TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD
Number 122, December 2016

Charpentiers Sans Frontières

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NUMBER 122 DECEMBER 2016

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On the cover, Andres Uus wielding a Swedish carpenter's axe on large French oak log, finish-hewing one face of new sill for barn dendro-dated to 1491 in Aclou (Eure), France, south of Rouen in Normandy. Photo by Evan Sachs. On the back cover, scribing wall braces into a layup of principal timbers for reconstruction of barn's gable end. In background, original gable laid out with component studs. Ground-plan laid out in strings is full-scale drawing of original. Photo by Andy Hyde.

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Printed on Anthem Plus, an FSC® certified paper

TIMBER FRAMING (ISSN 1061-9860) is published quarterly by the Timber Framers Guild, 1106 Harris Avenue, Bellingham, WA 98225. Subscription $45 annually or by membership in the Guild. Periodicals postage paid at Becket, MA 01223 and additional mailing offices. POSTMASTER: Send address changes to Timber Framers Guild, 1106 Harris Avenue, Bellingham, WA 98225.

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

BOOKS

Ancient Roof Frames

Hoffsummer, Patrick, ed., *Roof Frames from the XIth to the XIXth Centuries: Typology and Evolution in Northern France and Belgium.* Brepols Publishing, Turnhout, Belgium, 2010. 8⅝ x11 in., 375 pp., copiously illustrated. Softcover, $118 through ISD, Bristol, Ct.

RECENTLY I was asked to examine the Gold Brook covered bridge in Stowe, Vermont, and establish a replacement cost for insurance purposes. The unusual claim made for its date interests covered bridge researchers. Gold Brook is a Howe truss road bridge, 49 ft. long and in a remote location, and reported in town records to have been built in 1844. The first Howe truss, a patented type, was built in Massachusetts in 1840 for the express purpose of carrying the great load of railroad trains over long spans. Is it likely it would have shown up so soon at a small rural crossing? Maybe.

On examining the Gold Brook bridge I observed that all of the timber was circular sawn with the exception of some new bandsawn repair material and the hewn bottom chords, single stick 12x12s of spruce. Circular sawing of large timber doesn't show up in structures in northern New England, and much of anywhere else in the US as far as I know, until around the time of the Civil War. The bridge also has a laminated top chord composed of four 2x10s laid flatwise, bolted together, not a common assembly for rural Vermont framers in 1844, but not necessarily unknown. Establishing replacement cost was easy. Establishing a confident date isn't, particularly when everything else original to the bridge —timber, joinery, ironwork, blocking for braces and rods, bolts and nails—could be common to either 1840 or 1860–70. A smallish number of persons care about this dating, but some of them care a lot. I might tell them that I doubt the 1844 attribution because of the circular sawing, but I'm reluctant to date anything on the basis of one attribute alone.

Rather, I look for complementary corroboration from dendrochronology, documentation, materials and their method of conversion, layout systems, carpenter's marks, and type of bolts, nails and ironwork. Perhaps more reading of Stowe's selectboard minutes will reveal a new bridge being proposed for the site in 1867. It's possible that a nearby sawmill ran a circular blade at an earlier date than expected and no one ever published anything about it. I will probably try the US Census of Industry for Stowe in 1840 and see if anything is mentioned. There is no dendrochronological baseline yet for spruce/fir in northern New England. Consequently, I'll wait before exploding this bombshell on the world.

Patrick Hoffsummer's book, first published in French as *Les charpentes du XIe au XIXe siècle* (Paris 2002), deals with how this multifaceted process has been carried out on the historic roof systems of northern France and Belgium. Hoffsummer, both the editor and a principal author, is a professor in the building archaeology program at the University of Liège in Belgium and director of its dendrochronology laboratory. A vast heritage of antique framing exists in that part of the world, mostly in the form of roof frames covering masonry religious structures and public buildings as well as some barns and private houses.

While the public and religious institutions maintained records, some reaching back to the 1100s and before, the vicissitudes of existence including war, age and decay, stylistic reconstruction and modern repairs have made the concealed framing above the nave ceilings "a forest of intermingled beams" (Blain, Maggi, Hoffsummer, 2015). The range of educated opinion about the age of some of these roof frames has sometimes amounted to hundreds of years.

When we are asked to analyze an immense timber frame enclosed in a dark, dusty and dangerous roof space, how do we proceed? We might turn to books on the topic, and compare what we see to others of known date and inspiration. Hoffsummer gives a brief mention to what we call builder's guides, occasional in the 17th and 18th centuries and quite common in the 19th and 20th, which almost always disappoint, not because the authors are in error but because the few examples of framing shown are usually idealized and represent but a tiny fraction of the inventiveness of vernacular carpentry. More credit is given to researchers whom Hoffsummer considers his precursors, Henri Deneux in France and Cecil Hewett in England among others, who surveyed, measured and, in the case of Deneux, modeled a great number of frames and tried to establish typologies and draw conclusions about the evolution of framing.

Following a chapter on Deneux are others dealing with the history of forest utilization, timber conversion, layout systems and assembly marks, a bit about tools, and lots of drawing of joinery with locations and dates attached, which may help us come to our own conclusions. However, Hoffsummer does not have as much faith as, for example, Cecil Hewett that a chronology of joinery innovations would provide a means of discriminating the date of framing among and within buildings in a cultural region.

While the documentation and comparative analysis by architectural historians and building archaeologists is undoubtedly valuable (think of J. Frederick Kelly's *Early Connecticut Meetinghouses* (1948) or Abbott Lowell Cummings's *The Framed Houses of Massachusetts Bay 1625-1725* (1979), they suffer from a weakness pointed out in the book's foreword by Jean-Daniel Pariset: "This approach to frames is without doubt disconnected from the knowledge of master framers, who can easily discern the imperfections of the analyses of historians."

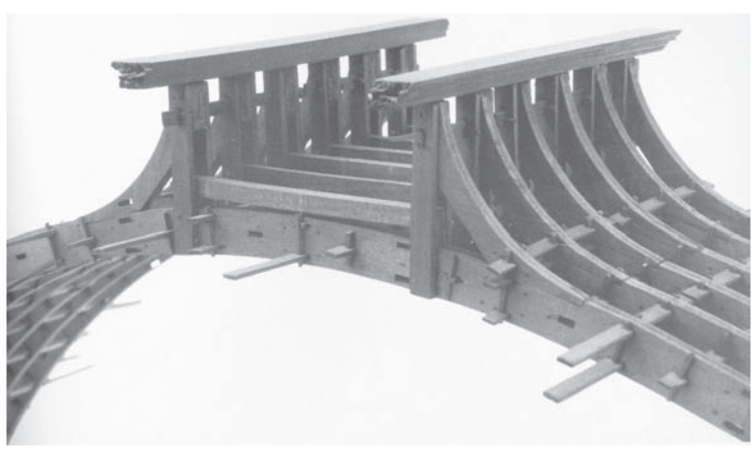
Pariset also goes on to say that today's scholarly researchers have something original and even decisive to contribute, in the technique of dendrochronology. A 74-page section of the book is devoted to dendrochronology, from its origin in tree-ring dating by the astronomer A. E. Douglass in the Arizona desert in 1906 through the development of a long chronology for oak in Germany after 1965 and further refinements since in France, Belgium, Britain and elsewhere. A number of case studies provide examples of how seemingly intractable problems might be solved by dendrochronological analysis of the timbers of a frame.

