TIMBER FRAMING

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Covered Bridge Typology

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On the covers, Swiftwater bridge over the Wild Ammonusuc in Bath, New Hampshire, built 1849, rehabilitated 1999. Now in two unequal spans bridging a total of 135 ft., the Paddleford truss structure displays its distinctive portal design (front cover) and characteristic diagonal ties crossing the posts and braces of the truss panels (back cover). Photos Ken Rower.

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TOPICS

Scribe Rule, Square Rule, Democracy and CNC

SOMEWHERE in the US Northeast, sometime before 1801, someone, no one knows who for sure, discovered an entirely new method of constructing timber frame buildings. The shift from the scribe rule method—an ancient practice transplanted and maintained for more than a century by America's first European immigrants—to the novel and ingenious square rule method is a significant and revealing historical detail. Arguably part of a wider revolutionary process, representing a move away from a world based on entrenched traditions of craft and hierarchy to a new, more dynamic one, based on principles of industry and democracy, the move from scribe rule to square rule also marks the beginning of a process of change in the evolution of framing systems. With the availability of accurately squared timber from the mill, and what has recently been termed *mill rule* having derived from square rule, yet another system, what we might call *CAD rule*, has emerged today. Understanding the development of each system in historical context and the relationship among all of them is useful for carpenters to put their own work in perspective and for historians interested in charting the course of culture.

Buildings are the visible symbols of a society's culture. No matter how rudimentary or crude, how extraordinary or breathtaking, the structures people build represent their interests and needs, their knowledge and skills, their attitudes and beliefs, their aspirations and values. The primitive dwellings of unskilled peasants, the more refined handiwork of traditional craftsmen and the professional product of highly trained architects are all physical expressions of a culture's character.

As a field of inquiry, the study of buildings has progressed from the classification and description of celebrated great works—the world's architectural crown jewels, so to speak—to the analytical deconstruction of more modest vernacular forms. While focus on the former has introduced us to the best and the brightest, the latter has taught us the value to be gained from the close "reading" or explication of buildings. Neither approach, however, has told us much about the significance of building construction. This is an important area that has been overlooked by both the compilers of great buildings and the explicators of vernacular structures. This is not surprising when one considers that much of the work done thus far has focused on the product of construction—the building itself whether of high or low status—rather than the process of making the building. We can learn as much if not more about a culture by examining how its buildings are made.

Alexis de Tocqueville, who visited the young United States from France and wrote about his travels in *Democracy in America* (1835), remains the most perceptive analyst of American culture. Tocqueville believed the process of constructing an American culture began with the efforts of 17th-century immigrants who "somehow unlocked the democratic from all those other principles it had to contend with in the old communities of Europe." The process that Tocqueville describes—America's destruction and modification of existing links and its creation of new ones: its unlocking of the democratic—can be seen in the evolution of timber frame construction in New England.

As a carpenter, historian, immigrant and American, what interested me most about taking apart medieval and postmedieval timber frames in England was the fact that many of the buildings I was dismantling and repairing had been built in the years the English were colonizing North America. These weathered and worn, seemingly impervious and still majestic oak structures carried the secrets of design and craft that would have been brought to the Colonies. They held the clues of what the first colonists might have built and the methods they might have used.

Two books confirmed some of my initial thoughts regarding English influence on early American methods of building construction. David Hackett Fisher's *Albion's Seed* (1989) and Abbott Lowell Cummings's *The Framed Houses of Massachusetts Bay 1625–1725* (1979) both seek to establish the English roots of American culture. Fisher's book is a comprehensive attempt to prove

> the importance for the United States of having been British in its cultural origins. . . . Today less than 20 percent of the American population have any British ancestors at all. But in a cultural sense most Americans are Albion's seed, no matter who their own forbears may have been.

Published in 1979, ten years before Fisher's book, Cummings's work, though focused specifically on early American vernacular architecture, was also an attempt to highlight the influence of English culture, specifically that of East Anglia, on the culture developed by the Puritans of Massachusetts Bay:

> The timber framed houses built during the century that followed the first settlement at Massachusetts Bay were fundamentally English. . . . If these houses have been dismissed as simple, box-like shelters, primitive in their inspiration and crudely fabricated by a group of rough and ready pioneers, then the evaluation is actually in error. . . . We have sought to explain that while four-square and uncomplicated in form, the early house frame embodies nevertheless a highly complex and sophisticated array of structural concepts, climaxing a thousand years of English experience in building with timber. . . . The tenacious persistence of inherited traditions among the transplanted Englishmen [confirms] popular notions about the characteristic British reluctance to depart from time-honored custom.

While transplanted English regional practices were influential in shaping many aspects of early American culture, it is important to note that their persistence was fleeting: Old World methods were quickly modified to deal with New World circumstances. Several factors, most notably the quantity and quality of immigration (as well as the quantity and quality of new world materials) made the maintenance of traditional English framing techniques unrealistic and therefore untenable. Initially, unorthodox methods were adopted in an effort to survive.

The first structures the Pilgrims built were cobbled together by necessity. Arriving in the wrong place after a difficult journey in the middle of a bitterly cold winter, the Pilgrims had no friends or family to greet them, no homes to move into. They were unfamiliar with the territory and the terrain and knew little if anything about the native population. They didn't know whom they could trust. They were hungry, weak, tired and sick; many were dying. Add to this what must have been an overwhelming sense of anxiety, fear, desperation, possibly doubt, loss, regret, anger, disappointment and probably a good dose of superstition.

As for the 102 passengers on the *Mayflower*, half were women and children. Most of the men on board had more experience dealing with wool than with wood. There were two tailors, a tanner, a silk worker, a camlet maker, a cordwainer, a wool carder, a hatter, a linen weaver, a wool comber and a fustian weaver. Only three of the passengers had any carpentry skills. One was a cooper, the second a sawyer; only one was a house carpenter. They were all from different regions and too young to have any significant experience. The sawyer died in the first winter.

Given the urgency of the situation and the background of the passengers, it is not surprising to learn that the first settlers lived in casks, caves, tents, "English wigwams," and even dug large trenches and lined and covered them with planks. Small groups of people splintered off from the main group soon after they arrived. In 1625, a Captain Wollaston and Thomas Morton founded what was to become Merry Mount, a small settlement whose shelters were more influenced by Native American design than by that of the English.

Unlike the underprepared and overchallenged Pilgrims, the Puritans came across the Atlantic a decade later like an invasion party. According to *The True Travels, Adventures and Observations of Captain John Smith* (London, 1630), the Higginson Fleet of 1629 consisted of "6 ships and 350 people, 115 head of cattle, as horses, mares, cows and oxen, 41 goats, some rabbits, all provision for household and apparel, 6 pieces of great ordnance for a fort, muskets, pikes, corselets, drums, colors, and with all provisions necessary for the good of man." The Winthrop Fleet followed in 1630 with 17 ships. Despite the well-conceived invasion, it was still difficult to maintain traditional English building practices. It was not until well into the 1650s, more than a generation after the Pilgrims arrived, that Edward Johnson (quoted in Cummings) could write in *Wonder Working Providence, 1628–1651*, "The Lord hath been pleased to turn all the wigwams, huts, and hovels the English dwelt in at their first coming, into orderly, fair, and well built houses."

Why did it take a generation to finally achieve "well built houses"? Clearly, the circumstances were challenging. Perhaps even more significant, however, were the lack of skilled and experienced carpenters and the urgent need for shelter.

From the outset, carpenters were in great demand and short supply, as Cummings reports from original documents. In 1629, Francis Higginson wrote: "Of all trades, carpenters are most needful; therefore bring as many as you can." According to William Wood, writing in 1634, one of the men most fit for the plantations would be "an ingenious carpenter." We can only speculate about what Wood meant by "ingenious" but I think it's fair to assume he was thinking of a skilled master who was experienced, clever and willing to be creative in challenging circumstances. According to Nicola Coldstream in *Medieval Architecture* (2002), throughout Europe and England during the period of North American colonization, to become a carpenter one was first required to spend five to seven years working as an unpaid apprentice. After completing an apprenticeship the aspiring carpenter was then allowed to work as a journeyman traveling and offering his services for a price. This period would last until the journeyman produced a work of distinction that was approved by his craft guild. He would then be designated a master and allowed to own tools and run a business. Becoming a master was difficult and time consuming. There is little reason to think that older, well-established master carpenters would have left behind all they had worked for to start over in a new world with uncertain prospects.

According to Cummings, again drawing from original documents, "the large number of incoming carpenters at Massachusetts

Bay during the earliest years gave their age as twenty or twenty-two. Of 146 carpenters arriving at Massachusetts Bay before 1650, 91 percent (a total of 133) were in their 20s or 30s or servants, apprentices or recently married with young children, while only ten or a dozen were well into their middle years." In 1660 a Boston selectman wrote: "Many youths in this town being put forth apprentices . . . for 3 or 4 years time, contrary to the customs of well governed places, [are] uncapable of being Artists in their trades [and] are unmeet to take charge of others for government and manual instruction of their occupations. No person shall henceforth open a shop in this town, nor occupy any manufacture or science, till he hath completed 21 years of age, nor except he hath served seven years apprenticeship." Bernard Bailyn's *The Peopling of British North America* (1986) cites lists kept by English customs officers on the eve of the Revolution recording the "name, age, quality, occupation, employment, and former residence of every person leaving Great Britain for the colonies." These lists reveal that the nature of the immigrants remained almost exactly the same as it had been 100 years earlier in the 17th century; it was dominated by large numbers of unskilled and semiskilled young men.

Without enough master carpenters on site with Old-World framing experience, in either the 17th or 18th centuries, the young carpenters moved away from methods over which they had little grasp and developed new and more effective ones that enabled them to build well-made houses, barns and churches quickly—structures in tune with the circumstances they faced and the environment in which they lived. Free from the heavy hand of the past, in a largely unregulated and bountiful new land, they began the process of unlocking the democratic. American vernacular architecture (and American culture for that matter) evolved from the piecemeal influences of a variety of medieval and post-medieval European craft traditions to the innovations of immigrants prepared (in fact, compelled) to improvise, to take chances and try something new.

Cummings comes to this conclusion, noting that "in broader terms . . . the story of architecture in New England throughout the 17th century is one of change and Americanization. . . . Innovation and adaptation begin almost at once."

SEEN against this backdrop, or prelude, the subsequent move in American timber frame layout from scribe rule to square rule, which appears to have taken place very late in the 18th century or early in the 19th, makes sense. Unlike scribe rule, a labor-intensive framing system in which no timber is interchangeable with another and frames might be put together and taken apart several times before their final erection, square rule is measurement based and far more efficient. Many similar parts of a frame, braces for example, are interchangeable. The frame does not need lofting, timbers do not need to be stacked one on top of another, scribed joints are eliminated, the frame does not need to be put together and taken apart before being erected. The system, essentially imaginary sawmilling, is fast, clever and innovative, an imaginative, and frankly brilliant, response to existing circumstances. While the square rule frame is less handsome to look at when compared with its scribed cousin, by eliminating scribed joints the speed of the entire framing process is increased dramatically, saving time and reducing costs.

Also, working to straight lines inside an irregular timber in an effort to create a number of interchangeable parts "democratizes" (and ultimately deskills) the framing process by making redundant the art and craft of scribing and all the complexity that goes with it. Square rule framing does, however, require a new skill: imagining a regular timber inside an irregular one and knowing how to realize this perfect timber through the careful placement of a series of lines. And there are still complicated joints to be cut by skilled hands.

Perhaps the move from scribe to square rule is best seen as a reskilling that sets in motion a subsequent process of deskilling. One point to remember, however, is that during this period, before the triumph of mechanization and specialization in carpentry and speculation in society, the American square rule carpenter was still in an important way very much like his European scribe rule ancestor: a hands-on craftsman who combined the talents of an architect, engineer and builder. Looking back with the clarity of hindsight, we are able to see what has been gained and what has been lost in the process of craft leveling initiated by the introduction and practice of square rule framing. At the time, however, in the early stages of this process, making things simpler and faster was a necessity, one not yet motivated solely by profit and, at least briefly, even considered to be something of a virtue.

