of covered bridges in TF 75, 78, 85, 87 and 102.) Ronald Knapp is a geographer at the State University of New York at New Paltz, specializing in Chinese vernacular architecture. His 2008 book *Chinese Bridges*, with photographs by Chester Ong, introduced Chinese covered wooden spans, as well as their stone crossings, to the wider world, where they are now something of a hot topic among bridge aficionados. (See TF 112, "Chinese Covered Bridges," by Philip S. C. Caston.) That neither of the authors is an engineer is not so great a handicap as it sounds. Almost all structural engineers attempting to analyze historic long-span wooden trusses will tell you that they can't initially make them work on paper anyhow, according to what they learned in college. A better approach for the modern engineer or builder, before touching any wooden bridge still standing at an average age of 140 years, is historical research into what the builders thought they were doing when they made the choices they made—and that is where this book spends much of its time.

Almost everyone loves being inside a covered bridge: the filtered light, the cooling breeze, the exposed heavy framing and its slight flexure under foot, the sound or partial view of the river underneath. To many, this experience is the essence of the bridge, but to framers and structural engineers, the wooden trusses that make spanning a river or gorge possible are truly the bridge, and the cover merely incidental to keep rain out of the joinery. The vast majority of the wooden bridges built or surviving in North America depended on wood trusses. The exceptions were some stringer bridges spanning small streams, and some occasionally very long trestle bridges (a series of bents supporting stringers) not crossing deep or fast-flowing water, but trying to flatten the crossing of wide, mostly dry, valleys. This is not true elsewhere in the world, for example China and Japan, where in spite of a long and distinguished tradition of carpentry, the long-span truss was never developed. Instead, their numerous wooden bridges depend upon wooden arch bracing, the interweaving of arching timber, and cantilever effects. These, as well as their stone bridges, were often covered.

Miller, and of course Knapp, are well acquainted with Chinese bridges and discuss them as well as European antecedents of American work found in Switzerland, Austria and Germany, which included kingpost and queenpost trusses, trussed arches, laminated arches and some longer spans such as the famous but long-gone Schaffhausen Bridge (364 ft. in two spans). This bridge combined trusswork, arch bracing and suspension rods in a confusing way that worked but raised doubts. Herman Haupt, the distinguished American civil and railroad engineer, observed in 1856, "With many excellencies this bridge had also serious defects, and it is certain that a much smaller quantity of timber judiciously arranged would have given far greater strength" (*General Theory of Bridge Construction*, 1856, p. 145).

Miller and Knapp suggest that Asian and even European bridges had no identifiable influence on the great North American bridge builders and designers of the 19th century, and they may be right, although we are probably looking in the wrong place. I suspect that early American bridge builders took their inspiration from the great timber trusses being erected over the naves of wooden churches and public buildings all over the eastern US and Canada, which themselves grew out of English and Continental roof framing sources from the 17th and 18th centuries.

Combine the old idea, imperfectly observed in European traditions but proffered in some builders' guides, of turning all



Above, Timothy Palmer's arched truss bridge at Newburyport, Mass., 113 ft., built open 1792, covered 1810, survived to 1882. Above right, William Birch's painting just before covering of Palmer's 1805 bridge over the Schuylkill River near Philadelphia, 550 ft. in total, middle span 197 ft. Covered view conveniently provided on riverbank.

At right, Thomas Pope's 1807 patent proposal for an 1800-ft. span over New York's East River, published 1811. Pope also believed he could bridge New York's North (Hudson) River with a similar span of 3000 ft.

forces into axial forces (which act along the length of the timber, minimizing or avoiding bending), with seemingly unlimited amounts of large-dimension high-quality timber, a need to build from scratch an entire continent's worth of church roof systems with spans commonly 60 ft. or more in the clear, and eventually bridges, and a willingness to believe that a local person without a specialized education might be trusted with these projects—combine all these and you get a flowering of truss design that led to the construction of the largest and most ambitious timber frames ever built, the large wooden highway, canal and railroad bridges of mid-19th-century North America. Of unusual interest in Knapp and Miller's book is a discussion of the eventual return of some of these now highly rationalized truss forms in wood to Europe, particularly England, Norway, Germany and Russia in the later 19th and early 20th centuries.

In their excellent chapter on origins, the authors survey what we can know of American attempts and accomplishments in longer spans, from John Bliss's "Geometry Bridge" (1764) in Norwich, Connecticut, a sort of queenpost truss with too many hinges, through to Timothy Palmer's very successful arched truss combinations in Newburyport, Massachusetts, and Philadelphia, as well as Thomas Pope's fantastic and simply unbuildable "Flying Pendant Lever" patent of 1807.

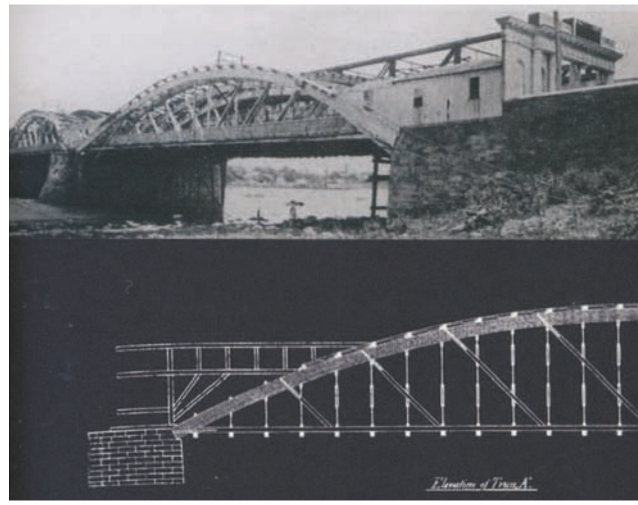
KNOWING what wood could and could not do, and willing to experiment with it on a grand scale, Theodore Burr in 1804–6 built a structure of five giant arches crossing the Delaware River, two of the spans at 203 ft. in the clear, eventually carrying trains, that lasted until 1875. In 1808, he bridged the Mohawk at Schenectady with a wooden suspension bridge that appeared catastrophic and soon required additional piers but also survived in use into the 1870s. Burr's 1804 "Burr Arch" (a multiple kingpost with assisting arches) across the Hudson at Waterford, New York, lasted until 1909, when it burned while carrying electric streetcar traffic and gas lines.

Burr was a builder with little formal education but with structural instincts, allowing him to quickly understand what materials could do and what the geometry of their relationships ought to be. These instincts were combined with a heroic temperament. Burr knew that the mark of a great bridge was not how long it was, but how far it could span in the clear. He tried unsuccessfully for 450 ft., and later his McCall's Ferry bridge across the Susquehanna near Lancaster, Pennsylvania, stood for several years at 360 ft. in the clear, until swept away by ice. Burr wasn't good with money and died in his 50s somewhere in Pennsylvania while building a bridge, and his grave is unknown.

Lewis Wernwag is also given extensive space in this book. His Colossus of 1813 outside Philadelphia (see TF 42) set the stage for a century of long-span bridges such as the world had never seen.

The book's second chapter explicates the truss designs of Burr, Wernwag, Town, Long, Howe, Smith, Child, Partridge, Paddleford, Brown, Haupt, McCallum, Wheeler and Post. A virtue of Terry Miller's coming from Ohio is that adequate attention is given to bridges and designs west of the eastern seaboard. Among the remarkable documents reproduced in this chapter are sets of bidding results for bridges in Ohio in 1867 and 1877, giving prices per linear foot for different types of truss and different wood species. Something for modern framers to speculate upon is why a truss of oak and poplar at the time might be $18.43 per linear ft. while fabrication in pine would have cost $23.71.

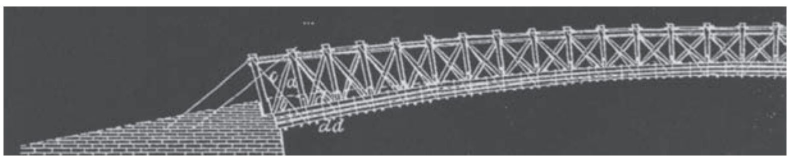
This chapter also enters into the debate about the relative contributions of arch and truss when used together. I never see why it is much of a debate: if an arch is very beefy, and climbs steeply and high, it can be the dominant member of this pair. Burr's 1806 Delaware River bridge certainly made the arch work. On one occasion, when examining the bridge at Taftsville, Vermont, with its tall, added laminated arches, I was able to move by hand all the bearing blocks under one truss end, indicating that the arch had it all at this point. The sadly departed Blenheim Bridge in New York state had an arch that rose 32 ft. to the ridge

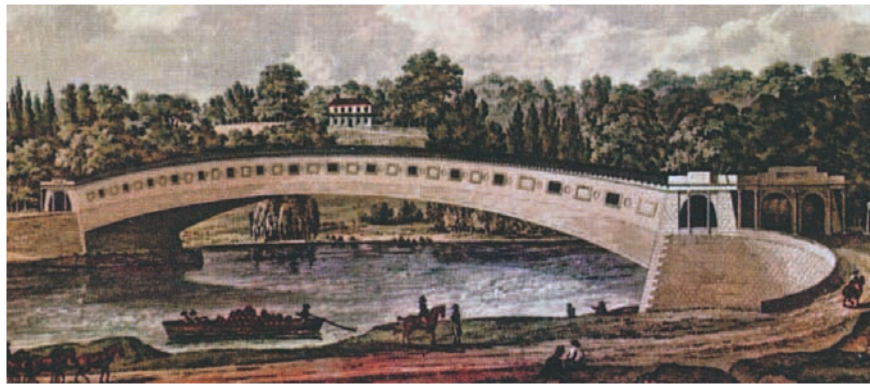


Above, 186-ft. Hillsgrove Bridge, Sullivan County, Pa., ca. 1850, typical Burr truss, siding removed for repairs.

At right above, partial view and framing elevation of Theodore Burr's 1000-ft., five-arch Delaware River crossing at Trenton, 1806.

At right and below, Lewis Wernwag's 340-ft. Colossus of 1813, Pa.





in the center truss and was built of three lamina of stacked 10x11 in. timber, shear-blocked and clasped in a 25-ft. tall double-posted Long truss. Probably this arch could accomplish something, although how the forces might be untangled I'll never know (see TF 102).

The distribution of bridge load between truss and arch remains a problem worth discussing. The longest wooden bridge entirely inside Vermont, a 154-ft. Burr arch, has been closed since a recent costly restoration, because, at the very least, of buckling failure of the plank arches that clasp the truss, in turn probably attributable to premature loading of the arches. Any truss, new or restored, will lose some camber immediately when first put in service, by the bringing to tight bearing of a great number of joints that merely look tight. Following that initial loss, experiencing mostly axial but partially bending moments, the truss will lose camber continually over its life, but at a decreasing rate, from shrinkage, heavy loadings and its slightly eccentric bearings, common to all timber work.

If the arch is much weaker than the truss but is made to bear the full load of the bridge right away, it may actually buckle at some weak point after engaging in a small amount of end grain compression. In the particular bridge in question, the plank arch was reduced in dimension significantly to pass around the bottom chord on the way to its spring point at the abutment. That is where it buckled dramatically. If the engineers or builders of this bridge had owned the book under review, they might have seen on pages 98–99 that the builders of the massive arches of a railroad bridge in St. Johnsbury, Vermont, in 1905 interrupted some bottom chords toward the ends where chord tension is low, rather than reducing the arch cross-section where it passed.

Abundant historic photographs in chapter 3 show the erection of covered bridges, most stick by stick on falsework across a river. Most covered bridges today are built and finished entirely on land adjacent to the bridge and then rolled across falsework in a long day, as the Guild did at Guelph in 1992. Miller and Knapp mention this method but, other than describing the relocation of a bridge in Iowa in 1921, they can't document it, and I'm not sure I can either. Given the tendency in 19th-century America to drag whole houses, barns, churches and steeples all over the place, well documented in the literature, I would be surprised if it wasn't common, and perhaps more evidence will emerge.

Covered bridges' deterioration, catastrophic loss and deliberate destruction occupy a chapter, with data from both the Lost Bridges Project (www.lostbridges.org) and the authors' own calculations that try to establish the actual number of covered bridges built. The Lost Bridges Project has so far identified almost 15,000 bridges, extant and past, in the US and Canada. Since Terry Miller has evidence for 4761 in Ohio alone, the total is probably far larger. The latest *World Guide to Covered Bridges* (2009) lists 814 in the US and 154 for Canada. The authors estimate this to be between 2 and 8 percent of those ever built, so there may have been almost 100,000 constructed over a 160-year period. Ironically, while wooden bridges were being destroyed on a grand scale in the name of progress during the 20th century, Oregon into the 1940s was building huge bridges designed to carry log trucks, and both Quebec and New Brunswick built long-span highway bridges into the mid 20th century as well. The fact that Ontario has only one surviving historic covered bridge (in addition to the Guild's 1993 Guelph Bridge) while Quebec has nearly 100, or that tiny Vermont has six times the number as much-larger New York with its similar topography and hydrology, suggests that there may be political and cultural factors to investigate related to wooden bridge persistence.