Dendro provides Patrick Hoffsummer and his associates the basis for assigning dates to frames and attempting a typology and a notion of evolution of framing. Much excellent work of this sort of combined approach (documentation, dendro and carpentry) can also be found currently in the research of Julian Munby and others in Britain. If dendro is always accurate, and a dendrochronological baseline exists for the locale and species, and the researcher knows enough about historic framing and timber conversion to avoid absurd results, this more scientific approach may produce revisions in some of the treasured narrative accounts of the carpentry in historic monuments that we all know and love.

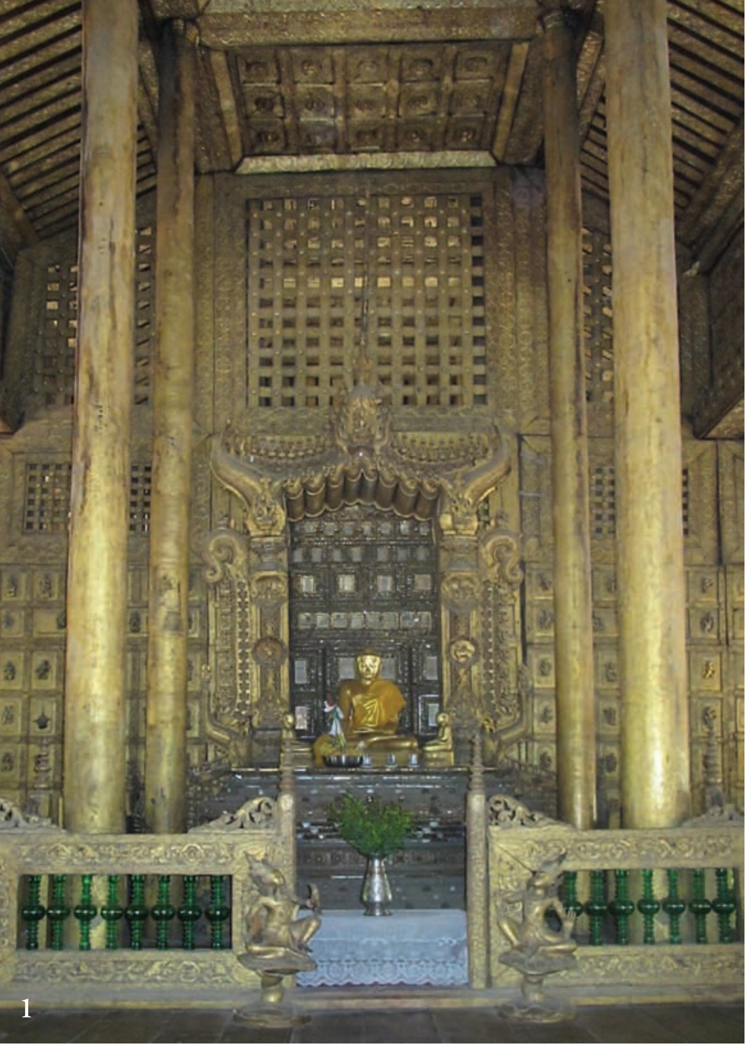
I find of most use the long section on the evolution of frames, but not necessarily because of any conclusions that might be drawn about what frame may have influenced what other frame and when, or when a particular scarf joint was first employed. In a region as densely settled and constructed, and for so long, as northern France and Belgium, the same problem exists, but even more so, as in the thin layer of European-inspired construction found in North America. None of us, if we looked every day of our entire life, would see but a tiny fraction of the extant structures, not to mention the much greater number lost or altered beyond recognition. This is not to say that the dating methodology isn't extremely useful. It is, and its results for one frame give us somewhere to start when first seeing another. I believe that is why this book (and another publication by Hoffsummer that I will discuss in the second part of this review) spends so much time introducing the idea of studying the details of framing such as conversion, layout, marking systems and tool marks, along with dendrochronological analysis.

Rather, with its hundreds of drawings of still-standing roof framing (and sometimes wall framing) from the previous 1000 years, the typology section provides one with a large library of timber framing options, mostly for spans under 40 ft.—but, most fascinating, rarely rationalized, idealized or displaying true truss action as defined by engineers in the 19th and 20th centuries. I have used this book twice as design inspiration for projects wanting a medieval aesthetic. The drawings also provide confidence and evidence for retention of historic framing when it doesn't meet modern engineering standards. These roof frames in their multitude aren't quite trusses in the modern sense, but most are still standing unassisted, and by choosing judiciously among them and perhaps increasing some dimensions, an entire new design repertoire is available. —Jan Lewandoski

To be continued in the next issue.



Detail of model, château roof framing, Saint Germain-en-Laye, France, 1557, in *Roof Frames from the XIth to the XIXth Centuries.*



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Photos these pages Laura Saeger

The Golden Palace Monastery

MYANMAR, called Burma during the British colonial period 1885 to 1948 and the ensuing decades post-independence of civil war and military rule until 1989, is one of the earliest-civilized countries in the world, and arguably one of the richest in natural resources. Recent excavations revealed villages and structures dating back to 1200 BCE. Historic religious architecture exists nearly everywhere in a land that has been more than 90 percent Buddhist for many centuries, and yet there is no real understanding of historic conservation. Monasteries are maintained to enshroud the Buddha images (Fig. 1) and house the abbots, monks and nuns who lead the practice of Buddhism, but when a building no longer serves this purpose it is abandoned and often torn down for the materials, or burned.

Few written records exist beyond the Buddhist manuscripts written on palm leaves and the tradition of telling the stories of the life of Buddha both orally and as murals in the pagodas, perhaps a collective effect of the entire nation practicing Buddhism, the invasion by the British in the early 19th century that made the people of Myanmar little more than slaves, and, following the postwar period, the extremely oppressive rule of the military until this decade. It is nearly impossible to find records that indicate when buildings were built or even when cities were established. What is clear is that Myanmar has, over the millennia, been ruled by many kings, some more benevolent than others, ruling from many different cities along the Ayeyarwady (or Irrawady) River.

The river delta and wide riverbed valleys upstream provide both sand, which today is used to make Portland cement mortar and concrete, and clay, traditionally used to make sun-dried adobe bricks. These bricks are roughly 8x16 in., a little over 2 in. thick, and when bedded in wet clay create the exceptionally stable pyramidal and conical stupas and pagodas that dot the Myanmar landscape (Fig. 2). Myanmar's geological features include the Sagaing Fault, 1200 km long, which follows the Ayeyarwady River and passes through major cities, making the country prone to major earthquakes, yet many Buddhist masonry structures from the 6th and 7th centuries still exist today.

When the World Monuments Fund, with whom we have worked before, asked if we would work as consultants on the conservation of one of their projects in Myanmar, we wondered what it would be like to work in such a faraway place where people who speak English are few and far between. (The British colonial period of full occupation from 1885 to 1948 is not looked back on with any favor, and in recent decades travel by outsiders in Myanmar has been severely restricted.) What would the food be like? How were timber buildings built there? Where would we be able to source tools and materials?