Square rule can be seen as part of the late-18th-century fascination with interchangeability, in both politics and manufacturing. In 1785, almost ten years after making the bold assertion that all men were created equal (interchangeable?), Thomas Jefferson, then the American minister to France, wrote a letter to his colleague John Jay extolling the brilliance of French gun manufacture. "An improvement is made here in the musket which it may be interesting to Congress to know. . . . It consists in the making [of] every part of them so exactly alike that what belongs to any one may be used for every other. . . . I put several together myself taking pieces at hazard as they came to hand, and they fitted in the most perfect manner" (quoted in David A. Hounshell, *From the American System to Mass Production, 1800–1932,* 1984).

This novel French invention, one combining the use of interchangeable parts and semiskilled labor, was first tried out in the United States to make guns. Proving successful, the process spread quickly to the production of clocks, sewing machines and harvesting equipment. Ironically, the process was dubbed the "American System of Manufacture" by the British in 1851 after they were impressed by a display of American gun manufacture at the Crystal Palace Exhibition in London.

It's easy to imagine Thomas Jefferson, the polymath, revolutionary and Renaissance man of the Enlightenment, thinking and perhaps hoping that an ideal democratic society would be one based on interchangeability in manufacturing and republicanism in politics. Walt Whitman was so intoxicated with the prospect of this sort of everyman democracy that in 1855 he opened his national anthem, *Song of Myself*, thus:

> I celebrate myself, and sing myself,
> And what I assume you shall assume,
> For every atom belonging to me as good belongs to you.

Whitman's idealistic high note of hope for America's democratic future, one that rings elegantly and perhaps a bit ecstatically with the promise and potential of Jefferson's enlightened concept of interchangeability, comes just 20 years after the appearance of its more pragmatic reality or undertone: the balloon frame.

Built on the outskirts of Chicago in 1833, St. Mary's Church has been described by John H. Lienhard as "the first unique [form] of American architecture." Composed entirely of 2x4s, 2x6s and thousands of nails, the church is one of the earliest examples of what has come to be known as stud framing. Apparently, a number of carpenters who were used to building sturdier and more substantial "braced" frames came to see the church being built and laughed at its spindly appearance. Convinced that it would be blown away by the first strong wind, they referred derisively to the frame as a balloon. In fact the balloon frame did in another sense take off, leaving its critics, their craft and their culture in the dust.

Mill rule carpentry, the practice of working by measurement from one or more of the four accurately finished sides of a planed or exceptionally well-sawn timber, and associated with modern large-section barn manufacture, might be traced back in a sense to balloon frame stud construction, with its assumption of standard dimensional section. This suggests the evolution of timber framing systems did not follow a tidy sequence with one system disappearing entirely when another emerged to take its place. What appears more likely is that versions of several systems were used simultaneously in different regions to suit different purposes. (There is certainly evidence that both scribe rule and square rule methods were used in a single building. To those of us still making frames, this is not surprising; I have used a combination of scribe rule, mill rule and double cutting on the same frame. Being familiar with all of the different systems enables one to draw on the best aspects of each, targeting specific methods to specific problems.) This less than fluid pattern of "progress" is similar to what scientists have recently told us about our own evolutionary process.

Unlike the scribe and square rule systems, the mill rule system is a product of mechanization, specifically the continuing improvement of sawmills (and concurrently the mass manufacture of nails). Instead of figuring out how to rationalize irregular-section timbers and then bringing them all together with a range of complicated joints, one could simply work with lengths. On frames like St. Mary's Church that used timbers of small section—"light frames"—nails completely eliminated the need for joints of any kind. In addition, the rise of professional architects and engineers, coinciding with the popularity and reliance on the use of pattern books, further reduced the carpenter's already diminishing role. The once admirable idea of interchangeability gave way to a robust form of machine- and profit-driven mass production. The architect, the engineer, the property speculator and standardized material removed much of the creativity and control—the craft—from the carpenter's work. Deskilling was in full swing.

The process was to be accelerated even further. In 1908, Sears, Roebuck and Company published its first *Modern Homes* catalog, offering its customers 44 pre-made kit homes to choose from. Below the quotation "Let us be your architect" were images of houses ranging in price from $695 to $4115. The kits came with everything. The Chelsea 111, for example, was delivered to site with a 75-page instruction manual, 750 lbs. of nails and 22 gallons of paint. After selling more than 100,000 of their prefabricated modern homes, Sears ceased production in 1940, but the mass-produced house was far from dead. After the war, the demand for affordable housing was met by large-scale suburban tract developments. Levittowns of stud frames were built throughout the country. The balloon frame, with full-height studs even for multistory buildings and floor joists set on let-in ledgers, had already given birth to the platform frame with its easy-to-erect single-story studs and joists set on plates fastened to the story below.

In the 1970s, a revival of traditional timber framing in the United States and a growing interest in the conservation of historic buildings worldwide (responses to mass production and debased quality similar in spirit to those of the middle and late 19th century articulated by Thoreau in his critique of industrial society *Walden Pond* and on a larger scale by the Arts and Crafts Movement led by William Morris and John Ruskin in England) helped to recover forgotten practices, restoring some luster to the carpenter's craft.

While at the beginning of this revival some were hewing timber and chopping mortises, resurrecting traditional designs and methods for wealthy clients eager to live in and with something handmade, in time engineers were refining computer-aided design (CAD) and computer-aided manufacturing (CAM) programs that would work with computer numerical control (CNC) machines, in theory to produce traditional-looking frames at a fraction of their handmade cost. Once again, the carpenter's role was being challenged by technology, this time ironically and perhaps cruelly by machine-made replicas of traditional handmade timber frames. It was hard not to feel the accumulated weight of Emerson's comment made more than 150 years ago that "things are in the saddle and ride mankind." What was a craftsman to do?

TRAINED as a timber framer in England by dismantling and repairing ancient buildings and scribe-ruling new historical reconstructions, I, along with a number of other framers committed to maintaining the practice of traditional methods, was critical and skeptical of the CAD-designed CNC-manufactured buildings. The ones I had seen lacked character and soul. There was, as Gertrude Stein once remarked, "no there there." However, as an American and the grandson of an immigrant carpenter (and an immigrant carpenter myself), I had to admit being more than a little intrigued by the new framing process. Though many of the CAD-designed CNC-cut frames I had seen did appear flat, perhaps this wasn't the fault of the new tools but of the people using them. In the right hands, those of experienced framers familiar with the history of traditional design, maybe all the new bells and whistles could be put to good use. I thought of those old carpenters in Chicago making fun of the balloon-framed church, unable to see the future being built right in front of them.

Not wanting to become more of a dinosaur than I already was and looking for ways to work with the free-falling economy and the increasingly tight-fisted banker clients who had caused the problem in the first place, in 2008 I agreed to oversee the erection of a couple of frames designed with Dietrich's CAD/CAM software and manufactured in Germany on a Hundegger CNC machine.

The hardest part of the job was getting my old-school, positively medieval framing partner Mike to come along for the ride. He possesses, in spades, what Cummings called above "the characteristic British reluctance to depart from time-honored custom." Despite this, he finally gave in. There just wasn't any other work on.

Very much like what receiving a Chelsea 111 from Sears must have seemed to a contractor 100 years earlier, the frames arrived on site, on time, in one trailer truck, with a set of construction drawings and, instead of the Chelsea's 22 gallons of paint and 750 lbs. of nails, a couple of big boxes of ¾-inch pegs. After all his initial outrage about machines, technology, the Devil and the Antichrist, when the frames were up Mike was able to see the potential of our making use of the new process, even considering all the design issues that would need working out. "Hey," he said, "we could do repair work and new-build at the same time."

With this in mind, I took on three jobs designed to use the CAD/CNC process with the knowledge and experience of a traditional English craftsman and the spirit of an enterprising American, all in the context of our two-man operation, rather than existing big-shop Hundegger machine operations. The first thing I did was talk to the CAD designer. I told him about the jobs I had lined up and asked him to consider himself as a draftsman rather than a designer. I would draw up the buildings specifying all of their dimensions and joint details. He would translate my drawings into nifty and very useful 3D models and create the all-important machine files. Two projects were historical reconstructions and one was a historical reinterpretation.

The Franklin project in Hertfordshire, England, was originally meant to be a repair job, but the client had the original house completely torn down "by accident" before we were able to do any repair work. We were able to pacify the irate conservation officer by proposing a historical reconstruction of the type of timber frame that might have been common to the region in the 17th century. Conservation and planning agreed. Fortunately a detailed survey had been done before the "accident," so we had some evidence to work from. I drew up a five-bay clasped purlin frame based on traditional design that was then redrawn using the CAD

All photos David Leviatin

program and then manufactured in Germany, using locally sourced German oak, on a Hundegger. We fitted and cut the braces and struts by hand back in England, in an attempt to maintain control of detail and to keep a proverbial hand in the game. To keep Mike happy, and because of access issues, we erected the frame with a pair of shear legs and a manual chain hoist (Figs. 1 and 2).

The Wedhampton project, another historical reconstruction, began when an architect sent me two photographs copied from a book and asked me if I could build something similar. The pictures were of the pergola in the baroque gardens of the late 17th-century palace Het Loo, at Apeldoorn in The Netherlands. The architect's client wanted a smaller version for his own garden in Wiltshire. Again I drew up the design and then had it redrawn in CAD and cut in Germany. The arches were made by joining nine sections in Germany. We cut the smaller window braces by hand and scribed them in place in our workshop in England (Fig. 3).

The Cambridge project also began with a photograph. This time the picture I received was of the President's Lodge at Queens' College, Cambridge University. The landscape designer wanted a pergola in the garden of the lodge that would visually connect the medieval timber frame of the lodge (the oldest building) on the river and the modern Erasmus building, while being overseen by the chapel standing between the two buildings. A historical reinterpretation, the open frame is meant to replicate the skeletal structure of the medieval lodge without its roof. My drawing of the frame was rendered by the landscape designer as a sketch and by the CAD draftsman as a 3D model and machine file. Again, the frame was machine-cut in Germany, the braces cut and scribed by hand in England (Figs. 4 and 5).

In combining aspects of traditional design and modern technology, I'm convinced of the value of bringing different systems of framing together, and even what some people in our community

Figs. 1 and 2 At top, hoisting a principal rafter reduced to fit collar seen just behind and to clasp a purlin yet to be offered. Above, three-quarter view of a frame that might have existed in Hertfordshire in the 17th century. Clasped purlins can be seen at gable end.

Fig. 3 Above, a vaulted pergola in Wedhampton inspired by another in the baroque gardens of Het Loo in The Netherlands.

Fig. 4 Above right, looking through a pergola in Cambridge toward the medieval timber frame of the President's Lodge at Queens' College, designed to appear as the ground floor framing of the lodge.

Fig. 5 At right, approach to the lodge before relandscaping and erection of the pergola.

would consider completely antithetical systems. This is clearly the way forward, keeping good design alive while maintaining control over new tools and technology. Call it *combined rule*—using the best parts of a number of different systems, being flexible and imaginative, the sort of thing journeymen on the tools have always done.

In 1837, in his famous Phi Beta Kappa addresss "The American Scholar" reflecting on American culture during the pivotal era after the Revolution and before the Civil War, Emerson observed:

> If there is any period one would desire to be born in, is it not the age of revolution; when the old and the new stand side by side, and admit of being compared; when the energies of all men are searched by fear and by hope; when the historic glories of the old, can be compensated by the rich possibilities of the new era? This time, like all times, is a very good one, if we but know what to do with it.

—David Leviatin

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All photos Paul Oatman

Fig. 1 Palmer-Barber-Bruns barn, Markleeville, California, ca. 1858, now dismantled.

Sierra Nevada Barn Evolution

THE Sierra Nevada Mountains of California, along with adjacent parts of Nevada, formed the last frontier of American timber framing brought west by immigrant American and European settlers. In the Far West of North America, in a 70-year period from the early 1850s until the 1920s, the Sierra Nevada Mountains were transformed from a wilderness into a landscape of towns, mines and thriving cattle ranches. A migration of some 300,000 people accompanied the Gold Rush in California, beginning in 1848, and the 1859 discovery of silver in the Comstock Lode in Nevada brought additional immigration. One result was a demand for beef that gave birth to agriculture in hundreds of valleys in the northern Sierra Nevada range. At times thousands of wagons and hundreds of thousands of head of cattle were on the road leading southwest from the Humboldt River to the Carson Valley in Nevada (Dangberg 1972). Along with this rapid development came the mass production of agricultural inventions that shaped the Sierra Nevada barn, originally built to house loose hay and provide stalls for work animals and dairy cows. The vast virgin forests of tall, straight trees made timber framing the most economical way to build; plank framing appears never to have been a consideration.