Something else for modern timber framers to think about is that while they spend most of their time constructing high-end housing, wondering how to span 14 ft. under a child's bedroom, timber framers in the past, while probably building more barns than anything else, also were asked to confront the challenging and risk-laden rigging and framing of 200-ft. spans carrying railroad trains, as well as to produce the vast number of small uncovered kingpost and queenpost trusses built and continually replaced everywhere there is a small concrete bridge or culvert today.

Covered bridges in our own time are represented in the book by many well-preserved bridges used for highway or foot traffic and as heritage tourism attractions. Anyone who has worked on a covered bridge site for a little while will be aware of how many persons from all over the world make covered bridges the focus of their vacation, and consequently their economic contribution to some locales is great. Replica and neotraditional bridges are also included (but, sadly, not the Guild's Guelph Bridge), including some of the immense highway spans designed by John Smolen, the former county engineer of Ashtabula County, Ohio, who continued the use of timber as the dominant structural component.

In the planning, financing, design, fabrication and erection of covered bridges, it can be hard to give everyone proper credit for what they contributed. For example, in the authors' kind mentions of David Fischetti and of me for the 1989 restoration of the Cornish–Windsor Bridge (450 ft. in two spans across the Connecticut River between Vermont and New Hampshire), the general contractor E. Davies Allan of Chesterfield Associates also deserved citation because he remained intimately involved and supportive of all aspects of the restoration.

The book's concluding tour of outstanding ("iconic") bridges across the continent, with its excellent photographs and commentary covering a wide range of truss types and locations, shows something of a fascination with very long multiple spans, which seem common in Indiana, Quebec and New Brunswick. The treatment here is at the macro level, with little coverage of construction and joinery details or visible modes of stress or failure. The authors wisely stay out of the subject of alternative restoration techniques and only briefly mention questions of "authenticity," which tend to be both very technical and vexingly controversial.

As I said at the outset, you can't lose by acquiring this book (and you might want the Knapp-Ong volume on Chinese bridges as well). For more depth or specialization, see Miller and Knapp's long reference list, from A(dams) to Z(acher), and return especially to the sources involved with the actual building of bridges: Herman Haupt, William Bell, Fletcher and Snow, and Theodore Cooper are good places to start, as well as Milton Graton's 1990 book, *The Last of the Covered Bridge Builders*.

—Jan Lewandoski

Below left, Smolen-Gulf Bridge, Ashtabula County, Ohio, 2008, 613 ft. long, 51 ft. wide, 40-ton load limit, nontraditional design.

Below right, bridge over St. John River, Hartland, N. B., 1901, 1282-ft. Howe truss in seven spans built open, covered in 1919.

Bottom left, Siegrist Mill bridge, Lancaster County, Pa., 1885, 102-ft. Burr truss reconstructed 2011 after displacement by flood.

Bottom right, footbridge at Henniker, N.H., 1972, 114-ft. Town lattice truss built by Milton Graton Associates.

Photos Thomas Allocca

1 Twentieth-century iteration of bridge at Bassano del Grappa, Italy, repeating most of 1569 design by Andrea Palladio.

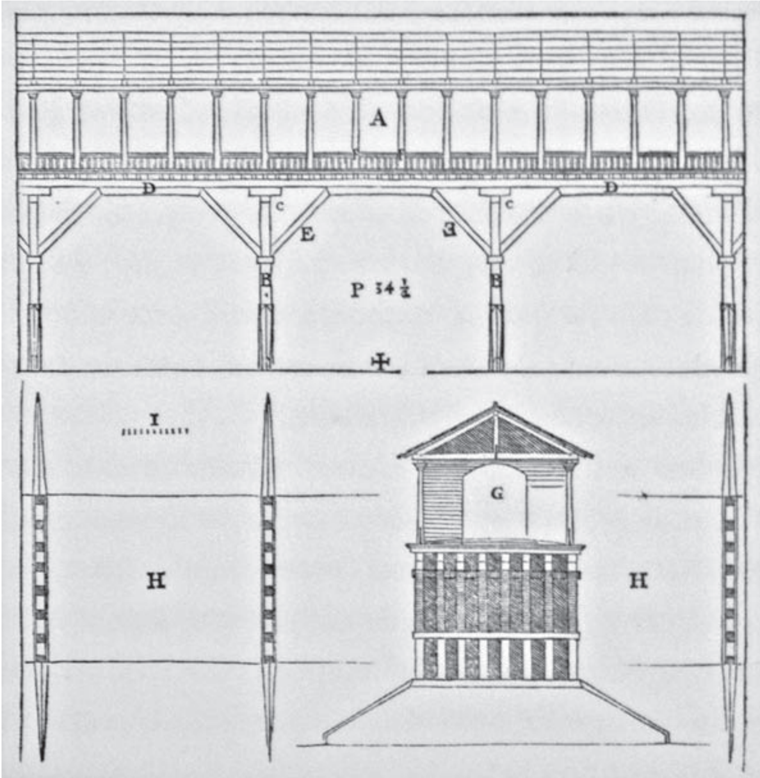
Bassano del Grappa's Covered Bridge

DESTROYED many times both by Mother Nature and by human error, but each time soon rebuilt, the bridge at Bassano del Grappa (Vicenza) in northeastern Italy is an extraordinary example of wooden construction, an 800-year challenge against floods, building mistakes and war, preserving its social, economic and symbolic importance for the town of Bassano (Fig. 1). Local people, asked what the bridge means to them apart from a tourist attraction, reply, "It is like our main square, the most important square of Bassano." Though linear in shape and joining two points of the town with no squares but rather tight streets, the bridge, about 210 ft. long and 26 ft. wide, is a passageway but also a place of rest and meeting, a sort of covered oblong piazza, with a paved floor and grand views of the city on the banks of the river Brenta, and to be compared with Florence's Ponte Vecchio, whose name it shares locally. Today the bridge is also known as il Ponte degli Alpini (the Alpini's Bridge) because after its destruction in World War II in 1945, it was rebuilt in 1948 with significant help by the Italian army's Alpine troops.

First news of a wooden bridge over the Brenta in Bassano appeared in the year 1124, and a town document dated 1209 reports the request by the mayor for trunks and planks of *rovere* or Italian oak (*Quercus robur*) to *rebuild* the bridge. From the first it seems, the bridge was conceived as covered by a wood roof, most probably with larch (*Larix decidua*) shingles from the nearby mountains of Trento and Belluno. The Renaissance architect Andrea Palladio was the author of the definitive 1569 design of the bridge as we admire it today. Between 1124 and 1569, Bassano's wooden bridge was rebuilt once with balustrade and piers of masonry (1524), a material never tried again after the bridge's destruction in October 1526 by an exceptional flood after tremendous winter rains.

The covered design was probably more nearly structural in intention than aesthetic, as the kingpost-trussed roof, framed with purlins and ridge-to-eaves heavy planking, keeps the sides of the bridge aligned in addition to sheltering the deck and underpinnings. For a long time, two stone towers at each end of the bridge protected the gates of the city. The end roof trusses abutted the towers, and the bridge floor beams were anchored inside the walls of the towers. Today the bridge still terminates in masonry, though in domestic rather than military structures, with an inn at one end and a museum at the other.

Palladio's design was affected by the great traffic of commercial ships passing through Bassano on the way to Venice, for the most part transporting valuable timber, and thus heavily loaded and dangerous when passing between the piers of the bridge. During the Middle Ages, the bridge had only two or three piers, too few to support such a span, while during the Renaissance and before Palladio's design, there were five piers. Palladio found the best solution in four reinforced piers, each comprising eight pilings protected by a covering of planks (today laid parallel to the flow of the river and the passage of ships), with cutwaters formed by additional pilings in line with those of loadbearing piers and



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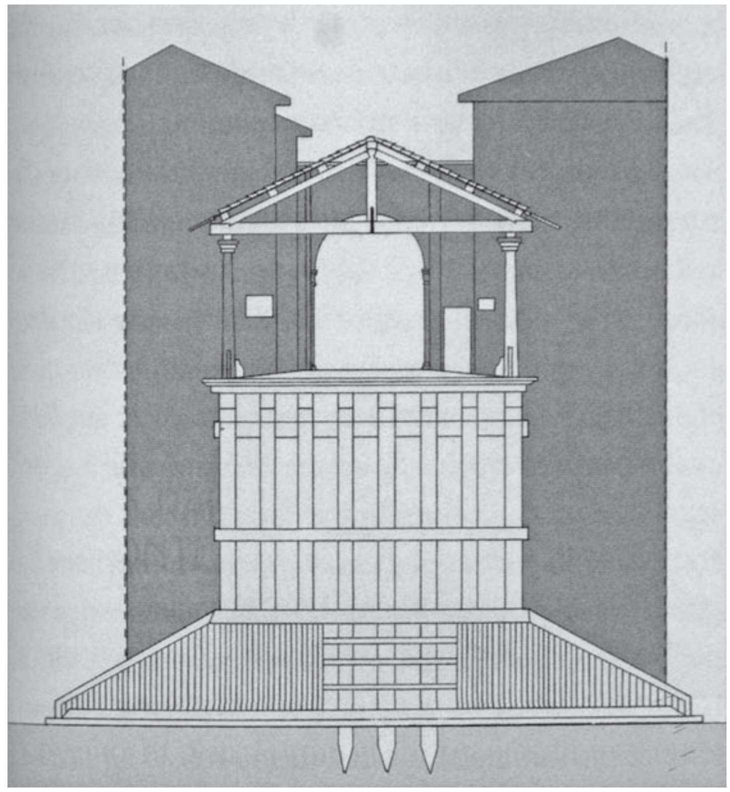

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likewise covered by the wooden planks, but successively descending to river level and capped with half-round timbers strapped to the lattice (Figs. 2–4).

Thus the piers present remarkably slender obstructions to both water flow and passing vessels. Diagonal braces rise in both directions from each piling to stabilize the piers, springing from a height above flood stage and presumably out of the way of any likely hull (in 1569) passing between piers. Finally, as we have seen, the bridge terminates at both ends in large masonry structures that stabilize it lengthwise.

In addition to revising the pier design for the bridge, Palladio also specified larch instead of oak timber, for durability and to produce a more elastic structure. Another innovation was to lower the bracing points on the pilings, reducing horizontal stresses and increasing the proportion of vertical bridge load on the pilings.

The roof over the Bassano bridge is supported by simple kingpost trusses (Fig. 5). The trusses, about 4 ft. 7 in. high, have a peak angle of 130 degrees, for a roof pitch of a little under 6:12. Dead loads (tiles, larch planks and purlins) on this truss have been calculated at about 24.5 psf. Expected snow load is about 28.3 psf as calculated for the most recent renovation after World War II (this last data from a technical document at the Civic Museum of Bassano). The kingpost is not tenoned to the tie beam but typically terminates 2 to 4 in. above, with a light metal strap making the connection. The light strap, usual in Italian roof trusses without ceiling load, appears to be meant to restrain the kingpost from twisting out of alignment rather than to make a functioning tension connection. The trusses, set on about 11-ft. centers, are made of 10x10 tie beams and 10x8 rafters and span 26 ft. 7 in. Seven purlins (including one at the ridge), on 5-ft. centers, run longitudinally over the trusses. Larch planks 1⅜ in. thick run from ridge to eaves and today support clay tiles (*coppo* type), while 38 solid larch posts 10x10 support the roof, 19 on each side, to which the balustrade and two midspan balconies are joined.

The original medieval idea to cover the bridge with a sloping roof, elaborated by Palladio in classical style, may have been to avoid the burden of heavy snow loads directly on the bridge deck in winter, and the practical need to clear the bridge after each storm. Certainly a covered passage was convenient for the citizens, and an unquestioned reason to cover the wooden bridge was to help keep it from decaying in the weather.

Today the bridge has an extraordinary fascination for visitors, both looking at it from the town and walking through it. The eight underdeck wood braces at each end of the bridge run to corbels on the brick walls of inhabited buildings, echoing the braces at the piers, and the triangular shape of the piers recalls the roof trusses. Wherever we look, the bridge recalls some other part of itself (Fig. 1).