Though it took an exhausting three days to get there (and would take three more to get back), and the daytime temperatures hovered around 100 degrees (nights were often only 15 to 20 degrees cooler), when we first saw Shwe-nandaw Kyaung, the Golden Palace Monastery, we found it the most exciting and beautiful building we had ever seen (Fig. 3). Made completely of teak, a wood we had never worked with, covered in ornate handcarved figural decoration and plated with gold on the interior, the temple was captivating. We decided we would have to learn to handle the travel and climate.

That the Golden Palace Monastery is a timber-framed structure might be attributed simply to the fact that it is a monastery, since

1 Buddha image at monastery including ashes from King Mindon Min's (1808–78) robes.

2 Historic adobe stupas in Inwa, site of early capitals of ancient Myanmar kingdoms.

3 Shwe-nandaw Kyaung or Golden Palace Monastery, Mandalay, originally part of palace now demolished.

all but one monastery we have since visited or read about are timber framed. In fact it was originally not a monastery but rather part of the Royal Palace of Mandalay, built ca. 1860 when King Mindon Min moved the capital there from Amarapura. The palace grounds, which took up three square miles directly adjacent to Mandalay Hill, were surrounded by a moat and the palace built on a teak platform a full story above the ground. It is arguably the first wooden palace built in Myanmar but definitely the first such built in Mandalay, and believed to be the grandest palace ever built in Myanmar. But why was it built of timber instead of masonry?

The answer may lie in the history of the trades. The wide availability of clay to make adobe bricks meant that masonry trades began long ago in Myanmar. Kings and queens would employ these skilled tradespeople to build their palaces, but the latter were built on earthquake-prone ground, and palaces are much more complex structures than stupas and pagodas, which are not even meant for habitation. Many grand and intricate palaces were destroyed by earthquakes and royal sites abandoned when they were reduced to rubble. When King Mindon Min caused his own palace to be built, he chose to work with a different tradesperson, the carpenter.

Before and during the 19th century Myanmar was rich in hardwood forests. (Today it has the third fastest rate of deforestation of any country in the world, and forest management is virtually nonexistent.) Indian rosewood, teak and other valuable trees thrived in dense forests in the mountain ranges that border the Ayeyarwady (one of the principal reasons the British invaded Myanmar). The tradespeople who knew how to fell these great trees for building had access to elephants able to drag the logs out of the forests to the rivers, where the logs could be rafted to the cities. The best and biggest teak logs were set aside to build the monasteries where the Buddha resided.

I have not discovered a way of determining how long teak monasteries have been built in Myanmar, but I have visited several supposedly built decades before King Mindon Min's palace. So the skilled timber framers who could build structures three and four stories tall above story-high teak platforms, incorporating immense teak columns up to 60 ft. tall, existed possibly as early as the 18th century, and my bet would be long before that.

When the king decided to build in Mandalay, he may have realized on his own that timber monasteries were more nearly earthquake proof, or he might have simply asked the local trades what to build that would be safe. Whatever the case may be, he chose teak, and what is today the Golden Palace Monastery was once King Mindon Min's private apartment. (Or it may actually be two buildings from the palace combined into one to become the monastery.) But how did it get outside the palace grounds, and why was it converted to a monastery?

When King Mindon Min died in 1878, his son was instructed by his very powerful wife and queen to remove the king's apartment from the palace to ensure the king's spirit did not interfere with her plans for how the country would be run. By giving the "Glass Palace" (so called when it was still part of the royal palace) to the monastic order, the new king and queen would earn great merit to ensure a favorable afterlife. In 1883 reconstruction of the monastery was complete.

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Photo at left, British Library; below left, Rudy Christian; at right, Laura Saeger

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IN 1885 the British invaded Mandalay and the royal palace became Fort Dufferin (Fig. 4). The king and queen were removed from power, and the age of kingdoms ended in Myanmar.

The British shared their power with the monastic order to keep the Buddhist population pacified until just before World War II, when the British departure was immediately followed by a Japanese invasion that included the bombing and burning of the royal palace and many other historic buildings, leaving the Golden Palace Monastery as the last remaining piece of what was once the grandest and only timber palace ever to be built in the city of Mandalay, and maybe in all of Myanmar. The World Monuments Fund has undertaken its protection and it has been our extreme honor to have been asked to be part of the team assembled to do so. But the undertaking has meant a very steep learning curve.

Separating fact from fantasy in the information provided and discovered about the history of a place or structure was a more formidable task than usual given the tumultuous history of Myanmar, compounded by the fact that the architecture and ways of building in Southeast Asia are radically different from anywhere in the western world. Finally, over time buildings change, either as a result of natural forces like earthquakes, wind, water and fire, or interventions undertaken by people in an effort to repair the damage inflicted by time, or to make them more suited to current or expected uses.

The conservation objective adopted by the World Monuments Fund for the temple was restoration to a particular period, in this case to when the relocated structure officially became inhabited by monks in 1883. The immediate challenge would be to determine which parts of the structure dated to the 19th century and which were modified or replaced in later interventions. Since there were no written records, no local scholars with any understanding of conservation work and no local tradespeople with any training in building conservation work, the information would have to come from the building itself. The only pictorial evidence we were provided was a few late-19th-century photographs and some pages from a scrapbook of pictures assembled by one of the government employees who had worked on the monastery in the 1970s and early 1990s.

The team to undertake initial research and documentation had begun to assemble two years before our initial visit to Mandalay. It was led by Jeff Allen, project coordinator for WMF, and included Steve Kelley, an architect from Chicago; Andrew Earles, a hydrologist from Denver; Brian Ridout, a specialist in insect and fungal infestations from England; Alexey Kirichenko, a professor from Moscow University; and François Tainturier, an architect who had been trained in France, had graduated from the College of Oriental and African Studies in London and had been living and studying in Myanmar for nearly a decade. We were the first tradespeople to be asked to join the team. Our work would involve the actual hands-on restoration of the monastery as well as educating local tradespeople in today's conservation practices.

The monastery with its surrounding veranda (Fig. 5) is raised one story aboveground and supported by teak columns. Originally these columns would have been placed in roughly 6-ft.-deep holes with adobe pavers at the bottom as footers. Unfortunately, in the late 20th century the column bases were reset in new concrete footings and connected by steel straps and bolts. Teak is naturally a very resistant species to both fungus and termites. Local evidence indicates teak columns buried directly in the ground can last for centuries because the ground can reabsorb any water that comes into contact with the columns during the monsoons. But when they are buried in Portland cement masonry, water is held against the columns indefinitely, encouraging fungal activity. Once the structure of the wood is compromised by fungus, it becomes a food source for both dry wood termites and subterranean termites, prolific in the tropical climate of Myanmar.

The columns directly underneath the monastery (Fig. 6) are protected from direct rain by the building itself and rest on or are

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Photo at left, Laura Saeger; above, Mandalay Department of Archaeology

4 Hampshire Regiment attending services at Fort Dufferin, formerly Royal Palace of Mandalay, Christmas Day, 1885.

5 Southeast corner of veranda. Gates lead to short staircases.

6 Underside of veranda showing raised slab under main building. Brackets on column faces are not original.

7 *Naga*, carved serpentine beings providing spiritual support to monastery and Buddha image inside, used as decorative elements.