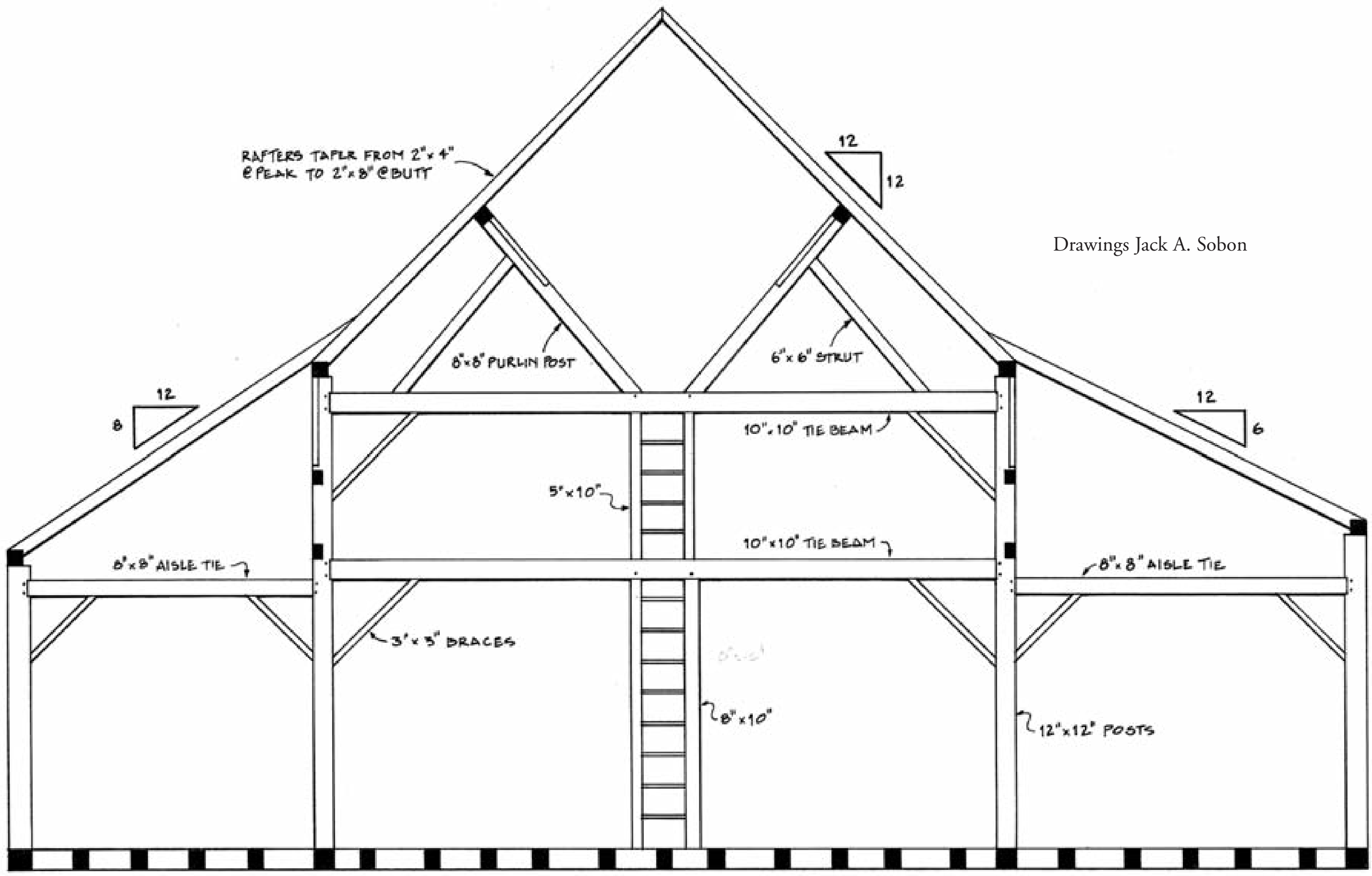
Over a thousand barns remain in the Sierras. So far as I have seen, all were laid out by the square rule method, which American carpenters apparently taught to European carpenters. The remarkable variety of scarf joints used (some unrecorded elsewhere[1]) is one indication of the diversity of immigrants in the valleys.

Different ethnic groups came to common ground in the shaping of these barns. The German or Englishman or Dutchman could build using the joints each preferred, yet still produce similar structures with central and side aisles and transverse driveways. Carpenters were in high demand in the Sierras: their wages were seven dollars a day, compared to four dollars a day for miners. The *History of the State of Nevada* lists 118 carpenters' shops in the year 1860, second in frequency only to teamsters, who numbered 131. There were only five lawyers (Angel 1881).

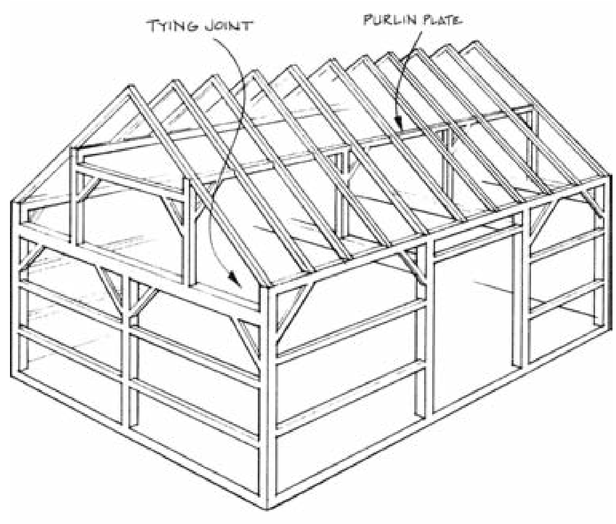
Sawmills sprouted like mushrooms, and even the earliest barns with hewn timbers have milled braces and common rafters. Lofts and floors are uncommon in the main aisle as hay was loaded from the ground to the peak of the roof. Side aisles might have wooden floors for cows or horses.

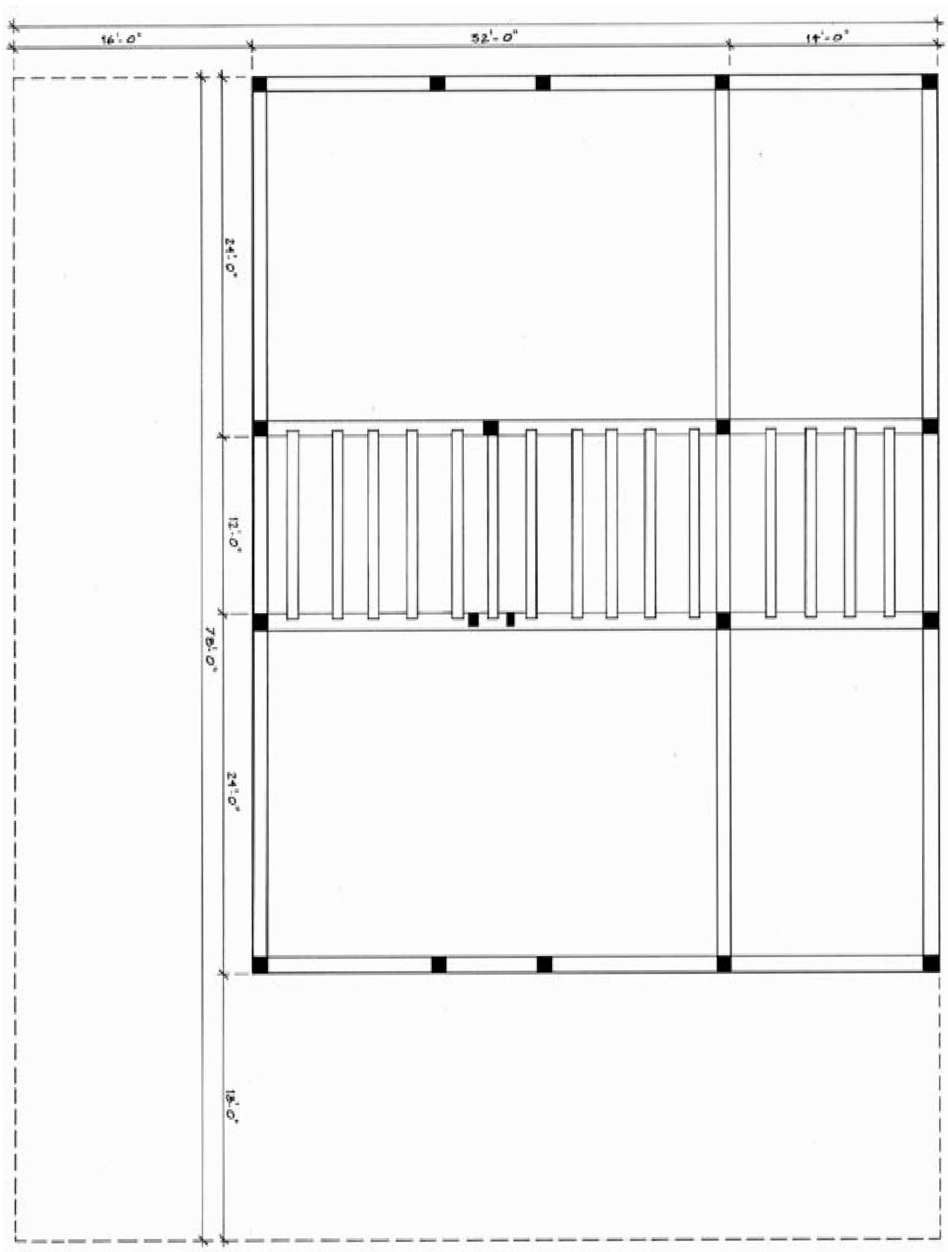
The early barns that predated the hay fork had transverse driveways opening on the eaves sides and 30- to 40-ft.-wide lengthwise aisles, which required one or two additional posts between the purlin posts to support the spanning tie beam. These early barns have much in common with the widely built 19th-century three-bay side entrance barn of New England and New York (Fig. 2). If one added side aisles to such a frame, the result would closely reflect the early Sierra Nevada barn.

TWO early Sierra barns found far apart reveal similar frameworks, yet a vast difference in timber sizing and spacing. The Palmer (later Barber, then Bruns) barn, ca. 1858 and now dismantled, stood just outside Nevada's Carson Valley in Markleeville, California (Fig. 1). The New England Ranch barn, ca. 1852, still stands near Quincy, 200 miles north, with a much more elaborate but functionally comparable core frame (Fig. 5 overleaf). The Palmer barn, apparently built at 46 ft. wide by 60 ft. long, with its additions ultimately measured 60 ft. wide, 78 ft. long and close to 40 ft. high. In the original plan, two 24-ft. bays flanked the transverse 12-ft. driveway to make up the 60-ft. length, and a lean-to with lapped



Drawings Jack A. Sobon





Figs. 2–4 Clockwise from above: mid-19th-century dropped-tie barn type of US Northeast; Palmer-Barber-Bruns barn cross-section showing side aisles applied as lean-tos (one apparently built simultaneously with central aisle); barn framing plan view at sills showing transverse driveway joisted with 8x12s and later side-aisle and gable outshot additions indicated by broken lines.

rafters was built against one side of the barn to add 14 ft. to the 32 ft. of width. Later a second 14-ft. side aisle and an 18-ft. outshot at one gable end were added, their roofs hipped at the corners to produce the gable-on-hip appearance of the completed structure (Figs. 3 and 4). Disassembly revealed the barn was originally built with a single side aisle. The newer side aisle sill was scarfed with a simple 6-in. lap joint whereas all other sill joints in the barn were stop-splayed scarf joints. Timbers were marked "Dutch Valley," an early name for the Diamond Valley where the barn stood, suggesting local fabrication.