Although today's stone pavement on the bridge deck fits the idea of a piazza, it doesn't respect the old concept of a wood-planked walkway and, at worst, it contributes to the instability of the bridge with higher loads. In fact, looking along the interior from one entrance, the floor appears curved (Fig. 5), like the delicate skyline of the nearby hills, but it is also a sign of a structure under stress.

—Thomas Allocca

Thomas Allocca (www.wooden-architecture.org) is an architectural and interior designer, journalist and medieval wooden architecture enthusiast in Siena, Italy.

2 Drawing of Bassano bridge by Andrea Palladio and originally published in his *I quattro libri dell'architettura* (Venice 1570), Book 3, Chapter IX (20). Lengthwise bracing system appears designed to funtion like upper chords of queenpost trusses.

3 Section through bridge, redrawn from Palladio by unknown draftsman, possibly much later, recording gatehouse towers built at ends of bridge. Tapered round columns shown with capitals are today replaced by square posts. Note direction of defensive sheathing on piers, corrected in modern times.

4 Eight-piling piers sheathed with horizontal cladding and covered at upstream and downstream ends with half-rounds. Braces spring from pilings at ledger fastened across them.

5 Bridge deck, carefully paved with shallow gutters each side, invites strollers. Elaborate balustrade, drawn in Palladio but missing from Fig. 3, is prominent remnant of Renaissance detail.

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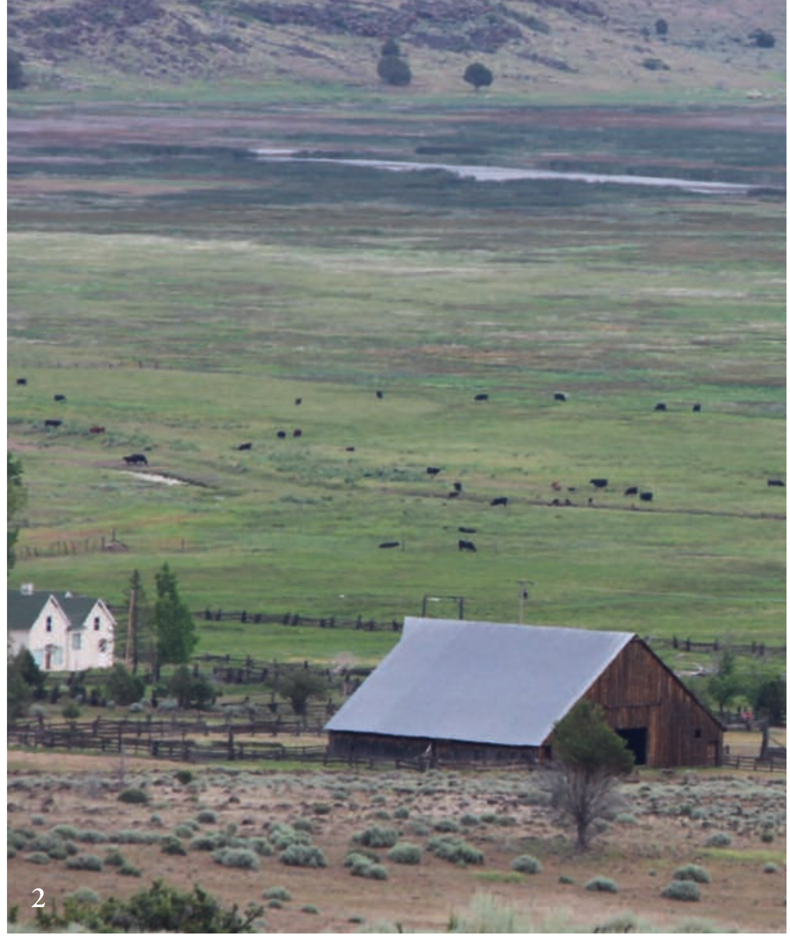

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Photos Paul Oatman

The Sierra Nevada Barn, Continued

EVER since I discovered the radical framing of barns in the Quincy and Susanville areas of northern California (Fig. 1), which I wrote about in TF 102 and 103, I had wanted to travel farther north, to Modoc County, a land of forests and valleys, to see if such framing also developed in that area.

My destination would be the Surprise Valley, near the Oregon border and just inside the state line with Nevada. Traveling through unexplored ranch country, to see and possibly inspect barns that had not been examined, I covered about 800 miles in two days, not enough time to survey, but time enough to glance at framing techniques.

Susanville was a four-hour drive from my shop in Pioneer, and from there I headed north on Highway 139, winding up and around Eagle Lake. The area is sparsely populated and the mountain roads cut through the forests and into valleys with grazing cattle. The first ranch I spotted was on the downslope toward Eagle Lake (Fig. 2).

The access road was gated, unfortunately. Farther into the valley I encountered another fine ranch and two barns that dominated the landscape with their size and flashy galvanized headdresses, but again without access.

Outside the hamlet of Adin, I was able to get close enough to take pictures from the outside of a barn framed in the traditional Sierra Nevada manner, three aisles (with lean-tos as later additions) with full-length purlin posts and dropped aisle tie beams. One unusual feature was the configuration of the heavy foot braces that extended from the base of a purlin post to just below the intertie on the next purlin post (Figs. 3–5).

This was a very well-built barn, with canted purlin posts complete with three-way bracing and resting on 10x10 aisle tie beams. The latter spanned about 16 ft. and were braced into the purlin and wall posts. The rafters were 2x6 with no visible deflection.

The next barn I was able to inspect was in Lookout. The owner was friendly and told me the barn had been built in 1888 by his great-grandfather and just recently restored by his nephew. A family affair. All the large timbers were hewn. It also had traditionally framed purlin posts and dropped tie beams, three aisles and further additions on side and back. A no-frills barn with minimum bracing (Figs. 6 and 7).

AFTER taking the back road to Alturas, I went on to Cedarville, in the Surprise Valley. These are small towns and, judging by the local architecture to be seen, the inhabitants never enjoyed the good old days. Alturas has a Moose lodge built in the 1920s, with brownish rough stone and gaudy turrets that give the overall impression of a Las Vegas castle. Cedarville has but one brick building. On the upside, neither town has any chain stores. I was able to photograph a number of their barns from a distance.

1 Big Sky Road barn, Susanville, Calif., detail of 60-ft. side aisle. Bracing style has not been found elsewhere.

2 Ranch barn at Eagle Lake (sliver in distance), with cattle. Note hay hood at end of roof peak to shelter hay track and fork.

3 Central aisle in barn at Adin, Calif., with heavy foot-bracing for purlin posts.

4 Side aisle of Adin barn showing fully braced canted purlin posts from aisle tie beam, secondary purlin, common rafters.

5 Gable-end view of Adin barn showing added lean-tos.

6 Barn at Lookout, Calif., exceptionally clean example of type.

7 Interior view of Lookout barn showing hewn posts, light bracing, common rafters, full-width lean-to addition at rear.


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8 Barn at Cedarville, Calif., with characteristic hay hood.

9 Mormon hay derrick, wheeled base obscured in tall grass.

10 Central aisle, Cedarville barn, with strapped tying joints.

11 Side aisle, Cedarville barn, with unusual canted purlin posts.

One in particular had been unmolested by the cutting of a gable sill for tractor entry, exhibiting its original doors in the side aisles and a hay hood for the trolley. I gained entry into one of its neighbors (Figs. 8–11). Hay hoods are common throughout the region as most of the barns were built after 1870. The hoods covered the end track and supporting beam for the hay trolley, the latter invented in 1867.

In addition to a hay hood, on the side of the barn I discovered—lo and behold!—a Mormon hay derrick still somewhat intact (Fig. 9). With its wheeled base in disrepair, it appeared as a giant praying mantis caught in a web of decay. This mechanism was the gin pole of the West! An old rancher a number of years ago told me that his father remembered how they raised a barn with the hay derrick.

The owner of the Cedarville barn, Yvonne Etchebarne, is a spry 86-year-old native of the Surprise Valley. She was happy to let me explore and relate to her what I could about the barn and its style, again a standard purlin-posted, three-aisle barn with segmented tie beam. It also has a secondary purlin plate, but with a curious form of unbraced canted post, which lands not on the aisle tie but at the joint between the aisle tie and the purlin post.

The timbers are circular sawn and the scarf joints are half laps. The use of wire spikes dates the barn between 1890 and the early 20th century. A concrete floor in the main aisle along with fresh siding and roof covering have given the barn new life.

ON my return trip, I took Highways 299 and 139, which brought me toward Adin from the north, and I stopped at a barn just outside. From the road, I could see it had the area-style hay hood and, even from a distance, the standard H-bent in the main aisle. The gate was open to the Triple-J Ranch and the owner was kind enough to let me in the barn (Figs. 12–16). The only problem was her dog, who was interested in tearing my lungs out. Once I shut the cow gate behind me, I decided I would not go back to my truck for a tape measure.

The barn turned out to be an engineer's delight and a builder's dream for pure assembly. From its first appearance in the 1850s all the way to the 1920s plank frame, at least in California, the full-

12 Barn at Triple-J Ranch, near Adin, Calif.

13 Side aisle tie, 2 in. thick, at purlin post, Triple-J barn.

14 Curiously notched foot-bracing in Triple-J aisle wall.

15 Center aisle, Triple-J barn.

16 Center aisle tie beam at purlin post, double pinned.

height purlin post accepts more joinery than any other member in the barn frame. Because it is so tall, many carpenters used centerline square rule layout to compensate for twist or crook.

The purlin posts in this barn are 8x8 but the tie beams are 2x10s, through-tenoned at the posts, with two pins for the central aisle tying joints and one for the aisle ties (Figs. 13 and 16). I have never seen such slender tie beams. The 4x4 braces for the H-bents are nailed flush to one face of the posts, and at the upper end thus lap as well as abut the 2-in. tie beams. The sills at the middle aisle are tripled 2x10s, with foot braces curiously notched together in the center of the bay (Fig. 14). The top plates are also tripled 2x10s. The aisle tie beam, through-mortised into the purlin posts, is sandwiched into a stick-frame wall plate at the outside. Judging from the barn's condition, the builder was correct in all decisions. Except for the traditional purlin posts, he made good use of the new technology of cheap nails, built-up members and sandwich framing. —Paul Oatman

Paul Oatman (sherwoodforesttimberframes.com) is a contractor and timber framer in Pioneer, California, who researches the Far West.

Medieval Germanic Roof Structures 2

IN the first part of this article (see TF 116), I described three early examples still standing of medieval Germanic roof carpentry. The basic structural idea behind the oldest of these structures was a simple triangular frame, forming a statically balanced unit that produced no horizontal thrust needing to be counteracted by supporting walls. The smallest of these roofs showed how the frame was simply repeated along the length of the space below to form a pitched roof. Such small frames with relatively short free spans still required internal support, which was supplied by simple struts or collars.

Statically balanced triangular trusses would dominate Germanic roof carpentry for centuries to follow. As the spans increased over time, so the internal support took on new forms, allowing changes in assembly and leading to unique, intelligent and economically advantageous developments.

A forerunner of developments was the 13th-century nave roof over St. Elizabeth's in Marburg (see TF 116), which uses short purlins to transfer loads to intermediate frames in an alternating primary and secondary frame system, with each frame type having different characteristics. The primary frame is stuffed full of internal supporting members, such as passing braces and a suspended central post, required to carry its own load and that of the adjacent secondary frames. The secondary frames, without tie beams or central posts, are just the opposite and have to be carried; the statically balanced triangle is absent. The structural system relies in the main on the purlins and short passing braces. The important aspect of this roof is that it functions as a three-dimensional structure when erected, but there are also architectural advantages. If the number of secondary frames is increased per primary frame, then a whole zone free of tie beams results, which can accommodate vaulting into the roof space.

The most extreme form is to use the roof structure itself as a vault, in so-called *open* or *wagon* roofs. One of the oldest still standing is over the nave of the Minster St. Maria and Markus (a former Benedictine abbey) in Reichenau-Mittelzell, Baden-Württemberg (N47° 41.940′ E009° 03.738′). The oak timbers have been dendrochronologically dated to the year 1235, plus or minus three years (Figs. 1–3).

The tie beams are not directly connected to any rafters, but instead hook over doubled wall plates surmounting the nave walls, at about 20-ft. intervals. This configuration represents a significant departure from a succession of simple triangular frames, but works because the wall plates collect the rafter ends on each side and the tying principle of a simple triangle is kept. With the horizontal or lateral thrusts balanced independently of the rafter pairs, the latter can be distributed in their own spacing along the nave according to the requirements of the ceiling boards and battens spanning between them. The result is a roof space more or less fully open to the nave.