8 Elaborate work in the 1970s restoring lost figural wood carvings on north face of monastery.

surrounded by an elevated slab that normally keeps flooding from reaching them, but the columns supporting the veranda are exposed to both rain and frequent flooding during the monsoons. This continual wetting, in combination with the masonry encapsulation, has led to significant deterioration. A study of the columns conducted by Brian Ridout in September 2014 revealed that half of the 42 teak columns supporting the veranda were hollowed out by termites beyond repair and the remaining half needed significant repairs. Undertaking replacement and repairs, however, would involve a significant amount of documentation and deconstruction of the veranda itself and the numerous decorative elements associated with it.

Before our arrival in Mandalay in August 2015 to begin documentation and development of a restoration plan, consulting architect Steve Kelley, whom we had worked with in New Orleans after Hurricane Katrina in 2005, had hired local carpenters to build temporary shoring under the veranda along the west side, where damage was significant, and to construct a shelving unit on the lower floor of the auxiliary building just south of the monastery to provide a place to store a number of *naga*, carved dragonlike creatures affixed to the short columns (Fig. 7), as well as water-seal boards and balustrade planks. An alphanumeric grid system, already established for condition documentation of the teak columns, was used for tagging the stored decorative elements as well. The next step was to establish guidelines for the originality, condition and authenticity of the various components, including the veranda itself.

When Mandalay was occupied by the Japanese in 1942, the royal palace (Fort Dufferin since 1885) was destroyed and the grounds became a military base and airfield for the Japanese forces. Monks and abbots were forced out of monasteries, which were then burned or occupied by soldiers. The latter was the fate of the Golden Palace Monastery. During the occupation, the vast majority of the figural decorations were torn from the walls and balustrades and used as cooking fuel. The exterior of the monastery remained nearly devoid of decoration until the late 1960s, when the Mandalay Department of Archaeology undertook a campaign to replace the decorations (Fig. 8). This work continued into the 1970s, enabled by woodcarving having remained a well-supported trade through the colonial period and into current times, although the quality of the workmanship has been diminished by many factors including commercial exploitation of woodcarvers. In any case, we know the majority of the extant teak decoration is reproduction work done as authentically as possible in mid-20th-century Mandalay, given the decrease in the level of skill of the woodcarvers who did the work compared to 19th-century craftsmen.

Determining the authentic way to reconstruct the veranda framing presented a greater challenge, but also the opportunity to begin to understand how timber temples were built in Myanmar in the 19th-century and probably much earlier. As in most Far Eastern architecture, the diagonal brace so common to Western timber framing is absent. But how the floor system is framed, including the veranda, was obviously something we had never seen before anywhere in our travels or studies. We were aware that the veranda decking and joists had been removed in the 1990s, work that included straightening or replacing columns along with shortening and connecting them to the new masonry bases. Investigation of the reconstructed deck framing indicated it had not been replaced the way it was originally built.

Likely the floor framing under the monastery would be the most nearly intact, since it was protected from the weather, so we began our investigation there. The majority of the floor inside the monastery is a raised platform divided by a centered wall into two large rooms. The reception hall is on the west side of the partition (Fig. 9 overleaf) and the Buddha hall is to the east (Fig. 1). The entire floor frame of the raised platform is supported by teak columns that penetrate the floor and continue up to support the

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Laura Saeger

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Above and at top, Rudy Christian

tiered roof system as shown in Fig. 9. The columns are connected together by heavy teak 2x10 planks at floor level, which run east to west and rest in through mortises in the columns. Rather than notch the floor joists directly into the connecting planks, a 2x5 plank is placed on top of the latter and notched to carry the flatwise joists that range from 4x3 to 5x3 (Fig. 10). In effect, the columns and planks connecting them create a foundation for the floor system. Notched carrier beams in the wooden foundation eliminate the need for fasteners to maintain spacing of joists, which rest loosely in the notches and run between two rows of columns, where they are half-lapped to the joists in the next bays. All the framing except the columns shows the tool marks of the ripsaw and the handplane. The columns also appear to be handplaned and clearly were worked from very high-grade logs.

The floor area just inside the exterior walls of the monastery is one step down from the main platform. To accomplish this, the temple builders incorporated a 2x10 ledger board (Fig. 11) parallel to the connecting plank passing through the center of the column but 8 in. lower, allowing the lower joists to land in a notched 2x5 carrier again placed on the ledger. The ledger itself is let into the face of the column approximately half its thickness, supported by a wedge block mortised into the column at the lower edge, and fastened by hand-forged spikes with rolled heads. We took spikes we found loose during excavation work to a traditional blacksmith in Amarapura, who confirmed they were 19th-century hand-forged nails. We also found one on display at the Archaeological Museum in Inwa identical to the spikes in the ledgers at the monastery. We were starting to feel that our 19th-century vision was coming into focus.

Assessment of the veranda reconstruction done in the late 20th century revealed a significantly different approach from the original. At the point where the joists passed through the 2x5 carrier just under the exterior walls, the notches contained voids where the half-laps from the adjoining historic joists had been (Fig. 12). Looking at the floor framing of the veranda revealed that all the joists were now placed on ledgers carried on brackets made to look old, circular sawn and attached with modern rosehead spikes, again to give a historic appearance (Fig. 6). The notched 2x5 carrier beams were eliminated and new 3x4 joists were toe-nailed to the ledgers. It was clear that in order to achieve a restoration of the veranda as authentic as possible after the columns were repaired or replaced, our carpenters would need to be shown what we had learned about identifying which framing was 19th century and which 20th, in order to understand what we were asking them to do.

Working with our carpenters turned out to be the least difficult part of the project. They are accustomed to using hand tools and clearly enjoyed not only working on one of the most important religious structures in Mandalay, but doing it using the techniques of the temple builders of the 19th century—not something they would be typically asked to do (Fig. 13). Significantly more difficult was sourcing the materials we needed to do the restoration work. Teak logs for the columns had to be purchased through the Department of Archaeology because logging for export was made illegal in 2014 and all legal logging can only be done under the sanction of the government. We visited several government-sanctioned sawmills in the Mandalay region before finding a sawyer to work with. Ko Min Min was honored to be providing materials for the Golden Palace Monastery and went

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Rudy Christian

9 Reception hall at Shwenandaw Kyaung, gold-leaf veneered.

10 Floor framing system under reception hall platform.

11 Ledger used to create the step down from the raised floor area in the monastery.

12 Empty laps revealed absence of historic floor joists beyond.

13 Carpenter U Aung Win (foreground) and nephew Aung Tin Oo handplaning replacement floor joists in space under monastery.