5

6

A good Timber Splice.—It is worth while to know how to make a neat and firm splice without nails, iron bands, or any other such things. The one here figured comes easily apart, on driving out the rectangular bar or pin in the centre. The locking ends are alike in shape, which is distinctly indicated in the engraving by the light and dotted lines of the upper piece.

7a, 7b

The New England Ranch barn near Quincy, today a horse-boarding facility 64 ft. wide by 62 ft. long at its core, has a different overall look, with its gable-on-hip roof and extensive outshots and overhangs (Fig. 5). But again the barn has two 24-ft. bays flanking the transverse driveway, at 14 ft. a little wider than the Palmer's (Figs. 6 and 8). All posts and plates including the purlin plates are hewn 12x12s. As far as I know, this is the only barn in the country recorded with double canted purlin posts, complete with double counter-bracing. Indeed, the 2x4 common rafters only span 8 ft. Even the aisle ties carry purlin plates (Figs. 8 and 9). This barn was evidently built to last.

The barn also includes a scarf joint, unrecorded elsewhere, that was pictured in the 1864 *American Agriculturist*, a copy of which was in my father's book collection (Fig. 7). I had browsed though it for years, and now to find this joint in use seemed preordained.

Fig. 5 At top, New England Ranch barn, Quincy, California, ca. 1852, with integrated side aisles and original gable outshot, to which a further lean-to was later added along with broad overhangs there and at the side aisles.

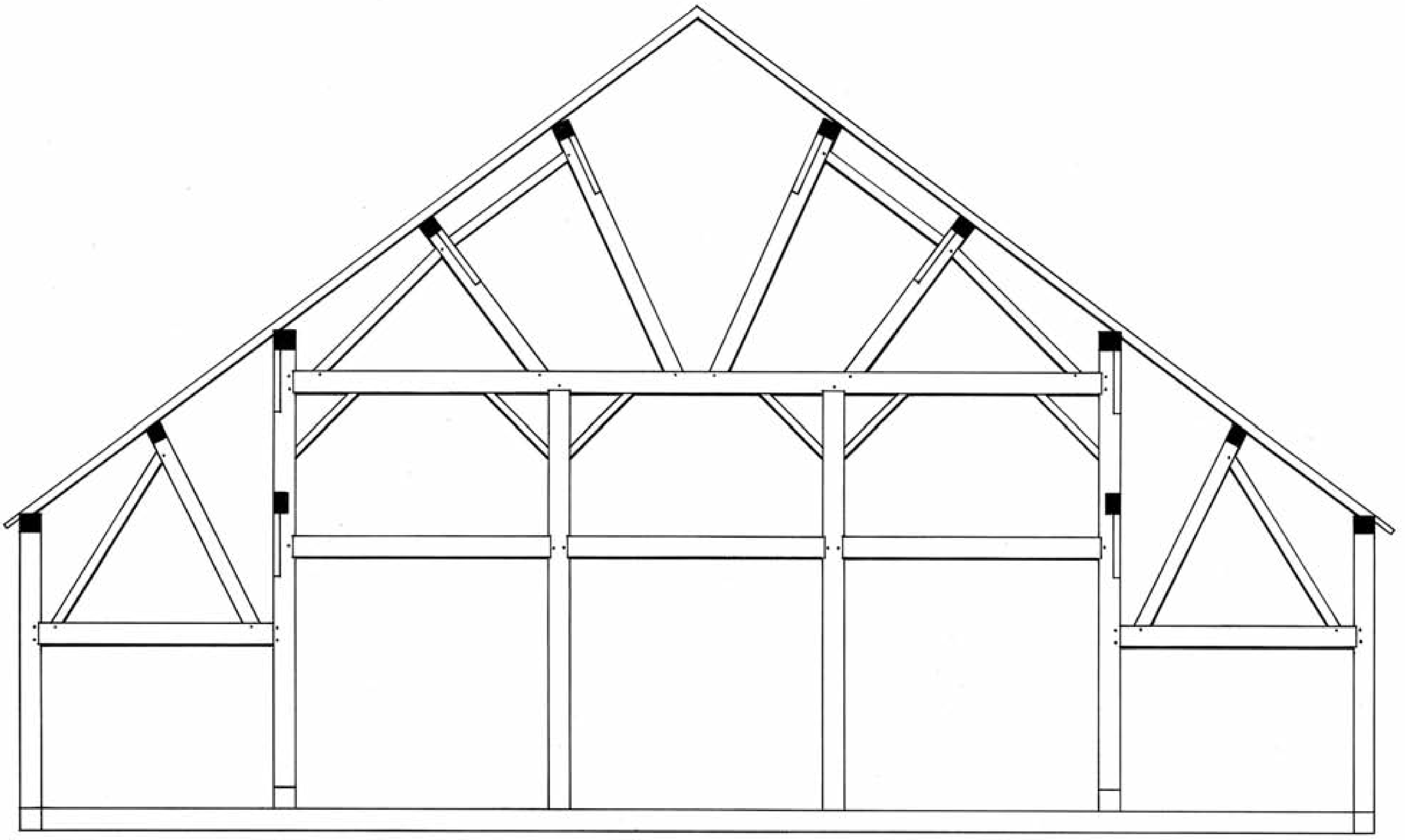
Fig. 6 Above left, array of struts and purlin posts in typical bent.

Fig. 7 Above right, (a) unusual scarf joint published in 1864, and (b) an apparent example in this barn cut some years earlier.

Fig. 8 Facing page upper, view of driveway bay showing tie beam and rear outshot roof framing.

Fig. 9 Facing page lower, bent elevation of New England Ranch barn, 64 ft. wide. Most principal timbers are hewn 12x12s.

8



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Jack A. Sobon

Fig. 10 At top left, Gansberg barn, Woodsford, California, ca. 1910. Partial view of central aisle and one side aisle. Hewn Ponderosa pine. Note cut sill (for tractor passage) and empty brace mortise.

Fig. 11 At top right, Gansberg barn, about 50x80 ft., exterior view,

Fig. 12 Above left, Goss barn, Sierraville, California, ca. 1880–1900, central aisle with loader. Mostly sawn. mixed species.

Fig. 13 Above right, Goss barn exterior, stretching some 100 ft. in length with additions.

Fig. 14 Facing page, Gansberg barn bent elevation (a) and plan view (b). Original central aisle sills now removed for tractor passage.

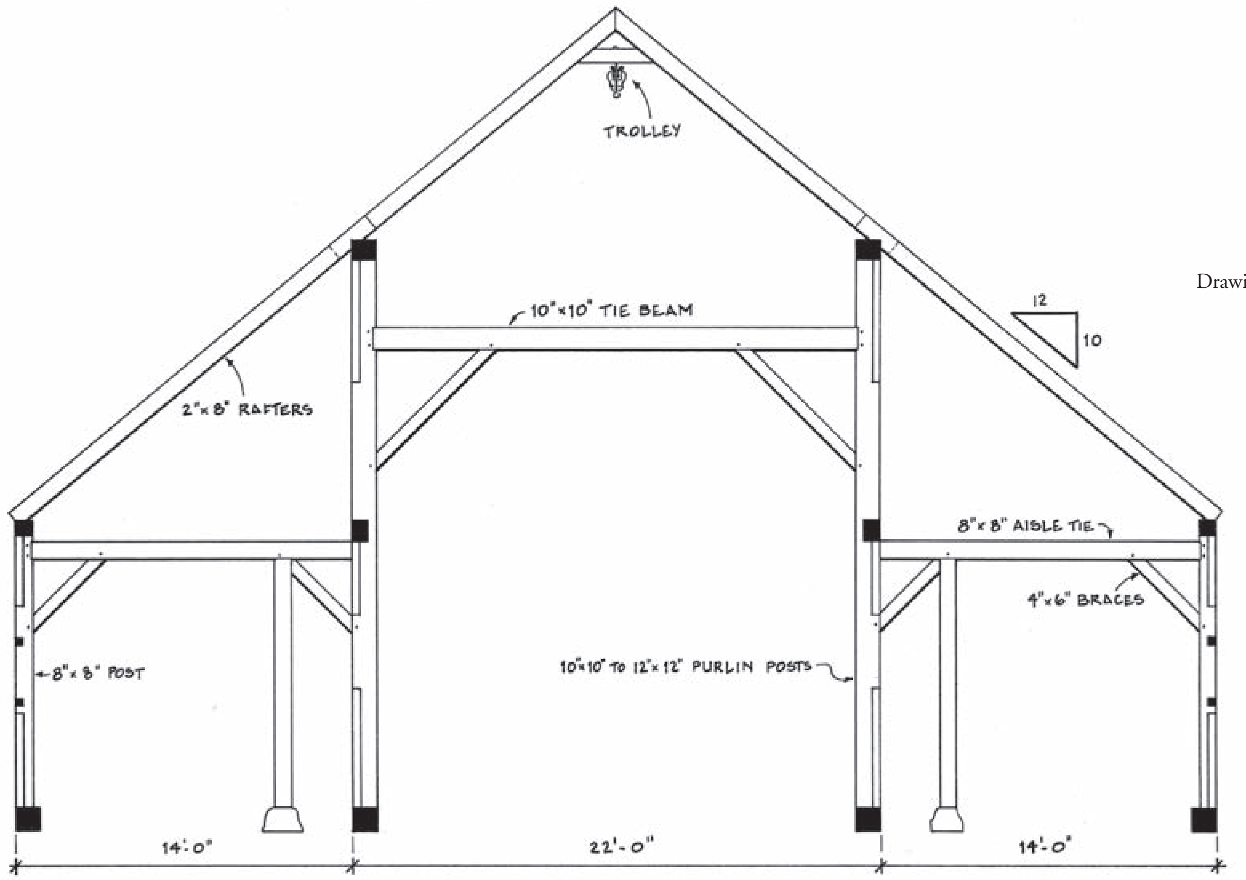
THE invention of the hay fork in the mid-1860s and the hay track and trolley system a few years later altered the shape and framing of the American barn. William Louden of Iowa is credited with the first patent for a hay trolley in 1867, but it took some years for it to catch on. "At that time he manufactured his devices on a farm near Fairfield. . . . Farmers were so skeptical that he could sell the hay carriers only by installing them and waiting until they had been successful through a seasons work before he received pay for them" (*Agricultural Engineering* 1921).

After the advent of the hay fork and trolley, the Sierra barn took a form more related to a Dutch barn. Since hay could now be unloaded from wagons parked outside of the barn, a driveway was no longer necessary, and gable entries became common. (One can usually date a retrofitted barn because the tie beam has been cut from its tenons and lowered to accommodate the trolley.) Side aisles remained the same and the main aisle became narrower, in the range of 20 to 28 ft., so that posts were unnecessary under the tie beam. The main aisle then was clear from the ground to the peak, the tie beams offering the only obstructions for loading loose hay. The barns also took a more elongated rectangular shape, with four to ten bays each spanning 12 to 18 ft. The transverse drive bay disappeared since the barn now offered gable-end center-aisle entries for wagons and side-aisle end entries for animals, and a large opening above the tie beams in the gable for lifting hay.

Although face-and-edge square rule layout seems to have been the norm for the transverse section timbers, centerline layout was used for the tall posts, perhaps because most had joinery faces on opposite sides and to ensure that curvature, likely with such long members, would not create problems with longitudinal joinery.

The Gansberg barn in Woodsford (Figs. 10, 11 and 14) and the Goss Barn in Sierraville (Figs. 12 and 13) are good examples of the impact of the hay carrier. In the latter case, one barn was built onto the end of another, yielding a barn over 100 ft. long with the same three-aisle plan. In the next article, we will take up the class of long-braced barns found north of the Sierra Valley. —Paul Oatman

Paul Oatman (pauloatman.com) is a builder in Pioneer, California, who researches timber framing in the US Far West. With William Hurley of Dos Osos Timber Works (Los Osos, California), he is preparing to launch the website cnbarn.org for news and information on California and Nevada barns. This is the first of two articles.