In this particular roof, the vaulting is suggested by the curved braces (soulaces) above, descending from collar to rafter, and curved ashlar pieces below, descending from rafter to sole piece. (The sole piece, sometimes viewed as an interrupted tie, crosses the doubled plates and provides a broad bearing for the rafter with ashlar.) The curvature is also taken along the hewn undersides of the rafters and collars to complete the effect. The joints vary in their detailing. The collar beams are lap jointed to the rafters, often with a dovetail, as drawn in Fig. 3. Sole pieces can be found in nearly all such joints of this period in Germanic framing. The braces are let into the rafters and collars and fixed with large wooden pegs from the underside. The pegs are highly visible from the nave and would seem to be a deliberate decorative detail.

Such open roof construction is not common in Germanic carpentry, but also not just a one-off, as Günther Binding showed in his 1991 book on historic Germanic church roofs, *Das Dachwerk.* Traditionally, the simple triangular frame in one plane continued to be erected in Germanic roof structures, but it would be strengthened with various devices. Extra members were even added to triangular frames in small-span roofs, increasing the overall numbers of parts, but also reducing their cross-sections.

A GOOD example can be seen in the roof over the Treptower Gate in Neubrandenburg, Germany (N53° 33.383′ E013° 15.295′), as shown in Figs. 4–6. The city was badly damaged toward the end of World War II, when much of the historic old town was lost, but amazingly two of the four medieval gates in the city walls survived intact. The Treptower Gate timber was felled in the winter of 1415–16 as established in a dendrochronological report, thus the roof framing is almost 600 years old. In 2002 two of my students, Michaela Pietruschka and Janett Kauert, recorded the framing, which had undergone modifications and repairs in 1978 but otherwise was generally still in its original form, and calculated whether it was structurally sound. Despite some fungal attack, the seven individual frames would still pass a modern-day German Industrial Standard (DIN) examination—and would be just slightly overdimensioned!

The frames are equilateral triangles with a span of about 30 ft. The tie beams are 10¼ x 7¾ in., the rafters 7¾ in. square, the additional diagonal bracing 7x4, the collars 4¾ x 6¼ and the ashlar pieces 7¾ x 4. The ashlar pieces are tenoned in at both ends.

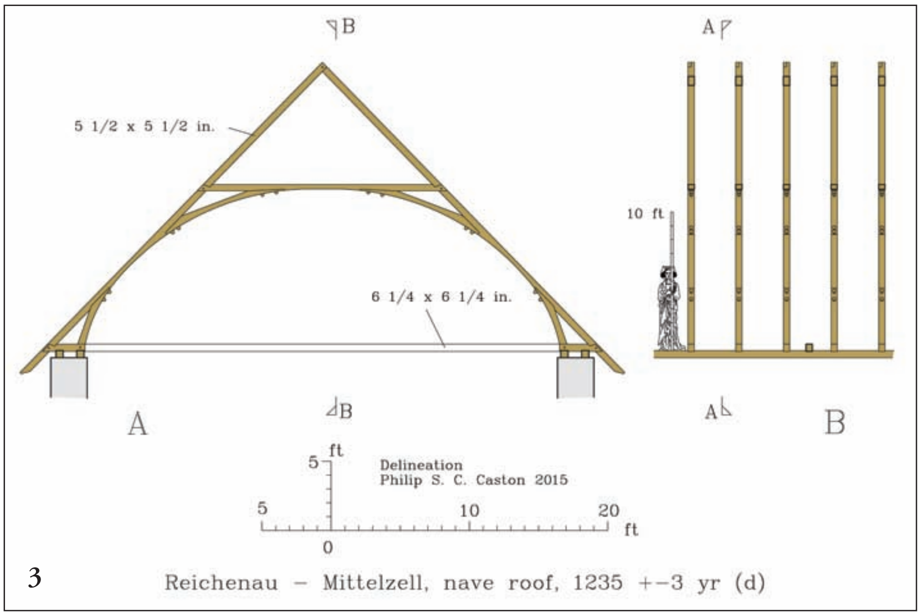
This raises an interesting question as to how the ashlars would have been inserted. All the other joints in the frame are lapped, each succeeding new piece placed in position without the need to move any of the existing assembled pieces, whether the frame was lying horizontally during assembly or standing vertically during the raising. The tenoned ashlar pieces require either the tie beam or the rafters to slide onto its tenons, but the rafters are joined to the tie beams in notched lap joints that do not allow for any sliding movement.

Our 1:20 scale model did not offer any explanations. Our model joints were loose enough (despite our best efforts to the contrary) and the model timbers sufficiently flexible to allow the ashlar pieces to be easily inserted and the rafters to snap-fit into the tie beams. I cannot imagine that this was the original assembly solution, but neither can I explain how it was really done.

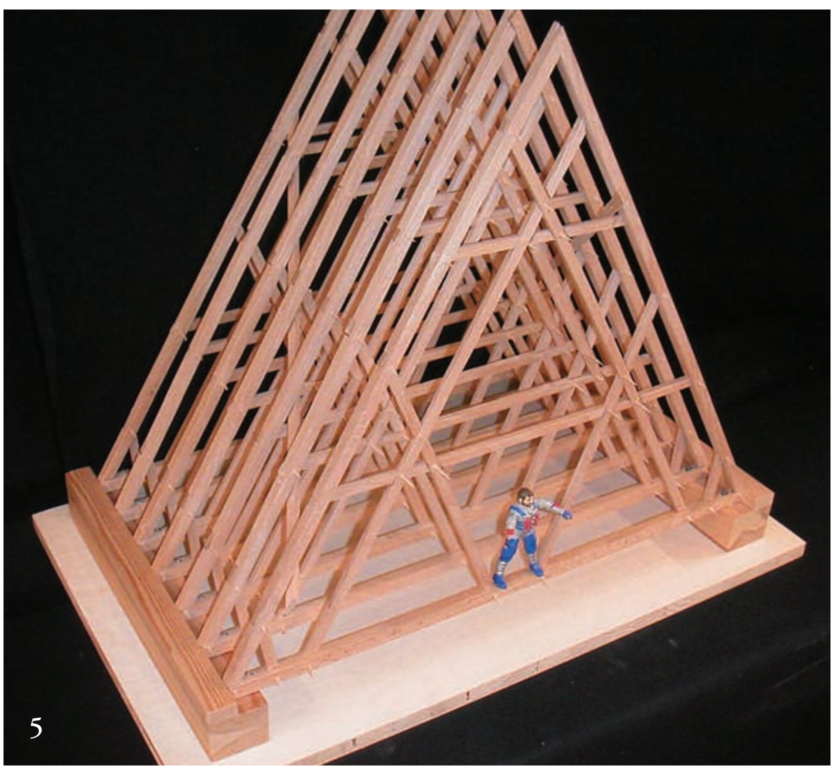
The assembly sequence for the remaining members can easily be deduced from the overlapping. After the initial triangle was completed, the collars were added, then the shorter passing brace pair followed by the long passing brace pair. Once all seven trusses were raised, their intervals were fixed by a diagonal brace fastened to the underside of each pitch, the whole array finally being sandwiched between two stepped brick gable ends.

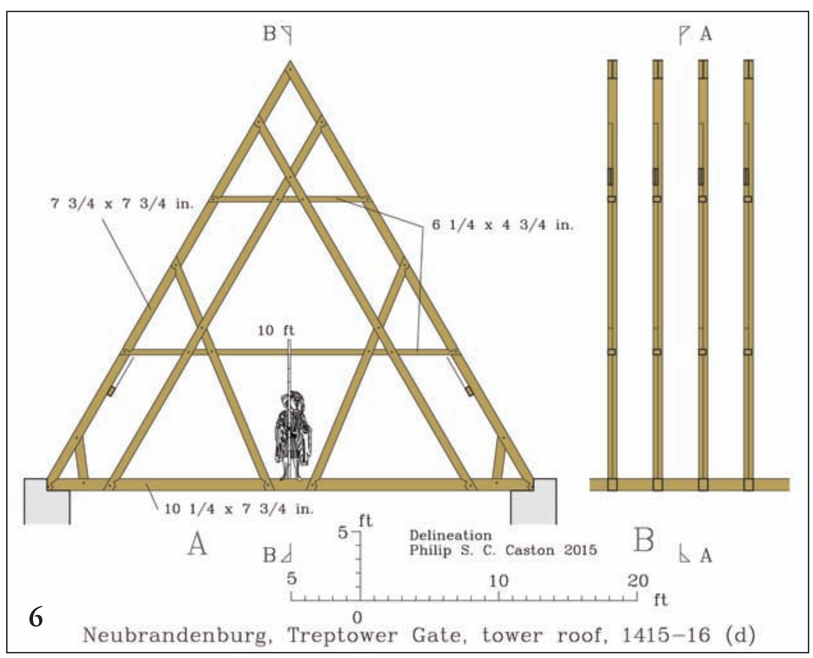
Photos and drawings Philip S. C. Caston

1–3 Minster St. Maria and Markus in Reichenau-Mittelzell, Germany, on an island in Lake Constance. Above, view of "wagon roof," ca. 1235, looking west. At left, elevation and part section.



4–6 At right, Treptower Gate, Neubrandenburg, Germany, 1415–16, once part of city walls, small medieval roof at top. Below, model shows diagonal straps left in place under rafters. Below right, elevation and part section.





7 **Cathedral at Schwerin, Germany. Nave roof frame about 44 ft. wide and high, 600 years old. Tower, 385 ft., is 19th century.**

THE idea of strengthening triangular frames can also be found in larger roofs, for example in the nave roof of Schwerin Cathedral (N53° 37.779′ E011° 24.867′), seen in Fig. 7, erected a few years before the Neubrandenburger gate tower. The frames here appear much taller than the gate tower roof but are in reality just three degrees more steeply inclined. The tie beams are some 45 ft. long, the free span about 8 ft. shorter.

The upper parts of each frame are identical. Three tiers of collars tie the opposing rafters together (or keep them apart, according to conditions), the lower two tiers overlapped by sets of crossed bracing. The crossed braces overlap each other as well, forming a multitude of small triangles, some overlapping, stiffening the upper part of the frame and linking the rafters to the frame at four additional points (Figs. 8–10).

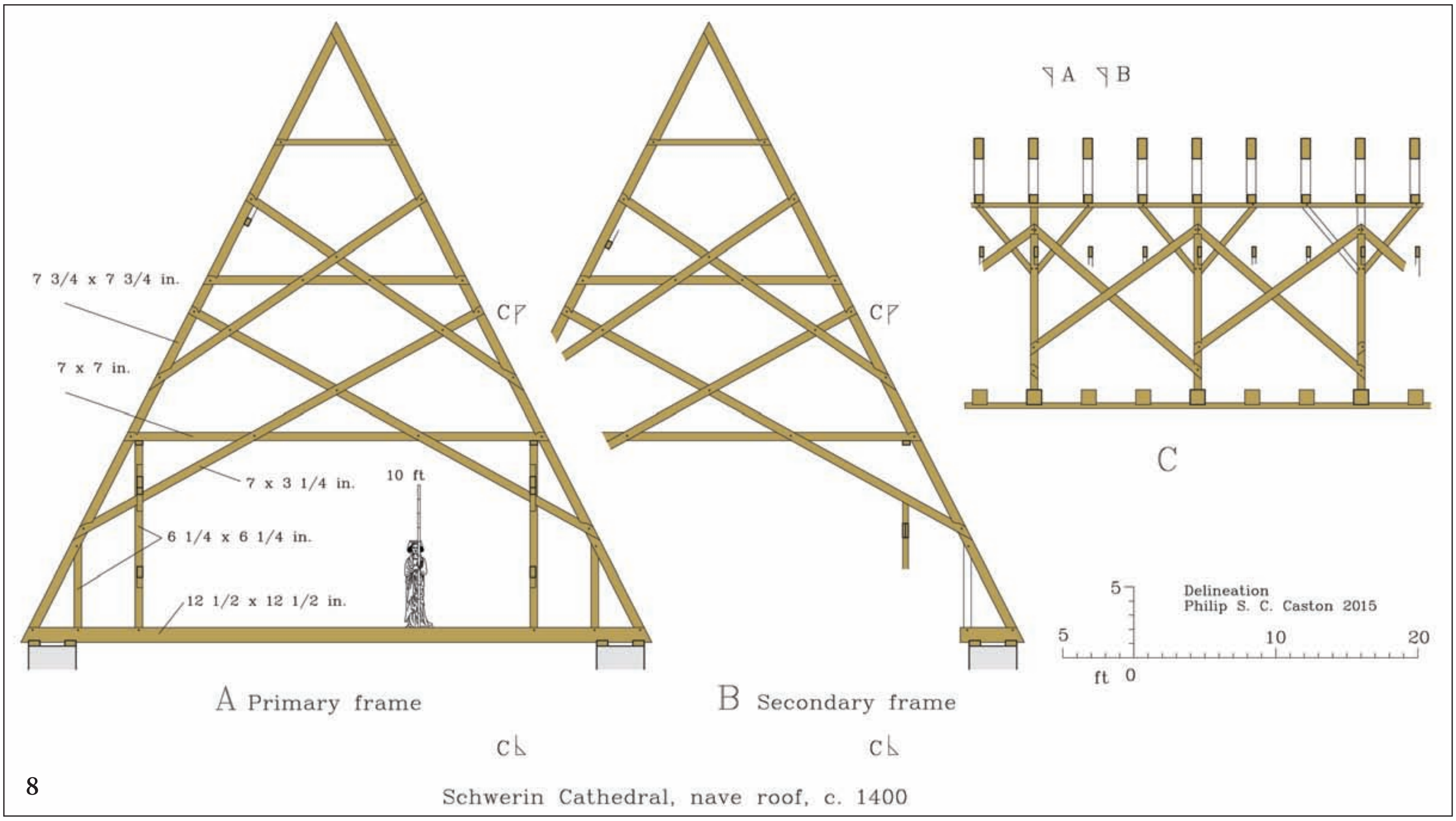
The lowest parts of the crossed bracing extend into the lowest level in each frame. Here the designer alternated primary frames employing tie beams and secondary frames with long sole pieces (perhaps better called interrupted tie beams). Otherwise, the members, sections (tie beams 12½ x 12½, rafters 7¾ x 7¾, collars 7x7, braces 7x 3¼) and joints are identical in both designs.