14 Delivering teak logs for replacement columns to tight site required strong shoulders and good posture.

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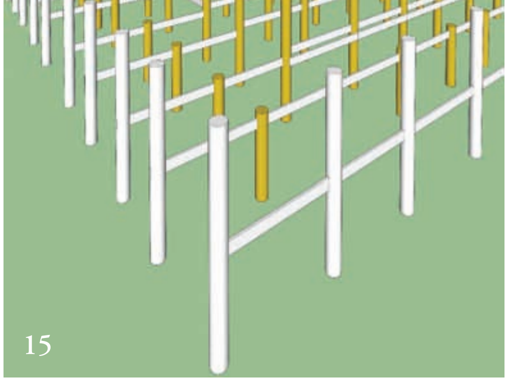
Laura Saeger

well out of his way to sell us the high-grade teak timber we needed for reconstructing the veranda. He also provided storage at his yard for the teak logs we had purchased so they could be delivered to the site, where storage space is limited, when we needed them. Access to the work site itself is also very limited, so deliveries are done by hand (Fig. 14). Five months after the order was placed for our first purchase of teak logs, we ended up traveling 12 hours by taxi, on very poorly maintained roads through restricted territory, to the government log yard in Loikaw in the Kayah State to inspect the logs that had been set aside for us. Unfortunately,



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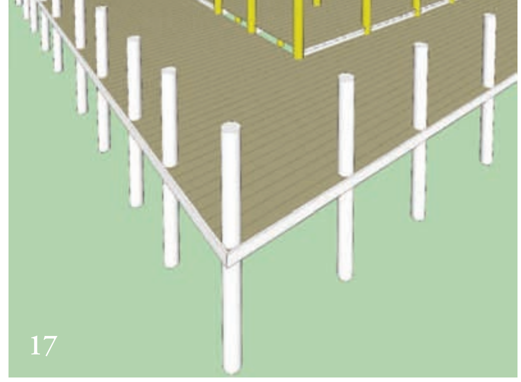

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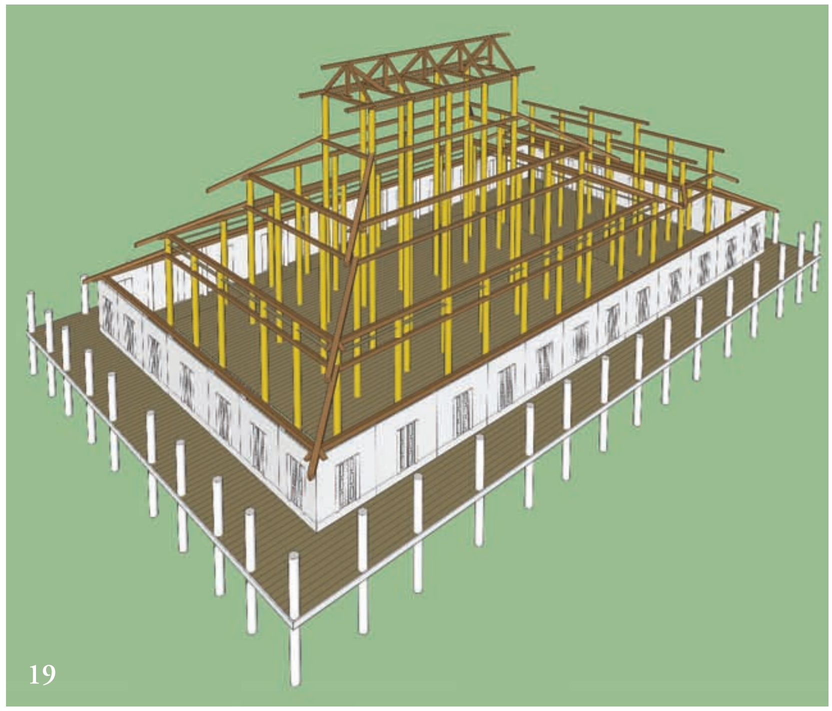
Rudy Christian



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Renderings Min Hein, World Monuments Fund

the traditional practice of selecting the best logs in the forests and setting them aside for temple building has long since vanished. Of the 30 logs set out for our inspection, only 12 were good enough to work with, ten fewer than we had ordered.

On our return trip from Loikaw, we took a day off and spent it in a longtail boat on Inle Lake. When we visited the Hpaung Da Oo Pagoda we were pleased to come across a Buddhist mural describing the placing of columns as laying the foundation for a monastery in 1314. This confirmed both that the wooden foundation concept is understood by the people of Myanmar and that timber monastery construction dated back at least seven centuries.

The method of building a monastery on a wooden foundation is illustrated in Figs. 15–17 and understanding this system led to the discovery of an anomaly in our floor framing that dates to the 19th century. The floor to the east of the Buddha platform is a large area one step down and at the same level as the surrounding veranda, yet the floor framing beneath (Fig. 18) has both ledgers and support beams mortised through the columns. Since the purpose of these two different support beams is to create a step in the floor, something must have been changed when the monastery was rebuilt after being moved. Investigation of the columns just above the floor revealed that the mortises for the support beams actually were 8 in. higher and have been filled in, meaning that section of floor was once a raised platform.

Visiting a number of timber monasteries has shown us floor platforms elevated for two different reasons in temples. In a monastery, the floor on which the Buddha image resides is elevated from the surrounding floor (access is denied to women), but studies of sketches of the palace, and anecdotal evidence found in novels, seem to indicate the floor of the residence of the king also would have been elevated above the surrounding palace platform. The two different roof profiles at the Golden Palace Monastery match the areas of raised platform floor framing below, indicating that the monastery is actually two buildings built as one, with the exterior walls moved away from the original by one row of columns (Fig. 19). In fact the columns in the outside walls of the monastery do not pass through the floor deck, but end at floor level with smaller decorative columns placed directly above them to support the current roofline.

Understanding how buildings are built in Myanmar has given us a window into a world where traditional materials and tools still dominate. Work that would normally be done in North America or Europe with a crane or extendable forklift required hand rigging and hoisting as well. Damaged columns were removed and new columns installed by the use of many hands and a tripod or a ginpole with a block and tackle made on site. The system of wooden foundations using teak columns connected together with what we are told might be called "shoulder" beams to support the solid wood structure above appears to be unique to this country, and we have much to learn about its origins. What is clear is that, apparently like anywhere else today, sourcing good building materials to work with is a much larger problem than it was when heavy timber building was in its glory. The quality of the deteriorated material is significantly higher than the timber we can readily source today to replace it.

When our most recent work mission ended in March of this year, we had received the logs for replacement columns only in late February, meaning only three new columns could be set before we returned home (Fig. 20). Our mandate to understand how to

Rudy Christian

15–17 **Sequence of timber assembly for raised platform framing.**

18 **Underpinnings of main building.**

19 **Walls coded white in rendering are relocated, with own posts.**

20 **Three replaced teak columns on veranda southwest corner.**

21, 22 **Replacing framing and decking using 19th-century traditional methods and the best materials obtainable.**

Above and below, Min Hein, World Monuments Fund

reconstruct the veranda authentically had been well addressed, and educating our carpenters in understanding the history of temple building in their own country had begun. They understood what they were now tasked with and for the weeks following our departure for the US they continued to work at restoring the veranda to its 19th-century beauty (Figs. 21 and 22) until the monsoons stopped their work. Knowing that we have been part of enabling the local tradespeople to begin the process of restoration of a building as important as Shwe-nandaw Kyaung, the Golden Palace Monastery, has been a tremendous reward. Believing we have helped plant the seed of conservation in the minds of the local people beyond the trades may be somewhat optimistic, but continuing our work in Mandalay is a part of our lives that is its own personal reward. —Rudy Christian

Rudy Christian (rchristian@planexus.com), past president of the Guild and retired executive director of the Preservation Trades Network, operates Christian & Son, Inc., in Burbank, Ohio. He undertook the Myanmar project and works closely with his wife Laura Saeger.