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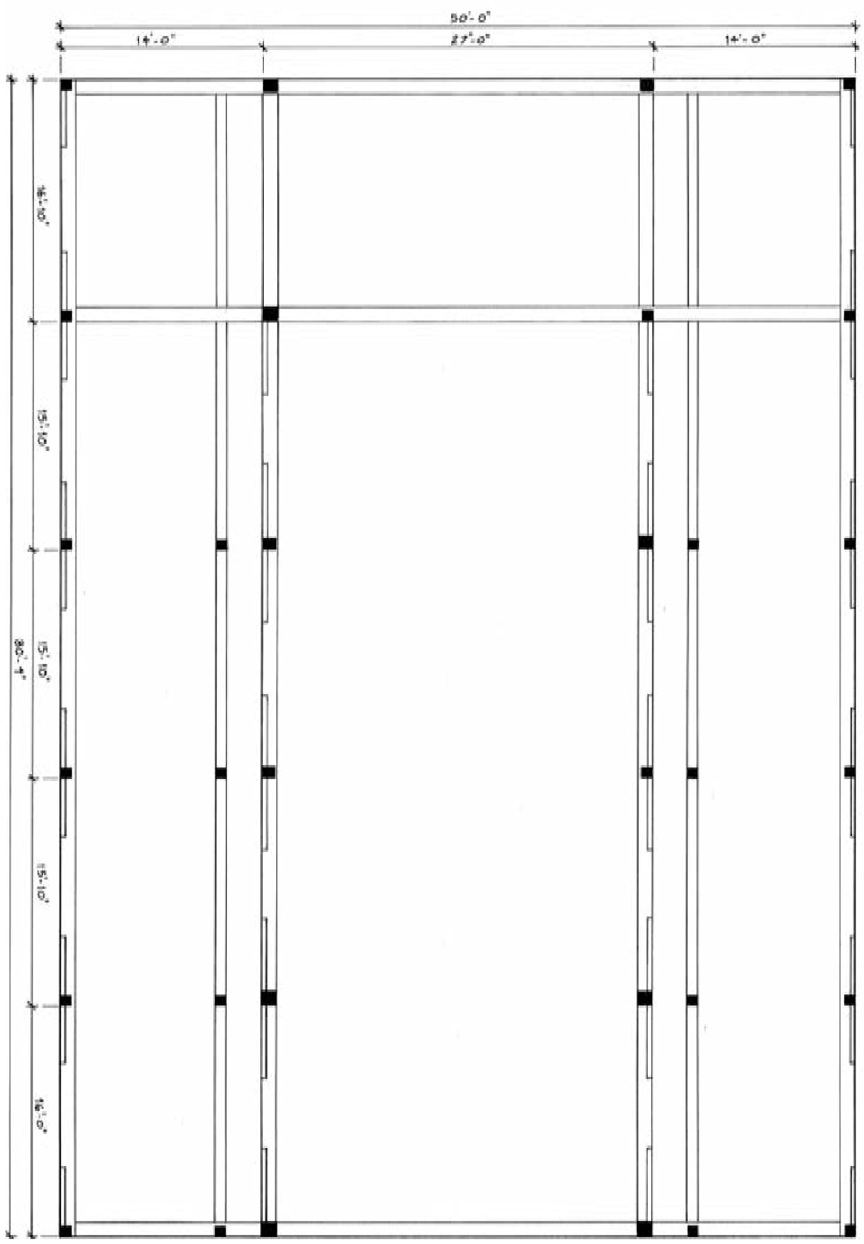

14a, 14b

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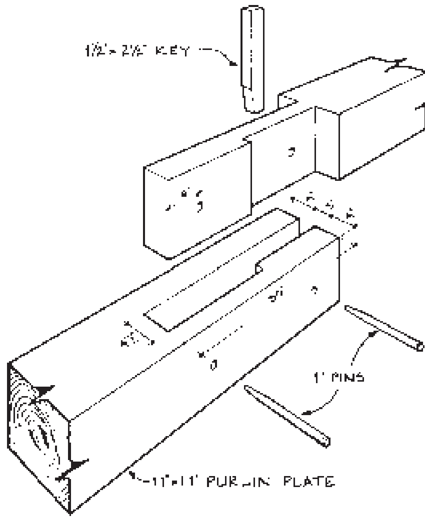
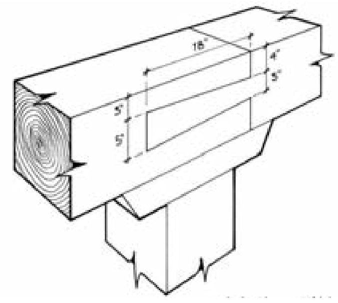
[1]Scarf joints found in Genoa, Nevada (upper), and Carson Valley, Nevada (lower), unrecorded elsewhere in the US.





Covered Bridge Truss Types

THIS journal has from time to time detailed some of the major truss types used in covered bridges. It will now be useful to survey the entire field to describe which trusses are used and where (a map is provided on page 21). The standard database is the 2009 edition of the *World Guide to Covered Bridges*, but many of its truss descriptions are fanciful, and the other compilations based on it repeat the same problems. This article is based on the author's own experience in visiting every covered bridge in North America between 1966 and 1977.

Several interesting covered bridges have been built since Milton S. Graton (1908–1994) revived the art in the 1960s, but for the purposes of this survey we will look only at the covered bridges from the historical time period, when they were built for simple economy only, with no thought of sentiment. This means for New England, before 1930; for the rest of the US east of the Rockies, before 1945; for the West and Canada, before 1960. The US has 672 covered bridges from the historical time period, while Canada has 143, for a total of 815 in North America. Of these, perhaps half are in something like original condition, while the others have seen major modifications in recent years.

The trusses are arranged in chronological order of their development, except that the types with only a few surviving examples are grouped at the end.

The KINGPOST TRUSS traces back to medieval Europe, and is familiar from roof frames. It has been widely used for bridges as well, but most of them were so short that they were never covered and have long since been replaced with culverts. The US still has 21 covered kingpost truss bridges scattered over a wide area, with a concentration in southwestern Pennsylvania. Canada has only one, but there are several noncovered kingposts, mainly in New Brunswick (Fig. 1).

The kingposts are mostly framed as true trusses, that is, the braces are fixed to the chords, so that the outward thrust is resolved as tension in the bottom chord; there is no top chord. Some noncovered examples foot the braces directly on the abutments, in which case there is no chord at all and the bridge is not really a truss. Late kingposts often use a steel rod instead of a timber post.

The QUEENPOST TRUSS also goes back to Europe, and has been used for roof frames. It is more common in covered bridges than the kingpost, with 70 of them distributed across the US. Examples longer than 50 ft. commonly have subpanel bracing, often in the form of little kingpost trusses inserted in the panels, and this gives opportunity for intermediate floor support (Fig. 2). The queenpost truss has a top chord only in the center panel, although engineers often conceptualize the end braces as part of the chord function. Like kingpost trusses, they require additional roof framing if fully covered. Noncovered queenposts were once common enough on American roads, the most famous probably being those over the Delaware Canal along the eastern edge of Pennsylvania, most of which have been replaced with non-functional replicas.

The more stoutly built queenpost trusses pass their posts through a two-part bottom chord, but examples exist in which the bottom chord is one-part with the posts attached by various means; this is common if steel rods are used instead of timber posts.

There are also eight covered examples in the US of what might be called an expanded queenpost truss, plus one in Canada. These are bridges over 80-ft.-span with an elongated center panel filled with other types of trussing. A prominent example is Green Sergeants bridge, the last covered bridge in New Jersey, which has four small Howe truss panels in the center of what is otherwise a very long queenpost frame.

The MULTIPLE KINGPOST TRUSS completes the roster of the medieval trusses. The US has 76 of them, and there are two in Canada. They are widely distributed, with concentrations in southern and eastern Ohio, central Pennsylvania, central Vermont, and adjacent west-central New Hampshire. There are numerous framing variations. Usually they have two-part chords both top and bottom, with the posts passing through and notched into each half (Fig. 3). Some however have one-part top chords, with the posts mortised in, like a Burr truss. Usually these have additional bracing sandwiching the trusses, in either queenpost or kingpost form; they are found in regions where the Burr truss is used, for bridges whose span is too short to require an arch (Fig. 4).

All photos Joseph D. Conwill

Fig. 1 Kingpost bridge at Parkindale, New Brunswick, with footed braces on the abutments instead of the chord, and so not a true truss. Note steel rod instead of timber kingpost and shingles on the braces to prolong the life of the noncovered bridge.

Fig. 2 At right, top, Moxley bridge in Chelsea, Vermont (1883), 56-ft. span, with one-part bottom chord, unseen below the floor. Posts are attached to chord by iron dogs and hangers, visible in photo near the floor.

Fig. 3 At right, middle, multiple kingpost truss at South Randolph, Vermont (1904), 52-ft. span. Note two-part top chord.

Fig. 4 At right, bottom, the 71-ft. span Kochenderfer bridge in Perry County, Pennsylvania (1919). The multiple kingpost truss often has a one-part top chord if it also has supplemental bracing. If this bridge had been longer, probably it would have been a Burr truss.

Fig. 5 Pomeroy bridge in Juniata County, Pennsylvania (1902), is a two-span Burr truss and at 278 ft. the longest covered bridge in the state.

Fig. 6 Bridge over the Delaware Canal at Uhlerstown, span 110 ft. Most regions of Pennsylvania used the Bur

Braces in central Vermont and western New Hampshire are placed at a higher angle than elsewhere, probably because of the influence of prominent local builder James F. Tasker. In south-eastern Ohio, builders sometimes hung the floor beams below the bottom chord, using a heavy iron strap that passed between the two chord halves and looped around a large wooden peg that straddled the chord on top. The San Toy bridge in Morgan County mortised the floor beams into the relish on the post bottoms, not the strongest nor the most secure method, but interesting for variety. Meanwhile in Columbiana County, builders mortised the overhead tie beams into the posts below the top chord, which pushed the brace-post joint to an unusually low position.

In eastern Ohio the multiple kingpost truss was sometimes known as the Buckingham truss, after the builder of the much-admired 1832 Y bridge at Zanesville. This bridge had doubled posts and braces, and the doubled form was sometimes used elsewhere in Ohio and in Kentucky.

The BURR TRUSS was described in TF 78, pp. 4–11. Patented by Theodore Burr in 1817, it consists of a multiple kingpost truss upon which is superimposed a timber arch (Fig. 5). The top chords of the truss are usually one-part, with the posts mortised into the lower face and pinned with two treenails. The treatment seems light, but the arches were expected to carry much of the load. Two-part top chords were the norm for Burr trusses in the upper South, and the Kennedy family also used them in Indiana. At present there are 190 historic covered Burr trusses in the US, plus four examples of a variant in New Brunswick. It is common in much of Pennsylvania, parts of Indiana, and northern Vermont, with occasional examples elsewhere, except for the West. (For an excellent and clearly written discussion of the behavior of the Burr arch-truss combination, see engineer Rachel Sangree's report in the *Historic American Engineering Record* MD-174, "Gilpin's Falls Covered Bridge," available online through the Library of Congress. The 2009 *World Guide to Covered Bridges* is especially confused as regards Burr truss identification.)

The TOWN LATTICE TRUSS, patented by Ithiel Town in 1820, was the first attempt to go modern (those trusses already described having made use of traditional joinery). It is still all timber, but composed entirely of plank pinned together flat with large treenails. Lattice web joints often have two treenails arranged vertically, but variants exist; chord joints have three or four (Fig. 6). There are no timbers notched together, nor any mortise and tenon connections in the truss, other than in the lateral bracing. Town is chiefly remembered as an architect and as one of the major proponents of the Greek Revival style, but he was so proud of his bridge truss that it is mentioned in the first line of the epitaph on his gravestone.

Writers often state that the Town lattice truss "could be built by ordinary carpenters," but it still required considerable skill in

Fig. 7 The floodplains of southern rivers and creeks often required long raised approaches to meet the bridge, here Red Oak Creek bridge (ca. 1840, 127 ft.) in Meriwether County, Georgia.

wn, Pennsylvania (1856, not 1832 as often stated), Burr, but Bucks County preferred the Town lattice.