The primary triangles make up every third frame along the length of the nave, leaving two secondary frames to fill in the space between. The sole pieces and the tie beams are joined to doubled wall plates running under them, probably with cogs to transfer the horizontal forces at the foot of the secondary frame rafters to the primary frames.

This is not the only lengthwise force transfer. Two longitudinal plates, each tucked up under the lowest collars where they join the rafters, run the length of the nave and give extra support to all the frames. The plates are supported by a line of X-braced posts tenoned into the tie beams that might have been added as an afterthought or a repair. (The general condition of the timber prevents an accurate appraisal of the joints.) The carpenter's marks appear to be Roman numerals or simple lines cut in with a chisel or a race knife, and could well be postmedieval.

The origin of such longitudinal frames is unclear. Any roof structure with posts in its triangular frames provides an obvious lengthwise bracing plane. Such bracing developed probably in roof frames with centrally hung posts, such as St. Elizabeth's in Marburg, or where special constructional circumstances could be used to the framer's advantage.

ONE such condition is given when the side aisles in a church are built at the same height as the central nave, turning a *basilica* church into a *hall* church. The latter form was quite popular in northern Germany in the Gothic period, where all three aisles were optically and physically united under one massive roof. Such a roof is found 10 miles north of Neubrandenburg, my university town, and has played host to visiting students from my model-making course, who study the framing. The Protestant parish church of St. Petri in Altentreptow, Mecklenburg-Vorpommerania (N53° 41.504′ E013° 14.162′), shown in Fig. 11, has a series of



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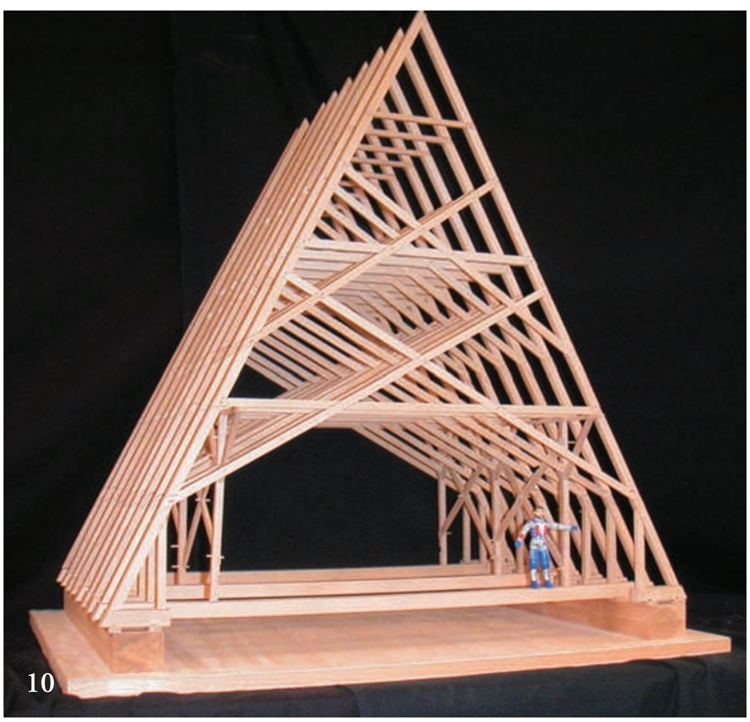
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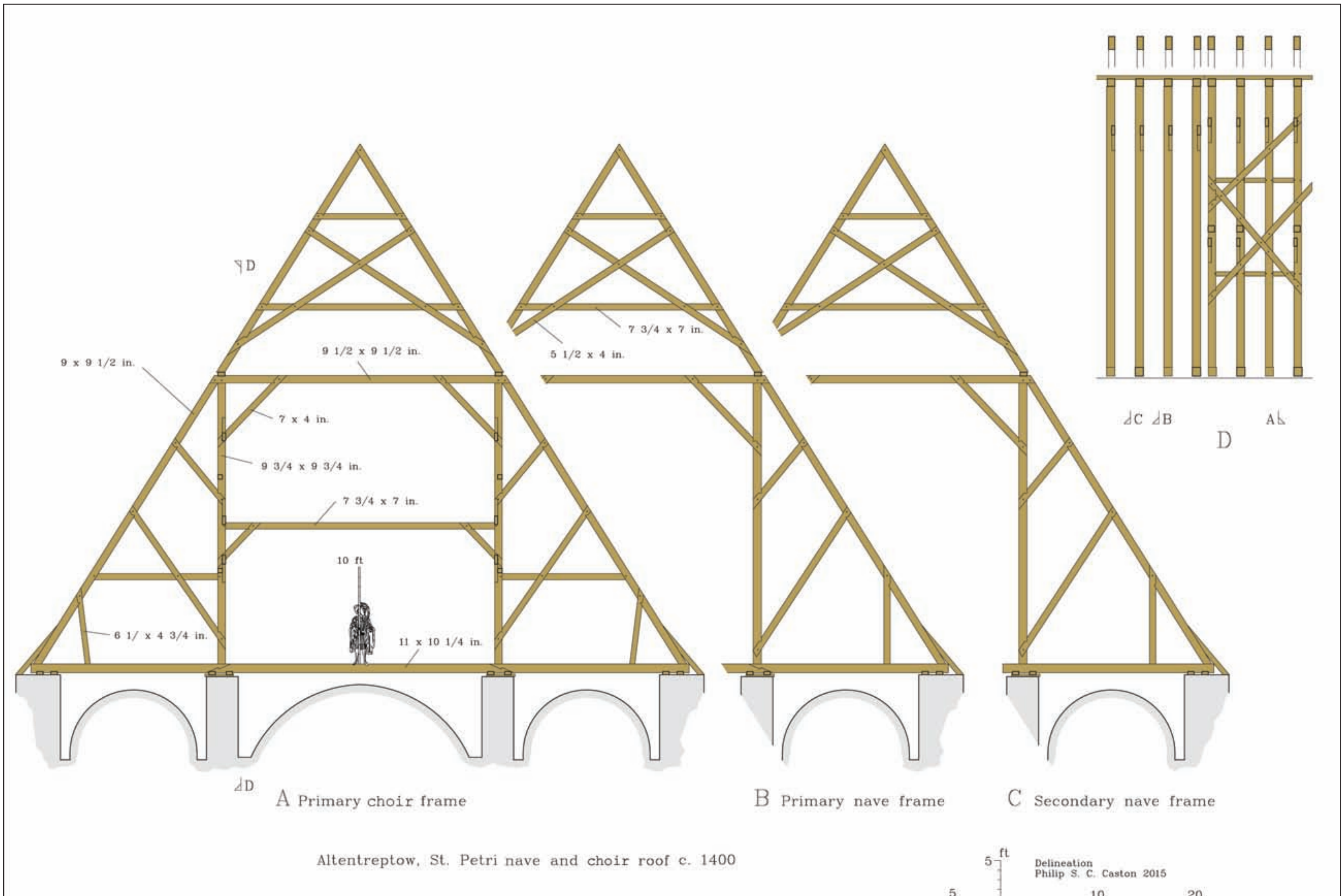
8 Schwerin Cathedral nave roof framing, ca. 1400, somewhat idealized elevations showing multiple lapped crossings. Section *C–C* shows longitudinal bracing with sectioned tie beams, collars and rafters.

9 Crossed passing braces in service in Schwerin roof. Iron bolts supplementing pegs at laps are recent and may be unnecessary. Lap joint depths change with timber size.

10 Schwerin roof frame model, made of uniform sections unlike original timbers. Representative group of trusses (nave is about 82 ft. long) reflects correct relationship of elements.

11 St. Petri Protestant church, Altentreptow, Germany, showing nave roof abutting tower on west and part of choir roof extending east to unseen polygonal termination. Roof framing ca. 1400.



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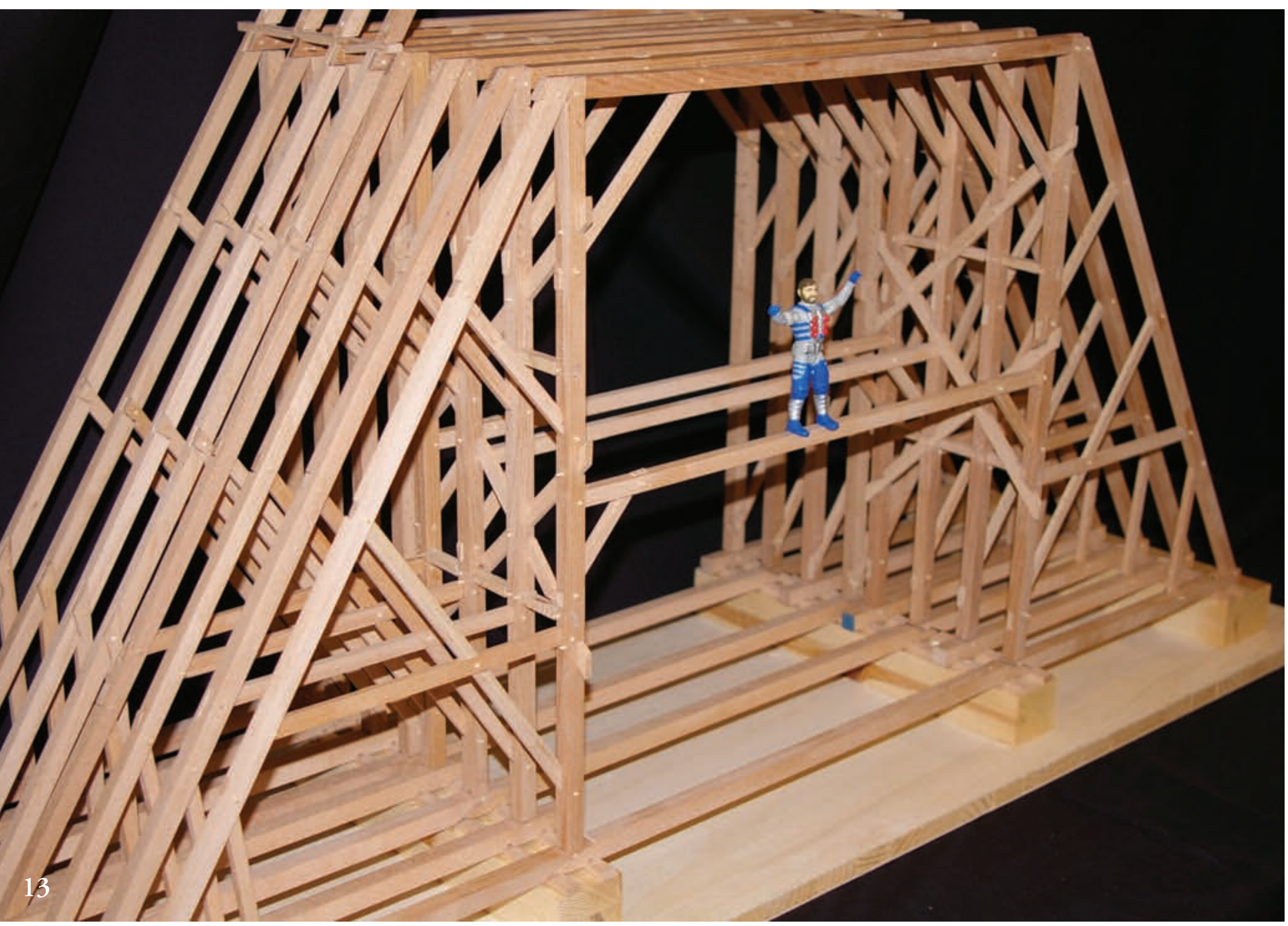

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12 St. Petri truss elevations, with longitudinal section *D* at junction of choir and nave structures. At end of choir (unseen at far right in Fig. 10 previous page), choir roof half-frames are arrayed over polygonal termination of choir walls.