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Kevin Ponton

Carpenters Without Borders

WE are all familiar with the international aid work of Doctors Without Borders, founded in Paris in 1971. Their name in France, Médecins Sans Frontières, is reflected in the name of another voluntary aid group in France, eventually called Charpentiers Sans Frontières, composed of timber framers and restoration carpenters and founded in 1992 by Dr. François Calame, an ethnologist, preservation carpenter and timber framer from Rouen (Fig. 1).

François's day job is as adviser to the Ethnology Service in the Directorate for Cultural Affairs (DRAC) for the region of Upper Normandy, located in Rouen. He's an ethnologist by training and a preservation carpenter by avocation, who sees the latter as one of the tools, like memory and recollection, that allow history to be recorded accurately. As he writes in the foreword to his 2007 book of essays, *La mémoire orale*, "Memory is not history, but it undeniably nourishes history. In our country of written laws and traditions, the powerful role of collective memory has been neglected for much too long, as lawyers and historians have criticized and disdained it as unreliable."

For the past 25 years, Charpentiers Sans Frontières has been quietly restoring historically significant buildings in and around Rouen in northern Normandy as well as internationally as far away as China (2015). François is in the final preparation stages for a project next year with indigenous people in Guyana. His growing band of carpenters works on a shoestring budget and an abundance of voluntary passion from skilled carpenters hailing from 17 countries. Few American carpenters are aware of the group's activity, though some have attended its previous gatherings such as at Ermenouville, Normandy, in 2005 (see "Topics: French Rendezvous" in TF 79) and two more attended this year's 45-person workshop "Aclou Rencontre 1491–2016" in Normandy during the first week of September.

Under François's leadership, the group has also emphasized rigorous study and research into the ethnic origins of preindustrial tools, skills and construction methods to work in the closest manner possible to the period of the original building. At the Aclou worksite all the tools were of course handtools, and even the biggest oak logs had been dragged out of the forest by authentic horsepower (an eight-year-old Ardennais mare named Prune).

After conducting a 2011 workshop on a 15th-century tithe barn in Normandy at Daubeuf-la-Campagne (Eure), François coauthored a bilingual book describing the project in minute detail. It included a chapter devoted to a particular Norwegian hewing technique, covering everything from positioning and securing the log to reading its grain to the handedness and changing stances of the hewer at each step in the process.

The hewing techniques studied during the 2011 project were newly discussed, developed and expanded upon during the Aclou 2016 Rencontre, a clearly defined historical restoration project designed to accomplish its goals within a prescribed 6-day timeframe. The axes that arrived with the international team's baggage included an array of designs, origins and ages ranging from examples depicted in the Bayeux tapestry to brand-new Gränsfors Bruks throwing axes. And, yes, we did have a throwing competition.

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1 Dr. François Calame, leader of Charpentiers Sans Frontières, at first team meeting of 2016 framing rendezvous in Aclou, Normandy.

2 Andy Hyde of UK Carpenters Fellowship demonstrates finish hewing with using double-bevel Kent pattern axe.

3 Florian Carpentier (in shin guards) trimming below juggling cuts with Norman-style *doloire*.

Practiced hewers like Andy Hyde of the UK Carpenters Fellowship (Fig. 2) quickly became known simply by doing their work: there were no special badges or name tags. Andy always drew a crowd as he tried out virtually every one of the axes on site. Masters worked alongside beginners, the only rules being safety and generosity (Fig. 3). At our first team meeting, everyone accepted responsibility to immediately stop what they were doing in order to (gently) alert someone else who might be performing a dangerous move—by teaching the correct move.

NORMANDY'S location on the north coast of France placed it directly in the path of historical incursions from the north into the Roman Empire, and it served as a melting pot of ethnic groups that throughout history mixed and battled with neighbors to its west in what is now Brittany and across the channel. The Norman era may be said to have begun with the arrival of the Viking Rollo ca. 911, who sailed up the Seine to Paris.

Normandy abounds in battlegrounds, ruins and ancient buildings; the entire old-town sector of Rouen is composed of well-preserved structures dating back over 600 years. Its central square is dominated by a massive modern timber-framed museum and religious memorial to Joan of Arc, the heroine and victim of the Lancastrian phase of the Hundred Years War who was tried and executed there in 1431 while the town was under English control. The building is a mixture of old and new. Constructed in the early 1970s, its timber structure combines impossibly long glulam beams, soaring compound curves, immense steel joints and salvaged stained glass windows.

Although he's not an ardent fan of the memorial, neither is François a historic purist: "Today's debate," he has written, "is not between ancient and modern—between progress and the past. The essence of modernity is in knowing and being able to choose one's own way undogmatically, making one's own mixture of the two, and then taking one's own preferred dosage of the mixture. Knowing how to make use of machines to create a contemporary architecture does not necessarily mean that one has forgotten the intimate relationship among the materials, the wood, the hands, and the head." As a timber framer and restoration carpenter, François has taken a particular interest in the hewing and splitting techniques and axe designs used in the restoration sites used by carpenters of the many cultures he has worked among. At all projects since 1992, all necessary timbers have been felled in local forests and axe-hewn using the techniques and tools appropriate to the culture and period of the building in question. Nevertheless, as Andy Hyde observed, all hewing axes are designed to be worked across the grain, taking advantage of the fact that most woods will cut more easily in this direction. The *Breitbeil* and its relations, known across the Germanic and other northern countries, and the French *doloire* usually have skew-angled handles to allow unhindered working of wide surfaces, without risk of injury to the knuckles. The finish of a freshly hewn timber is more the result of the hewer's skill and technique than of a particular tool.

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Kevin Ponton

One of the Carpenters Fellowship participants, an agent for Gränsfors Bruks, arrived with his car trunk filled with brand-new axes with a variety of single- and double-beveled edges and hafted for both left and right hands (Fig. 4). The team members tried them all, and all the axes went home a week later with new owners.

ACLOU is an agricultural hamlet with many more acres (915) than people (about 300) and buildings, none later than the 19th century, centered on a narrow two-lane country road squeezed between the church and the ancestral manor owned by generations of the Deshaye family. The predominant crop, raw flax, is cultivated and stored on the premises. Situated about 45 minutes southwest of Rouen, the manor was first documented in a Papal bull of 1144, confirming it to be under the lordship of the prior of Saint-Lô in Rouen, to whom all feudal tithes were due. In an undated late-12th-century charter, when the region was under the rule of the English crown, the manor is named as a possession of King Henry II. The manor was seized as a national property at the time of the French Revolution, then sold into private ownership. The nearest town, Brionne, lies about four miles away with half the acreage and about 4000 inhabitants, overshadowed by the ruins of an 11th-century dungeon, and is cited in historical records dated to 337.

According to François, the manorial farm at Aclou is "a morsel of British heritage and material culture" probably constructed by English builders during the Hundred Years War 1337–1453 (Fig. 5). The first documentary mention of the manor is in a papal bull of 1144, referring to it as a dependency of the priory of Saint-Lô. The manor house itself, tree-ring dated to 1360 by Erhard Pressler, is the only known example in France of its type. Houses of this date are relatively rare. The manor at Aclou is an open hall with a (two-bay) chamber open to the rafters, with a central base-cruck and crownpost roof, and features a base-cruck of a type known in South-East England, particularly Hampshire, as we learned one evening from the renowned UK cruck authority Nat Alcock of the University of Warwick, who came to tour, examine the manor in Aclou and give the restoration team an evening presentation titled "Crucks and Base Crucks in England and Europe." Alcock has studied and mapped every known example and type of cruck construction. He, too, is convinced that Aclou is a unique piece of French and English heritage.