Fig. 8 Colonization bridge near Rochebaucourt in the Abitibi region of northwestern Québec (1942) spans 118 ft. It still carries the traffic of a numbered provincial highway.

layout, especially when camber is considered, as anyone who has even attempted a small model of it can attest. Plank size was typically 3x10 throughout, but there is local variation. Skillful builders such as Nichols Powers (see page 22ff.) increased the plank size in the bottom chords, and took care to use long chord sticks to minimize splices. Usually the truss has two sets of chords both top and bottom, but examples exist with only one, and a regional variant common in New York has the secondary chords only on the bottom.

Most bridge trusses resolve the stresses on a relatively small area of the bottom chord, at the end of the last panel. The Town truss is a uniform lattice with no posts and no panels. It resolves the stresses on a larger area covering several feet at the ends of the bridge. It therefore uses longer abutment space than other trusses such as the Burr. Long bed timbers are also helpful. New York has a regional variant using fanlike planks at the ends, apparently in an attempt to resolve the stresses on a shorter area.

In the South, Town lattice trusses were often built on narrow piers instead of abutments, with a small length of the truss cantilevered past the pier, and long bed timbers for additional support. This may have been due simply to the topography of southern rivers, which often have shallow banks and thus large floodplains that cannot safely be interrupted with large abutments and fill behind them (Fig. 7). Ithiel Town built some early prototypes in the Carolinas, and it appears that he used this type of pier himself.

Town patented a revised version of his truss in 1835, which had a doubled lattice. It was mainly used on railroads, and four examples still exist in New Hampshire and Vermont, though none still carries trains. On occasion it found use for highway bridges, if wide two-lane bridges were desired without a center truss dividing the lanes. There is widespread misunderstanding that the doubled Town lattice was developed by T. Willis Pratt, but this is untrue, and the frequently encountered designation "Town-Pratt" is incorrect.

Bela J. Fletcher of New Hampshire developed a local variant in the 1850s known as the squared-timber lattice, or lock lattice. Instead of flat planks, it used 6x8 timbers notched together at the joints, and held by a single bolt instead of a pair of treenails. One example remains—the longest historical covered bridge in the US, over the Connecticut River in two spans totaling 460 ft., between Cornish, New Hampshire, and Windsor, Vermont. The lock lattice was never more than a minor regional style, but it has received disproportionate attention in histories because of a widely circulated but false idea that Ithiel Town held a patent on it.

The US still has 111 Town lattice trusses, making this the second-most popular kind of covered bridge after the Burr. They are common in central New England, New York, and the South, also in scattered other areas including Bucks County, Pennsylvania, the Western Reserve region of Ohio, and Madison County, Iowa. Town lattices have occasionally been adapted as roof trusses, and those in the 1832 First Presbyterian Church of Fayetteville, North Carolina, were designed by Ithiel Town himself.

We have no record of Town lattices on the West Coast, but Henry Grow used the plan for at least one noncovered wooden bridge in Utah. Local histories say that he used the Remington patent, another lattice design that in fact involved a form of cantilevered construction, but so far as can be determined from photographs, he really used the Town lattice. Grow also adapted the lattice in a curved form for the remarkable project of supporting the dome roof of the Mormon Tabernacle in Salt Lake City.

Québec has 76 Town lattices, of which a few are of the traditional type, but most are a later modification known as the colonization bridge. This variant was designed around 1890 by engineers with the provincial Department of Colonization for construction by the labor of settlers in new regions. Here is perhaps the only covered bridge type which was really designed for amateurs. In place of treenails, the colonization bridge used large spikes; the lattice plank size was reduced, so posts were added every 8 ft. for stiffness. Since metal spikes have a much smaller bearing surface than large treenails, they tend to cut into the wood, causing many of the bridges to sag. Covered colonization bridges were built into the mid-1950s, and despite their seeming skimpiness they have held up surprisingly well over the years (Fig. 8).

Fig. 9 Robyville bridge, Corinth, Maine (1876), span 97 ft., is very close to the Long truss patent, except that the floor has been replaced with steel beams in recent years.

The LONG TRUSS, patented by Lt. Col. Stephen H. Long in 1830, was described in TF 87, pp. 4–5. It was a new design with a new concept, namely prestressing the truss so that it would not deflect under load. But in joinery details it was a return to tradition, with every joint requiring custom framing work (Fig. 9). There are ten examples of the Long truss in existence, but many show some departure from the true original patent type.

The PADDLEFORD TRUSS (Fig. 10) was another new design relying on traditional joinery, and in fact it is probably the most intricate covered bridge truss to frame; see TF 75, pp. 12–15. The truss was never patented. It was long thought that Peter Paddleford developed it in the early 1840s, but recent research shows that he used it as early as 1834. The truss was very popular from Orleans County, Vermont, through Oxford County, Maine, and it appears that there may once have been an outlying example in Marysville, New Brunswick. Twenty-one examples still exist.

The HOWE TRUSS, on the other hand, was another attempt to do away with traditional joinery. Patented by William Howe in 1840, it resembled the Long truss in its panel layout, but instead of timber posts it had iron rods held by bolts (Fig. 11). The braces joined the chords on angle blocks, usually of iron although late examples sometimes used wood. The Howe truss was found everywhere on railroads. For highways it was rather rare in New England, but common across Ohio and Indiana, and especially in the West. The US has 103 covered Howe trusses, and there are 58 in Canada, which also has many examples of noncovered Howe trusses. Economic conditions in the remoter parts of 20th-century Oregon brought about a surprising revival of traditional framing in the construction of the Howe truss; see TF 85, pp. 20–25.

The PRATT TRUSS, patented in 1844 by T. Willis Pratt, was used very little for covered bridges, but should be mentioned here because from its timber beginnings it developed into the most widespread steel truss form. It was a Howe truss with the function of the members reversed: timber posts were in compression, and iron diagonals were in tension. The purest surviving example, the Sulphite Railroad bridge near Franklin, New Hampshire, was seriously damaged by arson in 1980 and the frame still stands uncovered. In its

Fig. 10 Mechanic Street bridge over the Israel River in Lancaster, New Hampshire (1862), with a 94-ft. span, a typical Paddleford truss.

Fig. 11 The former Wolf bridge over the Spoon River in Knox County, Illinois (1874), span 106 ft., was a classic example of the Howe truss.

metamorphosis to an all-steel form, the Pratt truss developed a modified configuration in its two end panels. This form in turn was sometimes built for reasons of economy in combined timber and metal, nearly always noncovered. One of these survives (just barely) near Carbondale, Colorado, and there are three remnants in Virginia. Two other more fortunate examples were later covered for protection, and are well preserved in California.

The SMITH TRUSS, patented in 1867 and 1869 by Robert W. Smith, was the last major entry in the timber-truss field. It came just as iron was becoming popular for bridges, but timber was still cheaper except for very long spans, and Smith made the most of this economy. The Ashtabula Disaster of 1876, in which an iron railroad bridge in Ohio collapsed with much loss of life, also brought renewed interest in timber trusses.

The Smith truss was all timber except for bolts, and the joints were notched together, with no elaborate hardware (Fig. 12). The method of building was far from traditional, however. Trusses were generally prefabricated at the Smith Bridge Company yards in Toledo, and shipped to the site. The company itself competed for contracts and found local people for erection; sometimes instead local builders got contracts, and bought the parts from the company. It was also possible to buy plans and cut the timbers yourself, but this seems to have been less common. The truss design involved a series of superimposed *W*s, the number of web planes varying from one to three depending on the length of the span. The angle of the web members varied, and there was a distinctive end-post treatment.

Smith trusses were widely built in Ohio and Indiana, and also on the West Coast through two licensees, the Pacific Bridge Company, and A. S. Miller & Sons. Pacific Bridge had a yard in San Francisco for prefabricating the bridge parts. Twenty-two Smith trusses remain, although only one of these is in the West. No Smith trusses are known to have been built in New England, New York or eastern Pennsylvania, where the older traditional timber trusses continued in use. This may have been due to conservatism on the part of local officials, but they were receptive enough to the overtures of Berlin Iron Bridge and other purveyors of metal trusses, so it may simply be that Smith Bridge agents never penetrated that far from their home base in Ohio.

Fig. 12 Cataract Falls, Indiana, has this fine example of the Smith truss (1876), with a 150-ft. span.

IN addition to the widely-built designs described above, covered bridges occasionally use other designs, some of which are important because they once were more widespread, or because they offer interesting theoretical issues.

The arch is a major bridge type in other materials, but because it is difficult to stabilize an arch in timber, it is rarely used alone. Timothy Palmer, builder of America's first known covered bridge, which opened at Philadelphia in 1805, used a trussed arch, although there is some discussion as to whether it might really have been an arched truss. In a trussed arch, both the upper and lower arch ribs are in compression, delivering outward thrust to the abutments; the trussing merely provides stiffening. In an arched truss, the lower rib is a bottom chord in tension, and all of the stresses are self-contained. From drawings it appears that Palmer's bridge was really a trussed arch, but some have questioned the accuracy of these drawings. Be that as it may, America still has two examples of an arched truss, a multiple kingpost design with radically arched chords. The design is historically interesting even if it does not trace back to Palmer (Figs. 13 and 14).

Vermont has four covered examples of a tied arch, in which laminated arches foot on a bottom chord instead of on the abutments. One of these, in Charlotte, is rather crude and has no other bracing at all; it was also unsuccessful, and has been supplemented by a kingpost truss since the 1940s. Three others, all in Windsor County, have stiffening trusswork under the arch (Fig. 15). The longest is the famed Lincoln bridge adjacent to US Route 4 at West Woodstock. At 136 ft., it has a full complement of Pratt-like bracing under the arch. Indeed, R. S. Allen and other historians have conceptualized it as a Pratt truss with an arched top chord. Giles County, Virginia, meanwhile has three examples of a segmented arch design, in which rectangular panels enclose straight segments that approximate an arch shape over the length of the bridge. Switzerland has a few bridges of this type, the most famous of which is at Monthey, but they have never been well publicized here in the US, and the unknown Virginia designer probably developed the form independently.

The HAUPT TRUSS, patented by Herman Haupt in 1839, was described as an "improved lattice," but it has posts, and resembles a series of multiple kingpost panels superimposed offset on one another. Haupt made major contributions to engineering theory and his books were widely circulated. His truss was in use from North Carolina through Maine, but it never gained a major regional following. Only one example survives, in North Carolina (Fig. 16). Two New England bridges superficially resemble the Haupt truss in having overlapping panel braces, but they have no historical connection to the patent and indeed one of them predates it by seven years.

The WARREN TRUSS has a complicated patent history, but the term is frequently used by metal-bridge historians to describe any truss which is a regular series of *W*s, either singly or superimposed on one another, with no or few posts. The Smith truss is sometimes described as a Warren variant, but its braces vary their angles. The design was always rare in timber, and only one example survives.

The CHILDS TRUSS was patented by Horace Childs in 1846, but the seven surviving examples date from several decades later, in Ohio. It resembles a multiple kingpost truss with iron tension counters inserted in the panels. Conceptually it is similar to the Paddleford truss, which also has tension counters, but they are timber. The Childs brothers, the Paddlefords, and Stephen Long were all from New Hampshire, and had connections by friendship and by marriage; the Childs brothers built the existing Rowell's bridge at West Hopkinton, New Hampshire, in 1853 using a design that closely resembles the Paddleford. These relationships would form a fruitful field for future historical research.

A frequency distribution map for all types appears in Fig. 17.

Figs. 13, 14 Humpback bridge near Covington, Virginia (1857), span 106 ft., uses a multiple kingpost truss with arched chords.

COVERED bridge design has led down many strange byways, fascinating for the antiquary, but perhaps less significant in the big picture. The McCallum truss, with patents in 1851, 1857 and 1859, was an attempt to provide prestressing for an inflexible bridge. It enjoyed some popularity with railroads, and one highway example still stands at Powerscourt, Québec. The Brown truss, patented in 1857, exists in two examples in Michigan; the 1870 Wheeler truss survives in one much rebuilt bridge in Kentucky; the inverted bowstring has two representatives in Ohio; five other Ohio bridges use the 1872 Partridge truss. A number of existing bridges defy any clear description at all, while other forms have disappeared completely. If nothing else they all testify to the fecundity of the human imagination, and the wonderful adaptability of timber design. —Joseph D. Conwill

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Fig. 15 Brownsville bridge, Windsor County, Vermont (date unknown), 45-ft. span, supported by a simple tied arch.