13 Model of St. Petri roof with some completed lower trusses readied as platform for erection of separate group of upper trusses. Total length of roof including choir

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almost perfectly formed equilateral triangular roof frames set out over the entire length of the hall. The tie beams are 68 ft. long from end to end but joined twice along their lengths. These 10½x11 timbers would normally sag from their own weight over that distance, but are supported by the two arcade walls extending up past the vaulting to the height of the crown of the exterior walls.

The roof structure, which has not yet been dendrodated, was erected in two phases that differ in some details. The nave was completed around 1400 and presumably also its part of the roof structure, and the choir a few years later with its similar and presumably slightly younger and "improved" structure. The basic design for both the nave and the choir roof frames makes use of the two arcade walls to reduce the overall free span and to provide a solid surface on which 30-ft. posts, or masts, could be stood.

The frames comprise a triangular zone under the apex and an isosceles trapezoidal zone below (Fig. 12). The upper zone has identical triangular frames repeated over both nave and choir, with two diagonal crossed braces, two collars and two rafters. There is no tie beam as such and the lower ends of a rafter pair rest on a longitudinal sill-like purlin (Fig. 13, upper left).

I could not determine the exact joint detail at the upper rafter foot, but assume there is some sort of hidden connection. The sill-purlins are notched over a crossbeam that forms the uppermost part of the trapezoid frame below and also acts as the tie beam upper frame. This opportunistic tie beam is unusual and clever, but its success literally hinges on the sill-purlin and the rafters not sliding off them. A 19th- or early-20th-century repair in the form of a large iron staple at each rafter foot (Fig. 14) may or may not have been necessary.

The lower zone is structurally defined by the masts and the tablelike main frame that they form. The masts are tenoned below into the tie beams and above into the top crossbeams. Every second frame has an interrupted 11x10¼ tie beam which spans from the aisle outer wall to the nave arcade, resting on doubled wall plates. The primary frames, which differ only in the presence of a non-interrupted but segmented tie beam, feature the same joint detail exactly over its scarf joints.

Concentrating forces where the timber section is at its smallest would seem to be taking a chance. In the through-splayed and tabled scarfs, each part is reduced by about two-thirds in section, and the connections have to transmit both horizontal and vertical forces. More section is lost by the mast tenon passing through them, though the mast's weight and its tenon lock the joint against the upper piece slipping over the lower (Fig. 15). Observing no visible deficiencies in the ability of the tie beam to tie or the masts to stand upright after 600 years of service, I can only conclude that this was an excellent choice of detailing by someone who knew his forces and materials—or that he was just lucky.

This joint raises the question of weight distribution in the whole structure. The upper zone's weight and wind load will be transmitted through the members of the triangular frame to the sill-purlins, which rest on the crossbeams at the top of the lower zone, and then directly to the tops of the masts. However, these crossbeams are also connected to the upper ends of the lower rafters. In a simple triangular frame it is the rafters that transmit all the loads to the walls via the tie beams. How much of this load either rafter or mast will receive depends on the quality of each individual joint and, over time, on how the members deform. It would appear that some of the load from the upper zone is taken up by the lower rafters, which relieve the masts of excessive forces, and might explain why the joints under the masts have not crushed.

The masts are braced to the crossbeam at their upper ends and also to the lower rafters. Ashlar pieces brace the lower ends of the rafters, with the tie beams completing the framing in the trapezoidal zone, making this shape light and rigid. In our study model at 1:20, we built the lower zone first and used the tops of the crossbeams as a platform to erect the upper zone frames. This appeared a logical thing to do, but there is no evidence that the original was actually erected this way.

The choir roof structure is in essence the same as the nave's, with additional bracing and rails in the lower zone, possibly to resist the polygonal east end of the choir, where half-frames radiate out from the last full frame and were probably perceived to push against the western end of the standard frames.

The resulting inner "hall" in this huge roof is a magnificent space, but the true marvel is just how efficiently the designer incorporated masts in the design to form a box-sectioned central space almost devoid of any construction, buttressing the two sides of the box with triangular construction, and then used a cross-braced "light" triangular apex effectively forming an arch to span the box and transmit loads efficiently to where they could be transferred safely to the walls. The designer didn't just rely on sheer mass to solve a structural problem. Instead, loads are transferred using carefully chosen joinery, bracing and a box.

AS IMPRESSIVE as this roof structure may be, there is one medieval superlative that outsizes (or outsized, as it was lost in the last days of World War II) any other known large medieval roof: that over the nave of St. Stephan's Cathedral in Vienna (N48° 12.512′ E016° 22.380′), portrayed on the front cover. The late medieval structure was recorded as early as 1886 and again in the early part of the 20th century. Detailed drawings were published in 1931, but not detailed enough to reconstruct all the joints unambiguously, and we know of only a few historical photographs. Still, enough information can be gathered to attempt a convincing reconstruction of the basic structure and dimensions (Fig. 16).

This was a truly incomparable piece of roof framing, 116 ft. wide at its base, almost the same in height and built in horizontal stages, the largest some 23 ft. high. (The nave vaulting and arcade walls extended up into the first stage.) The whole structure was over 300 ft. long. The tie beams sat on wall plates mounted on the crowns of the arcade walls and extended out to the rafters where they were half-dovetail lap-jointed. Each tie beam was over 91 ft. long but just 9½-in.-square in section.

The whole structure is renowned in having been made from European larch (*Larix decidua*), which can grow to 150 ft. tall, long enough to have made each of the tie beams, rafters and passing braces without any scarf joints. Such large pieces of timber would weigh around 1 ton. While medieval cranes working in unison could have lifted that weight, wielding such timber during assembly aloft might have been difficult. Perhaps there were longer and shorter pieces in use. For our reconstruction at 1:20, we chose to keep the tie beams in one piece but to join the passing braces and rafters at midlength.

By the end of the 15th century, the *stehender Stuhl* (standing chair), an upright roof frame subassembly, had long been in use as a structural aid to supporting triangular frames, and its advantages for the erection of large roof structures are obvious. Such framing divides the structure into horizontal stages, useful working platforms during assembly saving the need for building secondary, throwaway structures (Fig. 17). The designer stood braced posts on the arcade walls, stacked on top of each other where they could be, or under the ends of the tie beams and collars in the primary frames (Fig. 18). This last group of posts was then stiffened by long passing braces (in the position of inner rafters), again raising the question how the loads were distributed—through the posts or through the braces?

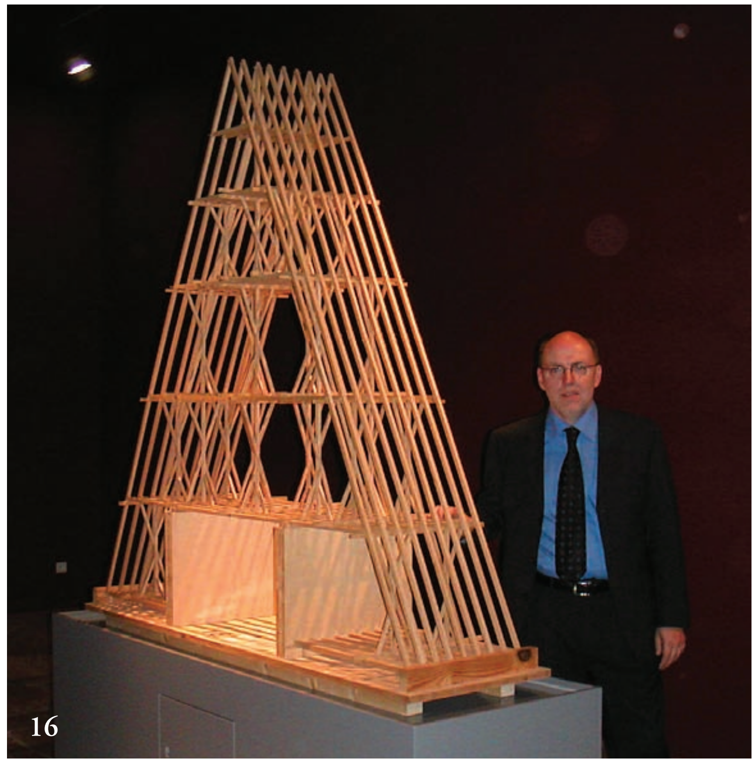
Of equal importance is how the designer saw the load distribution. He may have been thinking ahead to a point after long service, as well as about the moment of erection. For example, when the structure has settled, if the collars and tie beams have sagged then the posts would be suspended from the passing braces. But for assembly, the posts support each stage as it is erected. The thinking behind the posts lined up along the central axis is not clear to us as the survey drawings do not show if the posts continue through all the stages or are just short, stage-height pieces. If each stage has its own separate posts, then they are not suspended and become redundant after the assembly; in fact, they become unnecessary dead load. We considered this in the study model.

If, however, the posts extend through, then they would be suspended by the top ends of the passing braces. These 90-ft.-tall posts would also have to be half-lapped frequently to allow collars and purlins to pass and would thus reduce their cross-section by three quarters at points where nearby laps occur on adjacent faces.

Also, why are there so many lower short bracing diagonals at each stage? They would be a logical choice to stabilize short posts newly erected at every new stage, but seem unnecessary for longer posts. Another question we had was to determine how the purlins were joined to the collars. Did they simply rest on top or were they slightly notched? The survey drawings are ambiguous. Local medieval roofs show both solutions. For our model we opted for notches, but this is just our interpretation. Until new evidence turns up, these and other questions must remain unanswered.

—Philip S. C. Caston

Philip Caston (caston@hs-nb.de) wrote about earlier medieval Germanic roof structures in TF 116. This is the second in a series charting the development of roof framing in Central Europe, based on selected real examples investigated.