The Tithe Barn Restoration The focus of our work was across the drive from the manor house: its tithe barn, built by French carpenters of new wood dendro-dated to 1491 (Figs. 6–9). Our objective for the long week was the sill-to-ridge repair of its entire west end-frame, one of whose three wall girts had broken, along with a number of studs. The majority of the remaining studs had weakened or damaged tenons and the massive sill and all three girts above it also needed replacement, along with sections of corner posts at their points of juncture with the new girts.

The team arrived to find that the end frame had been removed and the entire structure laid out prone, in its original form, on the ground adjacent to the barn. All of the detectable 500-year-old carpenters' marks had been tagged and marked, to be rescribed on the replacement pieces. In addition, a full-scale ground plan made with Day-Glo colored string-lines in the grass nearby marked the location for setting out and test-fitting the replacement frame pieces (see back cover).

All that work had been accomplished by the site foreman, Remy Desmonts, along with his young son Loïc (in his final year of high school, but as strong as Paul Bunyan Jr.) in two days. And they had also installed steel scaffolding from bottom to top against the barn and temporarily supported the protruding side roof plates on it (Fig. 6). None of us at first believed that the two of them alone had actually accomplished all that in a mere two days, but their Superman performances during the following week suggested otherwise. We nicknamed Loïc *Louis Quatorze*, in honor of the prodigious 17th-century French monarch.

Neatly arranged on shoring and trestles nearby were the recently cut oak logs, the largest (for the sill) with a 60-in. butt diameter, all spray-painted to identify their future locations on the plan. After debarking, we began kerfing the largest logs at 2-ft. intervals using two-man saws, and followed up with hewing axes, wedges and mauls in a variety of configurations. As hewing progressed, a different team was busy taking precise dimensions from the barn and original materials and transferring them to the increasingly complex string-lined plan on the ground next to the barn. The ground-plan area was protected from disturbance by caution tape.

While we used two-man crosscut saws to kerf the largest logs (Fig. 10 overleaf), we turned to hewing axes to juggle (or joggle)

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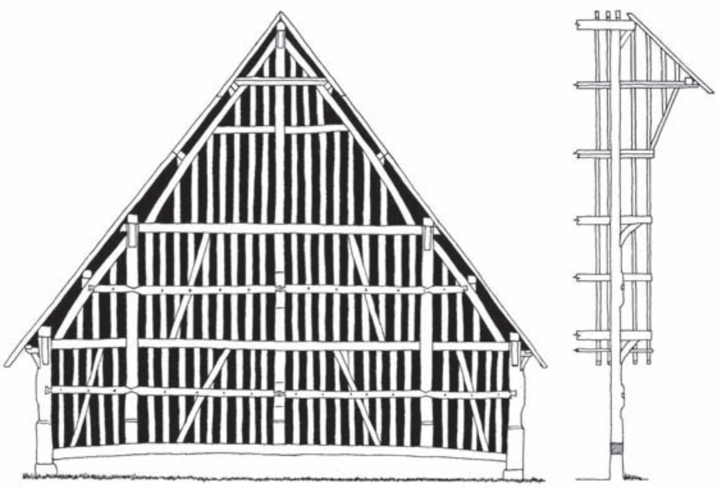

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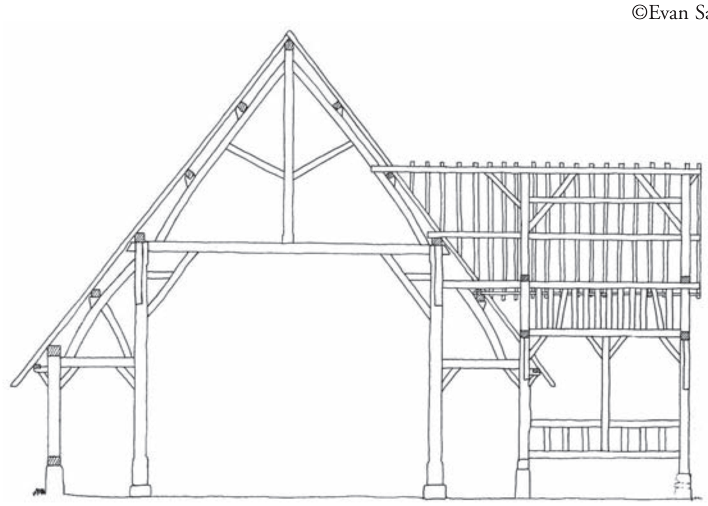

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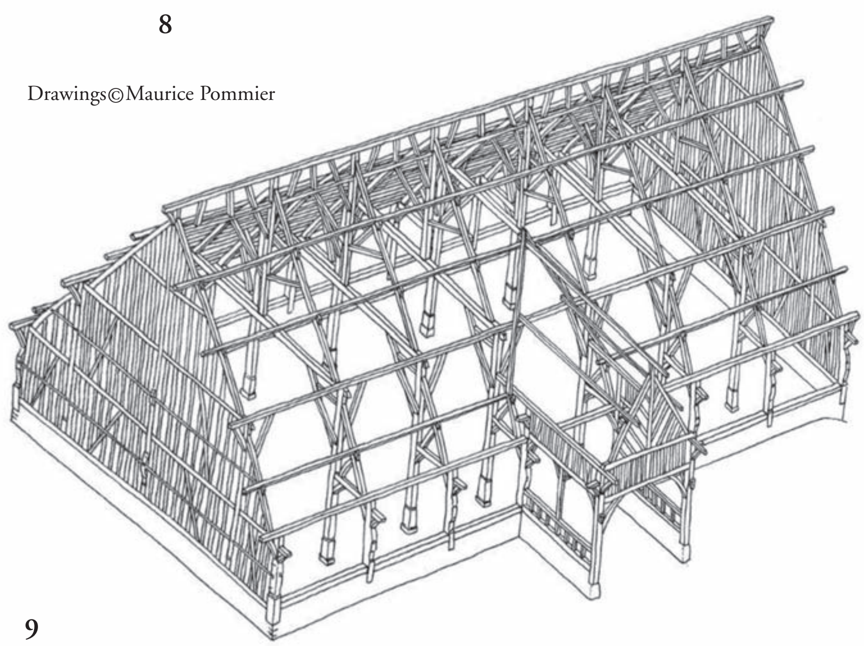

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4 Swedish axes laid out for sale at Aclou meeting.

5 Aclou manor house dated 1360 and believed built by English carpenters during the Hundred Years War.

6 Aclou tithe barn dated 1491, west gable end fully staged and dismantling begun.

7 Tithe barn west end frame elevation with north–south section showing regionally typical detail known as *queue de geai* or jay's tail.

8 Tithe barn transverse section at fully framed side entry porch, restored by German master carpenter Axel Weller in 2007.

9 Tithe barn, view of all framing. Note use of trussed ridge *(faîtage et sous-faîtage)* for longitudinal stiffness instead of English-style purlin-to-ridge wind bracing.