Fig. 16 Bunker Hill bridge (1895), 81-ft. span, Catawba County, North Carolina, the last Haupt truss in existence.

Fig. 17 Frequency distribution of covered bridge types in eastern US and Canada. Covered bridges in the West mainly use the Howe truss.

Blenheim Bridge, a Remembrance

All photos Jet Lowe, Historic American Buildings Survey, 2004

Fig. 1 The Blenheim bridge over the Schoharie Creek, North Blenheim, New York, 210-ft. clearspan, built 1855, destroyed 2011. It served road traffic until the 1930s, when it was supplanted by a steel bridge.

CALLING anything "the greatest" is usually meaningless since things can be great in different ways. Many cultures in the world have candidates for the most marvelous timber frame and any of them may excel in design, joinery, square footage, complexity or antiquity. The only way to get more concrete about this topic is to look at a timber frame's quantifiable ability to defy gravity and heavy loading over time. Here two forms spring to mind: tall steeples, towers and pagodas, and long-span wood-truss bridges.

From this point of view, the Blenheim bridge in North Blenheim, New York (Fig. 1), was probably the world's greatest surviving achievement in timber framing until its demise on August 28, 2011. It was pushed off its abutments by the waters of the flooded Schoharie Creek, reacting to the vast rainfall of Tropical Storm Irene, in particular to an unaccustomed surge of water released into the flood from a dam upstream. I visited the bridge many times and with Ben Brungraber took a busload of framers to it from the Guild's Troy conference in 1991. I urged many framers and engineers to visit and "worship at the shrine." It's unlikely that any framer will ever again construct an object this ambitious in timber.

Built in 1855 in a now-remote location in the beautiful Schoharie Valley, the "double-barreled" Blenheim bridge was framed with three trusses, the central one incorporating an arch, and was arguably the longest single-span wooden truss bridge in the world, its clearspan given by knowledgeable observers as 210 ft. abutment to abutment, with a 228-ft. truss length. (Some uncertainty arises because the abutments are concave, possibly as a result of long-term frost action. The 210-ft. measurement was taken at the bridge centerline.)

Blenheim was not the only long-span wooden bridge built in the 19th century. Theodore Burr's McCall's Ferry bridge near Lancaster, Pennsylvania (1815), extended 360 ft. in a single span but was lost to ice coming from far upstream on the Susquehanna a few years later. Louis Wernwag's "Colossus" of 1812 spanned 340 ft. in the clear over the Schuylkill River at Philadelphia and was lost to fire after 30 years. A great many other long spans were constructed but many could not make the grade. The 200-ft. Pulp Mill bridge over Otter Creek in Middlebury, Vermont (1855), was built in imitation of a very good 180-ft. double-barreled Burr Arch type built by John Johnson in Essex, Vermont, in 1825–27, but the Middlebury builder misunderstood the resolution of tension in the bottom chord joinery, as well as the height of truss needed, and the bridge had to be subdivided into three spans within a decade.

Other surviving long spans include the Cornish-Windsor bridge between those respective New Hampshire and Vermont towns, a timber lattice with two spans, each 204 ft. in the clear, which has needed substantial repairs at least twice to keep it cambered. The Bridgeport Covered bridge in California (1862) is a Warren truss with wooden diagonals and iron verticals, and spans 208 ft. abutment to abutment along one edge and 210 ft. along the other (abutment faces not parallel). About 40 miles south of North Blenheim, in Downsville, New York, stands a 174-ft. single-span modified Long Truss bridge, formerly near failure but recently restored under the engineering direction of the late, great David Fischetti.

As these examples indicate, other builders have pushed the limits of timber as a structural material, but none with so much success as Nichols Powers (1817–1897), Blenheim's designer and builder. Blenheim in 2011 appeared to be in almost perfect condition, with positive camber, neither racked nor bowed, almost all its original structure intact (not including boarding, flooring and roofing), no evidence of distress, easily carrying its own immense self-weight (probably between 450,000 and 500,000 lbs.) and the deep snows of the area that might lie on the roof. Always designed to carry heavy loads, the bridge was comissioned in 1855 because of the needs of numerous sawmills and tanneries to move their raw materials and products. As with most large wood-truss bridges, the load of vehicles, ancient or modern, that could fit in them was always modest compared to the self-weight. It was bypassed by a three-span steel bridge in 1932 because of difficulties with its approach geometry and the narrow width of the lanes. In 1973 the 20th-century covered bridge builders Milton Graton (1908–1994) and Arnold Graton did $2,920 worth of work on the bridge, mostly rebuilding chord and arch abutment bearings.

THE structure of Blenheim can be described as a double-posted, double-barreled, modified Long truss with an arch clasped by the posts of the center truss. There were three trusses, two on the outside 19 ft. in height and a central one rising to the ridge of the roof, 27 ft. tall. Each of the trusses had two parallel lines of posts and braces with a single counterbrace between. The central truss clasped an arch that sprang from the abutments a few feet below the bottom chord and rose to the ridge. What made the Blenheim truss not simply a multiple kingpost with clasped arch were the wedges at the top of the counterbraces, an important component of the patented Long truss (see p. 18 and TF 87), which allowed the truss to be prestressed and in theory vibrate less under dynamic loading (Fig. 2). We often associate counterbraces with tension members in wooden trusses, such as in a Paddleford truss (see p. 18 and TF 75), but in a Long truss they are meant to be compressed only and have no tensile connection.

The bottom and top chords were composed of four lines of 4x11 timber in mostly 40 ft. lengths, allowing three continuous and one jointed line in each panel, based upon 10 ft. center-to-center panel spacing. The chords dapped into and clasped the posts. The single bottom chord butt joint in each panel was given tension capacity by a pair of bolt-o'-lightning fishplates bolted across the joint (Fig. 4 overleaf). There appeared to be 56 of these complicated scarfs in the three bottom chords.

The central truss might carry almost twice the load of either outside truss, so it must be made much stronger. The 27-ft. height adds a lot of strength and particularly stiffness, just like a deeper joist, and this clasped arch is one of the few timber arches designed and detailed well enough to do much. Nichols Powers (a man with no formal education) knew that the height of the outer trusses was insufficient to give an arch enough height, so he put one only in the tall center truss, where the great span still makes even 32 ft. of height marginal for the arch. It was made extremely stiff and strong: three lines of stacked 10x11 timbers joined to each other by tight hardwood shear blocks and each lamina through-bolted at the post crossings (Figs. 5 and 6 overleaf). Clasping the arch between the posts interrupts most of the counterbraces, so they were segmented and had double tenons cut on their ends where they met the arch, and a wedge inserted within, to tighten them against the arch. It would take a brave engineer to untangle the forces and load paths operative in this center truss (I hope someone wants to try). One of the virtues of a double-barreled bridge is that the joists for each lane need be neither long nor large. A disadvantage is two dark, narrow lanes.

As the accompanying photos and drawings show, the interior of the Blenheim bridge was a beautiful complex gallery of trusswork, arch timbers and of course transverse bracing, tie beams and rafters (Figs. 2 and 3). To make matters more complicated and beautiful, Powers saw the forces acting on each part of the bridge so clearly that he sized many of the truss members according to load.

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Fig. 2 View of uppermost part of central truss, with clasped arch running just below ridge of bridge roof and showing wedged connections for lateral and transverse braces and truss counterbraces.

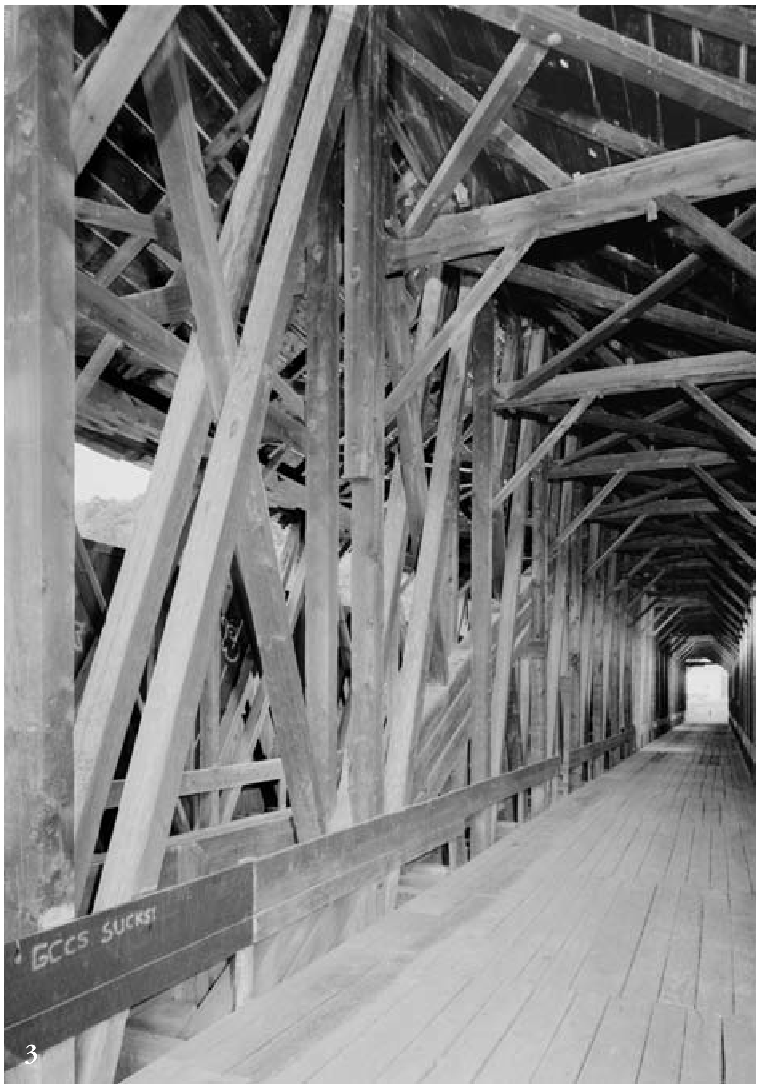

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Fig. 3 Prospect down one lane of double-barreled bridge from near the middle, with array of braces and counterbraces in central truss.

Beginning at the center kingpost, which has entasis, each pair of posts and braces gets slightly larger in dimension as they accumulate load and approach the abutment. This means that the layout of each panel is slightly different, with the braces and counterbraces varying in length as well as dimension, and even slightly in angle of intersection. (You can see why combining a planned variation in member sizing with the geometry required to camber the bridge, differing in each panel, means that even late-period large wooden bridges were among the last bastions of scribed joinery.)

The bridge has the appearance of modularity (an unlovely concept strangely beloved by moderns) but is not quite so. A note to myself from the 1990s, on the back of a handwritten sheet laying out the variation in post sizing, reminds me to record the panel spacing. My memory is that it varies as well, getting closer as one goes from center post to abutment. Unless at least three panels are intact, washed up in a cornfield downstream, no one will ever get to check this.

Decreasing panel spacing from the centerpoint of a bridge toward each end is a sophisticated design element that shortens and steepens the slope of the increasingly heavily loaded compression braces and puts these main brace intersections with the verticals more in line with the long axes of the posts, and thus less likely to bend them. Herman Haupt used this technique on his Sherman's Creek railroad bridge sometime before 1851.[1] Haupt was a pioneer of mathematical modeling of bridge trusses (see page 20). Could someone like Powers, having behind him a craft tradition, vast experience, an ability, perhaps instinctual, to envision load paths and their magnitude, and probably a very fertile three-dimensional imagination, arrive at the same design?

The overwhelming majority of the timber in this bridge was old-growth Eastern white pine, in large pieces, with white oak for blocks, wedges, fishplates and the lower segments of the arch where it made roadway and ground contact. Milton Graton thought the arch was spruce above the oak ends shown in Fig. 5 and it might have been. The only iron was in bolts and nails. There were no tension rods or straps in the trusses.

NICHOLS MONTGOMERY POWERS was born in Pittsford, Vermont, in 1817 and built his first bridge at age 19 years in that town. He owned a large farm in nearby Clarendon but was increasingly away from home during the 1840s and 1850s building larger bridges, often for railroads, putting him in contact with a wider range of truss types and engineering concepts. In 1855 he was called to North Blenheim and completed his masterpiece. Accounts from the time say he assembled the trusses on land, then dismantled and re-erected them on falsework over the river.