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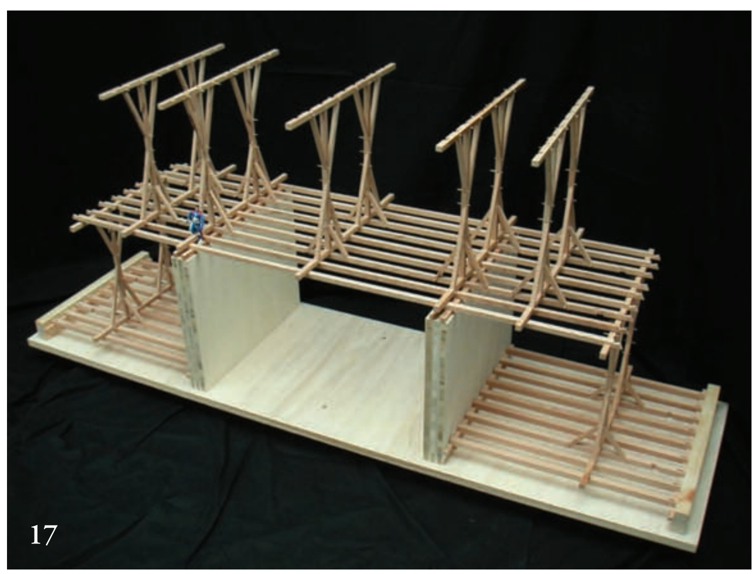

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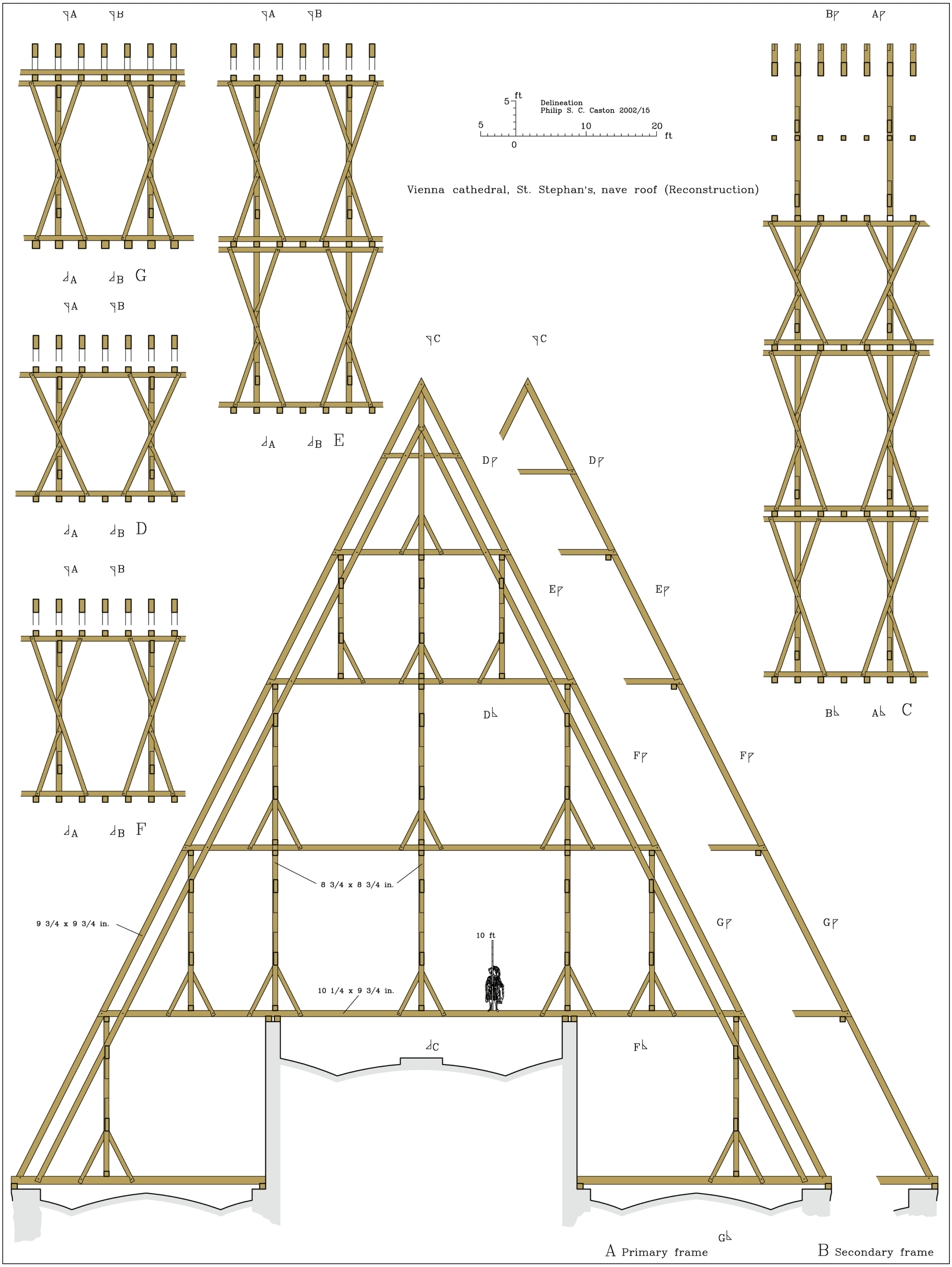
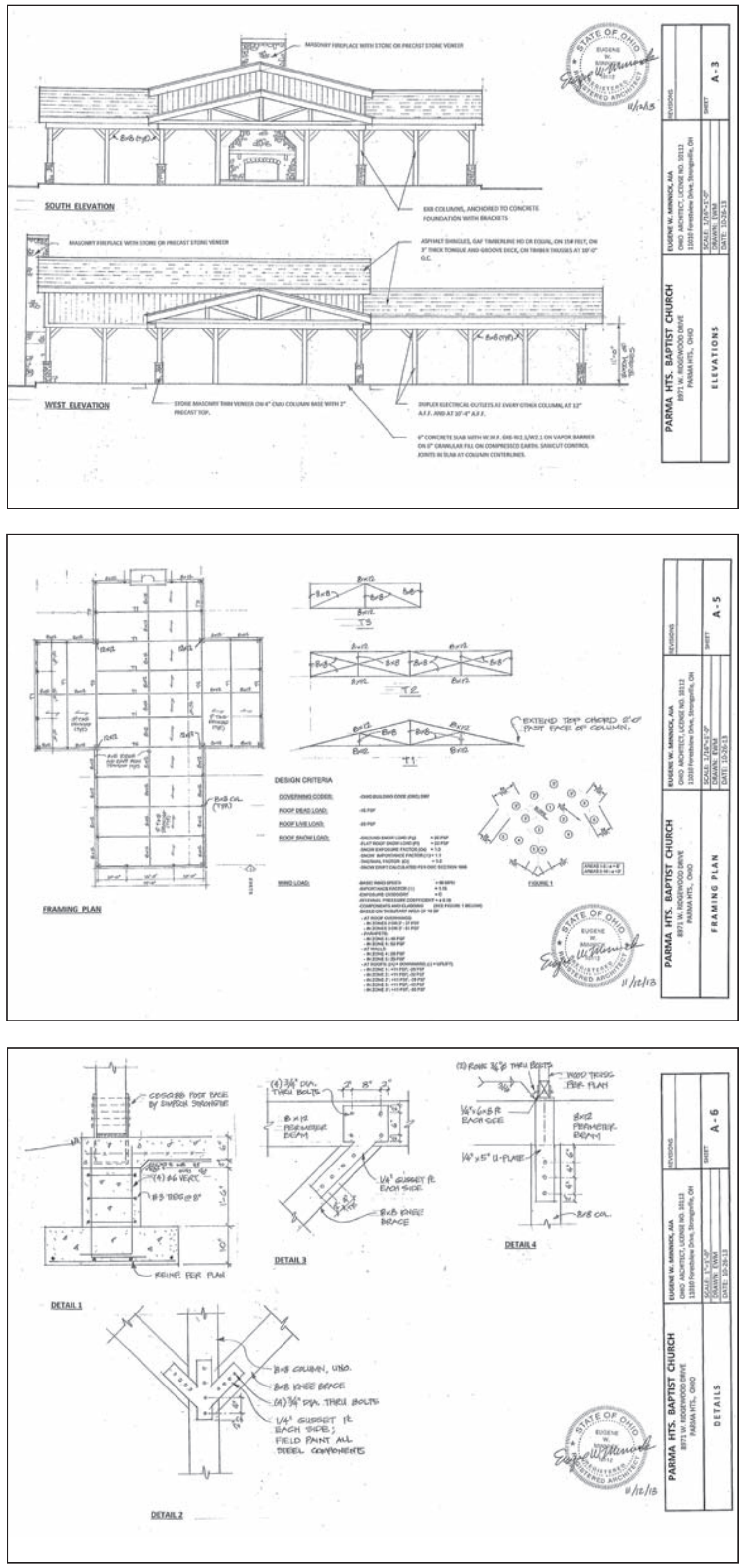
16 Representative 1:20 model of Vienna cathedral's 15th-century roof framing, burned 1945 and replaced with steel 1952. Model shown (here with author) at Palais de Chaillot, Paris, 2009.

17 Two lower stages modeled. Half-dovetail tie-beam ends at top of first stage await lap-joining to rafters.



18 Vienna cathedral, lost wood frame, sectional views of frame types and longitudinal bracing in each stage. Surveys from 19th and 20th centuries do not explain whether central post is one continuous suspended member or is segmented at three collars.

Combining Tradition and Technology, A Pavilion for Cleveland Church



1 Eugene Minnick, AIA

WHEN the pavilion project for Parma Heights Baptist Church in Cleveland, Ohio, came to our company, a great deal of "planning and design" had gone into the project before we were approached about fabricating the frame. Because the church has a large congregation, they needed a spacious multipurpose structure, which would be primarily focused on their youth ministry. A group of parishioners formed a committee to undertake the planning. Early on they decided they would like to build a nearly 5000-sq.-ft. pavilion, with a cruciform footprint.

One of the committee members was Gene Minnick, an architect who already had an interest in timber framing and once had even taken a timber frame workshop, but when it came time to commit something to paper he felt he wasn't qualified to design the pavilion as a true timber frame. Instead he opted to design it as a post-and-beam frame held together with large steel connectors and bolts. One of the design goals he was given was to make the entire pavilion a clear-span, with posts only at the perimeter. He chose to use kingpost-like trusses requiring massive 8x12 bottom chords and 8x8 struts and braces—something short of elegant.

To complicate matters further, the committee had added the requirement of clear sightlines to a fireplace to be constructed at one end and to the large attached presentation screen well above the mantelpiece. To accomplish this he used a "camel back" style which elevated the ridge line from the apex of the crucifix to the fireplace end (Fig. 1).

I knew Gene had put in a fair amount of gratis design time, but he was also open to suggestions. My immediate challenge was to begin to design the pavilion as a real timber frame, so I negotiated a design contract that would include the services of an engineer. This was to be a public-use building, the building permit would require an engineer's stamp, and truthfully I had no interest in taking on such a frame design without the support of a qualified engineer.

When I sent Ben Brungraber (Fire Tower Engineered Timber) the original camelback design Gene had developed, he mentioned that setting trusses on posts meant the frame would tend to be tipsy because of its "leggyness." I agreed and at first thought I could deal with the problem by using queenpost trusses with long braces from truss bottom chord to post, but this would be a real challenge in the elevated area because of the long posts required. I also was not happy with the sightline requirement and wanted to eliminate the high roof area, but massive queenpost trusses on short posts would block the sightline to the screen. In this configuration the trusses also would feel uncomfortably close to the ground.

Having traveled to England on a Guild tour in 2000, I had memories of massive tithe barns built there centuries ago. I remembered having been particularly struck by Leigh Court's tithe barn in Worcestershire (Fig. 2), with its clear-span, cruck-style trusses and principal-rafter, principal-purlin, common-rafter (major-major-minor) roof frame. I thought I should be able to make something similar work, but it was not anything I had done before. Ben produced photos of frames he had worked on that might solve the problem of huge trusses close to the ground, open up the sightlines and reflect the cruck truss I was trying to fit into the pavilion design (Figs. 3 and 4). They were modern looking, however, not quite the style I wanted to work in, but at least now I had a starting point.