From Blenheim he and at least one of his sons went to Havre de Grace, Maryland, in 1866 to fabricate and eventually design large railroad bridges, some including draw spans, over rivers. His wife, who remained back in Clarendon, felt that she and the farm were being neglected and wrote to him so. Powers responded, "If you could see this work going ahead and the place I hold I think you would tell me to stay until the job was done. I am treated with more respect here in one day than I am in Clarendon in one year. . . . When I get the job done you may reckon on my staying to home after that."[2] Powers's complaint about Clarendon society falls under the principle "He can't be a genius because I knew his grandfather."

Powers died in 1897, but as late as 1880 built Brown's Bridge, a 112-ft. single-span Town lattice over the Cold River near his home in Rutland County, Vermont. As was the case for Blenheim, this bridge appears to be in perfect condition today. Its condition is so good that the Vermont Agency of Transportation's covered bridge study in the 1990s (which I was part of) chose it for live load testing. As usual, Powers's work exceeded all our expectations. The first live load test, allowing two state trucks weighing 42,000 lbs. combined to traverse the bridge close together, resulted in no measurable deflection from stretched strings. The test was rescheduled using more sophisticated dial gauges located on tripods. The resulting deflection was measurable only in tenths and hundredths of inches. (The strongest reactions of the bridge were in response to the rapid stopping of the heavy trucks at midspan.)

What is so good about Power's Cold River bridge, which is after all a lattice, generally a very flexible truss, subject to sag and thus rack and bow? The only unusual features I noticed were the careful use and placement of very long 32-ft. bottom chord material rather than the shorter stuff with many end joints so common in late period lattice trusses. Sizing for load is evident in chord dimensions (though not in the lattice). The bottommost chord is built up of 3x12s, the next above 3x11s, and the two upper chords are composed of 3x10s.

In a sophisticated refinement that only shows up occasionally in centuries of timber framing, Powers solved the dilemma of the failure of short relish, in this case tie beam relish where it laps over the top chord. Such failure vitiates the triangulation of the transverse knee braces between the tie beams and the secondary upper chord. Powers removed the short-grain lap relish and replaced it with firmly nailed-on blocks oriented with their grain perpendicular to that of the tie at each location. Keeping the system of tie beam, knee brace and chord working is not just protection against being racked by the wind. If the hollow bridge can be kept in a straight line, buckling failure under load can be further resisted.

Nichols Powers was fortunate to have a legacy that survived well beyond his lifetime, but his great masterpiece, the Blenheim bridge, is now gone. Though many people have thanked me recently for having urged them to visit Blenheim, probably none of us gave it the study it deserved, always reserving such research projects for another day.

In addition to near and distant bridges, in his Vermont hometown Powers built a gristmill, now a residence. "Although the Mill River reached an all-time flood level," one of the gristmill's current residents reported, "and although nine out of twelve primary supporting posts were torn away by the torrent, the architectural ingenuity of Nick Powers prevented [the mill] from coming down. I'm so glad I took the time to visit the Blenheim bridge a couple of years ago."

I think I will take the time to have a look at this gristmill.

—Jan Lewandoski

[1]Haupt, Herman. *General Theory of Bridge Construction*. New York, 1856, p. 219.

[2]Vermont Historical Society Library collections. VHS Ms-62, October 5, 1866. Powers is not merely enjoying respect but is being offered large sums of money for his continued supervision of the work. In addition, his son Charles is with him and wants to stay.

Fig. 4 View of bridge underpinnings. Quadripartite lower chords of trusses comprise mostly 40-ft. 4x11 timbers, with three chord lines continuous at any panel and one line butt-jointed but clasped by bolt-o'-lightning fishplates (one visible near top left of photo).

Fig. 5 Detail of keyed arch integrated in Long truss near one end of bridge. Lowest segments of three arch lines are white oak, upper segments of white pine or spruce. Counterbraces of truss are interrupted by arch and end-wedged to maintain bearing.

Fig. 6 One of three sheets of Historic American Buildings Survey drawings made in 1936, this one showing details of central truss. Remaining sheets (available at loc.gov/pictures/item/NY0745, along with more photos) show part side and end elevations and plan views of floor and roof framing.

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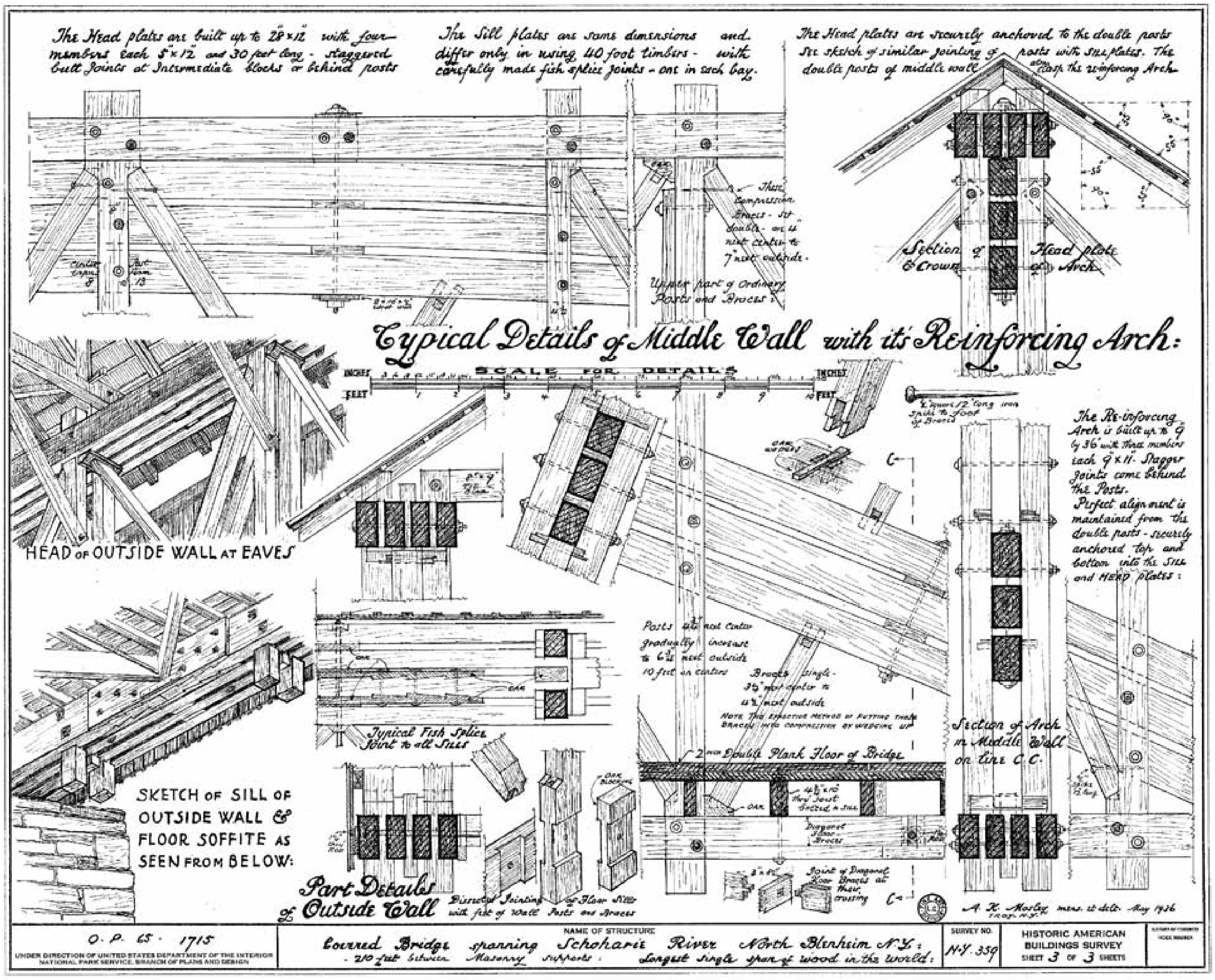

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A. K. Mosley, Historic American Buildings Survey

Bell Tower in the South Tyrol

THE province of Bolzano in the southern Tyrol of northeastern Italy is a region where most natural resources are under protection as national parks and local traditional architecture came from the north under Germanic influence, which continues in building design and a bilingual culture.

The recent bell tower at the church of Saint Michele at Saltusio (or Saltaus), a rural village of the town of San Martino in Bolzano's Passiria Valley (490m), is modern in technique and design but represents the quite new tendency of Italian architecture to rescue timber as a main building material and presiding spirit. In Italy, modernity has often been confused with innovation in its worst sense: to delete the past, which in reality is our main resource, not just one of several but the best.

Given the exposure of wooden structures in Bolzano to snow, frost, rain and sun, as well as great thermal excursions between night and day, summer and winter, the timber chosen was the local Alpine larch (*Larix decidua*). Winter cut at the right altitude (up to 1000m) and well dried to avoid deformations because of its high concentration of resins, larch promises high performance both in stiffness (modulus of elasticity can be above 15,000N/mm^2) and weather resistance without any need of chemical preservatives.

The main structure is simple and clear with a good balance between engineering and architectural needs. The four pillars of engineered (glulam) larch timber, 20cm thick by 150cm long by 23.6m high, support all the rest—walls, stairs, roof, bells. With a base of 3m square and a height of almost 24m, the overturning ratio is 8:1, and the pillars are locked to a steel plate fastened to another cast into the concrete foundation. There is no direct contact between larch and concrete, to avoid the possibility of stain or decay from standing water from snow melt or rain. The six wooden landings of the spiral steel staircase are designed to work as bracing, keeping the pillars locked into one solid structure without further framing. The walls are completed by horizontal larch louvers assembled behind the internal profile of the pillars.

The tower carries three bells, two at 170kg installed at a height of 20m and one at 260kg at a height of 23m. A maximum deformation at the top of the tower of 2cm was calculated under the forces of bells playing and of 10cm under wind pressure. It was imagined that deflection from the action of the bells playing might be exponentially increased during a windy day. Testing reported actual maximum deflections about ten times lower. The half-solid wall design with alternating timber and louvered freespace seems to work well as a windbreak, and it presumably contributed in no small part to the test results. The wall design also works to avoid effects of resonance.

To reduce building time and costs, the main frame of the tower was first assembled in the factory and then transported by truck to the site, where it was necessary only to fix it to the concrete foundation and then complete it with wall panels and the spiral stairs.

The minimal design endows modernity on the church but at the same time gives new force and character to local architectural history through the use of larch, and without conflict with the traditional landscape of vertical lines from coniferous forests and horizontal lines from rivers and valleys, well recalled respectively by the pillars and the louvers. The Saint Michele bell tower is a model to inspire what architecture might be: the noble art to continually reinvent the past, redesigning it, but never losing relationship with it.

—Thomas Allocca

Thomas Allocca (www.wooden-architecture.org) is a journalist and architectural designer in wood, in Frosinone (Lazio), Italy.

1

All photos Holzbau

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Figs. 1, 2 At top, St. Michele bell tower at Saltusio, Bolzano, Italy, designed by architect Walter Karl Dietl and built by Holzbau (Bressanone) in 2007. Above, box joint at roof, with mitered corner.

Figs. 3, 4 Facing page, detail top left, top of tower in transit, with steel box frames grouped for concentrated load of bells. Detail upper left, inside the tower looking down steel service stair.

Figs. 5–7 Facing page, starting from upper right, erection sequence.

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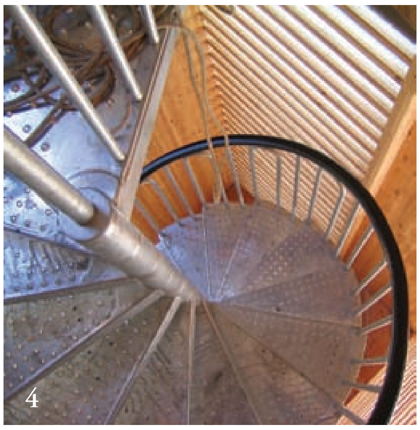

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