2

Will Beemer

3

George Sherman

4

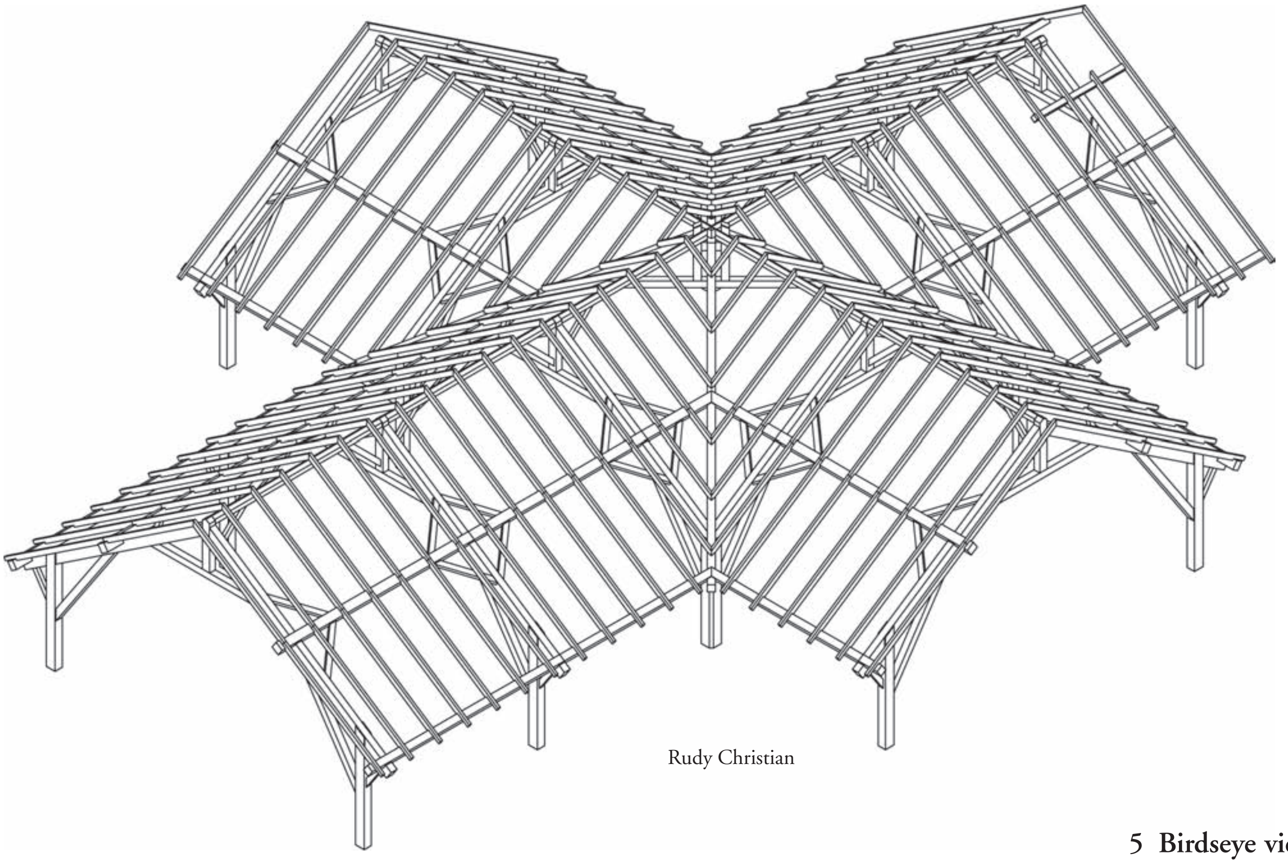
South Mountain Company

1 Initial trial elevations, plan view and connection details for pavilion, by Eugene Minnick, AIA.

2 Leigh Court's cruck-framed tithe barn, Worcestershire, England, 1344, visited during Guild UK tour.

3 Studio frame in Ipswich, Mass., designed by Weatherall Design and framed by Amstutz Woodworking, 2010.

4 Barn frame, Martha's Vineyard, Mass., designed and built by South Mountain Company, 2012.



Rudy Christian

5 Birdseye view of framing plan.

POSTS that connect directly to principal rafters or to chords of a truss make it difficult to incorporate a plate to carry the ends of common rafters. Additionally, in a pavilion design lacking walls, large roof overhangs would be advantageous to help protect posts from the weather. I decided to use flying plates, but rather than compromise the ends of the extended principal rafters by cutting mortises for the plate tenons, I set the plate inboard a little from the ends of the rafters and used a stacked connection, where the plates could lap over the rafters in housings (Figs. 5 and 6). The connection would of course require mechanical fasteners, but they would be concealed in the finished frame. These plates provided good bearing for common rafters at the eaves, but the great size of the roof (the trusses spanned 36 ft., yielding a 25-ft. rafter span) meant further support would be needed to keep the commons to a minimal size, lending elegance to the frame.

At midspan similarly I chose to stack the principal purlins on the top chords, but housing them 4 in. down on the chord face allowed 4x6 wind braces to be framed in flush simultaneously with the top of the truss and the bottom of the purlin. My principal-rafter, principal-purlin, common-rafter roof system was coming into focus. Now it was time to have some fun. By incorporating both up and down bracing at the purlin–top chord intersections, a wonderful diamond pattern appeared, repeating itself at every interior bent. From the purlin, the commons would ascend to the ridge line, and a decision was necessary whether to incorporate a ridge beam. We could just join the rafters to each other, but I felt the design would look incomplete. I decided to incorporate a braced ridge beam to run from bent to bent. This then required a crownpost to rise from the collar beam to join the ridge and receive the braces—which, it turned out, brought closure to my desire for the appearance of an early English roof frame.

The next challenge was the apex of the cross. Four valleys would need to meet the trusses, flying plates, purlins, ridge beams and common rafters. Each apex corner post would need to provide bearing for a valley, two principal rafters and a strut from each. The solution was to mill six-sided valley posts, providing five faces perpendicular, respectively, to the valley, the valley bents and the struts (Fig. 7).

The sixth face provided a location for an outboard strut from valley post to valley, below the flying plate. Staying with the stacked roof design, I lowered the valleys and landed the common rafters on top with no backing cut on the top of the valley. This also provided additional bearing for the plates and purlins since they would bear in housings in the valleys and lap over them.

The final design problem was the intersection of four valleys and four ridges at the apex. Typically I see a short, large-section, eight-sided post, often called a boss pin, used to join the eight pieces together, but the size of the valleys and ridges here would have required at least an 18-in.-sq. workpiece—likely a shrinkage nightmare and with it the possibility of this massive piece hanging inelegantly at the apex.

Instead I chose to break the boss pin into four pieces. By bringing four 8x8 posts up from the crossing valley collar beams, I had a simple bearing for the top end of the valley. The posts would then continue up between the ridge beams and, by connecting the four posts together with two short compression beams, bearing would be provided for the intersection of the ridge beams. Now the massiveness disappeared and instead you could look right through the valley intersection under the compression beams (Fig. 8).

Initially I had drawn the frame with a boss pin, and that was how it looked when I sent the frame, modeled in 3D AutoCAD, off to Fire Tower where Duncan McElroy would subject it to a loading analysis. (I call it The Smasher, where computer-aided design meets computer-aided forces of the real world.) There was a fair chance my work would need to be adjusted, but I was delighted when word came back that my frame design flew (or would if we didn't anchor it down). That was the good news. The bad news was that we couldn't necessarily use mortise and tenon joinery where we wished. The next step was to send traditional joinery details to Fire Tower and wait to see which ones came back with green check marks and which ones were marked for TimberLinx connections—uncharted waters.

Photos Rudy Christian

6 Frame erected awaiting common and jack rafters. All timber is Idaho No. 1 Douglas Fir.

7 Six-sided post designed to receive two principal rafters, one hip rafter and three heavy braces in simple-angled connections.

8 Four-posted built-up "boss pin" designed to avoid shrinkage problems of 18-in. solid octagonal timber.

9 Raising first apex truss on cruciform slab, using crane and spreader bar, with reinforcing straps fastened across vulnerable part of assembly.

10 Lifting one of trusses built in church parking lot, using telehandler and carefully centered spreader bar. Author (in white hat, at left) directs lift.

11 Sliding truss under the overhead power line, using rope-pull technique to keep post feet from plowing furrows.

12 The finished pavilion frame with its wetting bush.

DESIGNING for raising is a key element of successful timber frame projects. Fabricating the frame would be an effort, but with support from my tireless and talented wife Laura, Fire Tower, qualified subcontractors including Ric Beck, Arvel Aldridge and Andrew Schaeffer, and with a carefully 3D-modeled set of piece drawings, we knew the frame could be cut. The question of how to raise it was a little more of a challenge. The stacked roof design would definitely simplify things, but as Ben observed early on (I paraphrase), "I like the design, but isn't raising that thing with those big floppy trusses going to be a good trick?" He was right. The apex truss posts were 50 ft. 3 in. apart, center to center. The site was completely surrounded by trees, which meant we had to work with the crane on the slab and needed to leave room for the telehandler to hold up the first truss while we raised the second.

Since the apex trusses crossed one another, it made sense to raise the first as a full truss and the second as two half trusses. The width of the truss was one problem, but the balance of loads as it flew was also a serious consideration. A 22-ft. strongback on each side of the truss, screwed to spacers fitted between the truss members, solved the floppiness problem. If the strongbacks were stiff enough, the hinge points in the truss would be reinforced for the lift, but we would still be faced with two 650-lb. posts hanging at the ends of the top chords once the truss left the ground. To assure the truss could handle that load we attached slings to the top chords just inside the split boss-pin posts and the opposing valley post and connected them with heavy-duty comealongs. By attaching the comealongs on opposite sides of the truss, the likelihood of folding the truss when it went vertical was eliminated. The final component was a 20-ft. I-beam spreader bar to keep the cables to the pick points nearly vertical. When the moment of truth came for the crane to cable up, the truss stayed completely flat and flew with no perceivable distortion as it was lowered onto the post anchors (Fig. 9).

We had room for only one crane, so we used the telehandler to stabilize the full apex truss as we raised and connected the two half-truss sections that were perpendicular to it. This actually worked pretty well because the size of the truss, and its openness, allowed the telehandler to sit directly under the truss that was already raised. Once the crossing apex trusses were fitted and pegged, the frame was stiff enough to stand on its own and the raising of the rest of the frame could proceed without need of stabilizing sections with the telehandler while other sections were connected. Since the trusses that landed on the six-sided posts had no posts of their own, they had to be flown without the struts that connected them to those posts. That meant we had to install the struts first on the posts and secure them with ratchet straps while the trusses were flown into place. The only way to make this work was to have two scissor-lifts on the slab so someone could be in two places at the same time to align the joinery.

Once the valleys and apex trusses were completed, it seemed simple enough to raise and stabilize the full truss bents while the stacked roof framing was attached. There was no room to preassemble the bents on the slab, so we repaired to the church parking lot and then, using the spreader bar, picked up the truss bents with the telehandler to drive them to the raising site and hand them off to the crane (Fig. 10). This would have worked without a hitch if the aerial power line to the church's security lighting hadn't crossed the driveway from the parking lot to the pavilion site, a fact that I had totally missed. Ric Beck suggested that we had enough manpower to tie ropes to the post bases and pull the bents backward while the telehandler moved forward, in effect laying the bent down as we passed under the power line. That worked like a charm, and since both sides of the road were grass we could drag the posts without damage (Fig. 11).

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Raising the bents and tying them off to the trees around the pavilion while the ridge beams and braces were connected went well, and we were able to send the crane away and finish dropping in the plates, purlins, rafters and jacks with the telehandler and scissor-lifts. We had one minor hitch. Most of the raising crew was from out of town, and we knew we would need to work straight through to finish the frame so we didn't overrun our equipment rental contracts. This was just fine with everyone but the pastor, who really didn't want us working on Sunday during church services. Had we stopped, we would have lost a good number of the crew, who already had commitments for Monday, so we leaned on the pavilion committee chair, to see if we could get a special dispensation. It took some time, and I'm sure some sweet-talking, but eventually the pastor relented and we had permission to work straight through, although the pressure to watch our language was at an all-time high. By Sunday evening we were finished with the telehandler and by Tuesday the last jack rafter had been set using a scissor-lift (Fig. 12). A lot of work by a lot of good people was now something we could stand back from and be proud of.

—Rudy Christian

Rudy Christian (rchristian@planexus.com), past president, founding member and for many years a director of the Timber Framers Guild, is president of Christian & Son, Inc., Burbank, Ohio, and retired executive director of the Preservation Trades Network.

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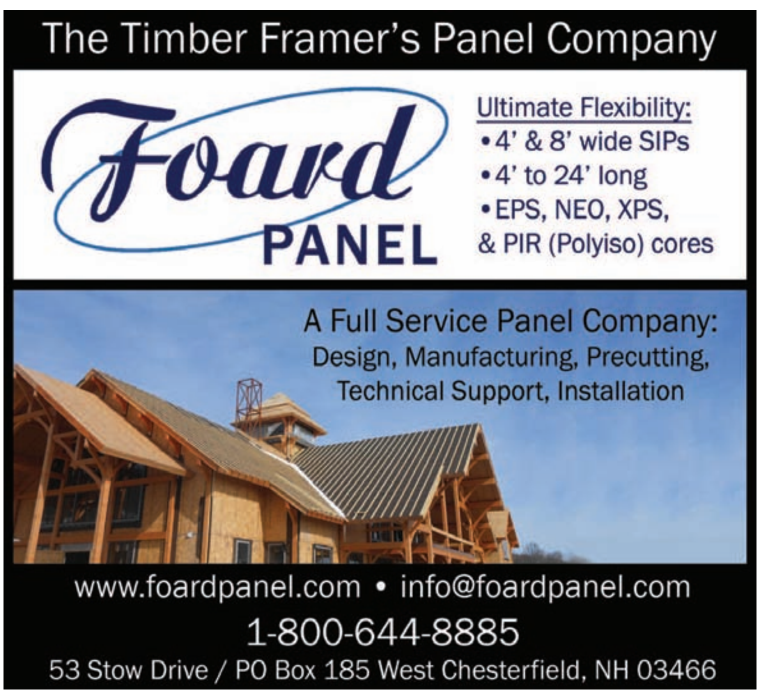
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