10

Above and below ©Evan Sachs

smaller logs that didn't have enough girth to allow us to stand on them. After striking the lines on the debarked log, we would kerf to within ¼ in. of the line, then rough-hew to the depth of the kerf (Fig. 11). In a second step, a more skilled worker would hew the last ¼ in. to the line and assure the face was plumb using a framing square or plumb level. Axes were sharpened continually.

The new 18x20 sill plate, about 30 ft. long, needed to be hewn to a camber to fit the foundation—and, to reuse the largest number of original studs possible, the curve was exaggerated so the shortened ones could be used where the curve was greatest. For the same reason, the thickness (depth) of the sill was also increased over the original dimension, and the studs salvaged by recutting their tenons or adding slip tenons into bridles cut in the stud ends. Given the importance of the sill plate, measuring and snapping its curved final cut lines caused a little anxiety, so a team of four measured and remeasured four different times just to be sure.

As hewing progressed, other teams concentrated on fabricating special joints, one an aisle post repair with a new top joint scarfed on (Figs. 12 and 13). A trestle was constructed to ripsaw several replacement studs and other secondary elements from 20-ft. timbers (Fig. 14). Using a large frame-saw, one sawyer stood on top of the log and the other below. The straightest cuts resulted when a third pair of eyes watched the line from below and continually gave hand signals to both sawyers, freeing them to maintain their rhythm. Sawyers recited the mantra, "Pull only, never push!"

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10 Gang-kerfing down nearly to rough-hewing lines.

11 Rough-hewing off the waste. Oversize bully oak log yielded sap-free timber with minimal knots. Flax bales stacked behind.

12–13 Apprentice Alexis Raussin (left) finds plumb on newly scarfed aisle post while Pascal Petit oversees. In place, to make up joint, necked portion of tie beam will enter deep slot in new material, and wall plate will drop over top tenons. See Fig. 7.

14 Maurice Pommier (pitman) and Patrick Macaire frame-sawing test piece on trestles incorporating flax-shed posts.

15 Gustave Remon trimming tenon shoulder with his *bisaiguë.*

Above, Andy Hyde. At top right and at right, Kevin Ponton

Tenon shoulders and mortises were trimmed efficiently with a 4-ft. French *bisaiguë*, a heavy double-ended trimming tool with mortise chisel forged at one end and bevel-edged paring chisel at the other (Fig. 15). Most of us had never seen one in use. The bisaiguë in combination with dividers and square composes the herald of the carpenters of Les Compagnons du Devoir, of whom several participants were experienced journeymen. Another participant was an experienced German *Zimmerman*. These highly trained carpenters rarely mentioned their prowess, but it became obvious as they worked. It surprised me that they were in general no more proficient in hewing than the ordinary carpenters on site.

Our presence in Aclou became widely known after a Rouen film crew aired its footage (youtube.com/watch?v=1T7xBH7ZEN4), and growing numbers of visitors circulated through the worksite. Many had been unaware that the work was on a designated French heritage site, and several close neighbors who had lived nearby for decades admitted that they had never before seen the compound from inside ("After all," they said, "this is private property!"). Even fewer were aware of the age of the manor house or that it was the unique example of its type in the entire country, not to mention that it had probably been built by English occupiers during the Hundred Years War.

No one who toured the site could possibly remain unaware of the camaraderie that had quickly infected the team (Fig. 16). Although no music was playing during the day, the environment was filled with laughter and the noise of hand tools. Virtually every visitor remarked on the felt sensation of having been transported back into history. Language was no barrier: French and English predominated, but never impeded communication.

On the final evening, to celebrate the newly reframed wall (Fig. 17), a local band came to play impeccable New Orleans blues and jazz sets for an audience that included some 75 neighbors, well provisioned with bottles of Calvados, the high-powered and unregulated locally produced distilled apple spirits. One of our team did an impromptu juggling performance followed by acrobatics with a finely honed Breitbeil axe balancing on his nose. And when the long-haired master carpenter from Estonia invited François's wife to dance 1950s swing, all of us broke ranks, paired up with our new neighbors, and danced.

An invitation to American timber framers I asked François what he sees in the American timber framing and restoration carpentry picture that might most help Charpentiers Sans Frontières meet its international aspirations. Without missing a beat he replied, "We need your typically American enthusiasm and capacity for imagination!" He is appreciative of this journal and eager to develop a deeper rapport with its subscribers.

He is certainly aware of the long-term challenges of his group's minimal managerial structure and thin financial capabilities, but his record of accomplishments over the past 25 years suggests that those challenges are surmountable given the passion, expertise and generosity of his colleagues. During my days with him on the Aclou site, I never heard him refer to individuals on the team as "members," and I am unaware of any such reference in his books about the group. He always talked about "us." My brief, intense experience with François and his merry band of carpenters convinced me that participants in the Timber Framers Guild have as much to learn from his group as Charpentiers Sans Frontières have to learn from our own brand of ingenuity, imagination and organization. —Kevin Ponton

Kevin Ponton (kevin.ponton1@gmail.com) operates Zenas Brooke Restoration, Inc., in Marshfield, Mass. François Calame's 2011 book, written with Atle Ove Martinussen, is titled Charpentiers sans frontières: l'atelier de Normandie / Carpenters Without Borders: Workshop in Normandy.

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Kevin Ponton

16 Remy Desmonts (France), center, supervising with his Japanese *sashigane*, Ian Ellison (Canada), left, a returning participant, and Loïc Desmonts (Remy's son), sawing a shoulder.

17 Barn gable end wall framing nearly complete on last day of meeting, last studs to be slip-tenoned into place and masonry infill to come.

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All photos Philip S. C. Caston

1 Covered bridge in Erlenbach im Simmental, Switzerland, interior view looking toward road below.

Erlenbach Bridge Bicentennial

ERLENBACH IM SIMMENTAL, in the Simme River valley of the Bernese Oberland area of Switzerland, has an unusual wooden covered bridge. It is steeply inclined, so much so that the only way to pass through it is to ascend or descend using steps. It is in fact a covered stairway, but as the stairs pass over a small stream, that is good enough reason to consider it a bridge. It stands behind the village church on the edge of a 32-ft. drop to the road below and was clearly built as a shortcut for the villagers when attending service. At the lower end, the date 1816 is carved into an upper crossbeam, making this year its bicentennial.

The bridge, at N46°39.651′ E007°33.140′, is approximately 70 ft. long measured along the hypotenuse of a notable pitch of 6½ in 12 (28–29 degrees), and it has to cross two freespans, one 34 ft. (30 ft. horizontal) over the Wildbach stream and the second 26 ft. (23 ft. horizontal) over inclined ground. The stairs, with a clear width of 10 ft. 6 in., fit between two parallelogram-shaped trusses. The bridge is covered by a gable roof, half-hipped at each end, and on the sides up to the handrail level. The roof is open on the inside and there are no ceiling braces or full tie beams (Fig. 1). It was built by David Tschabold (probably 1783–1861).

Of the several interesting aspects of the design, the inclination of the trusses is a major consideration. What are the consequences, what were the alternatives, and how did it affect the framing? And how does the gable roof work without tie beams?

The design would appear to be unique in its combination of incline and detailing, but at the same time there are tried-and-true elements of the construction that can be seen in other nearby covered bridges. Mr. Tschabold obviously was no novice, knew his carpentry and had seen other bridges.

The traditional truss design in Central Europe at the beginning of the 19th century is to carry the deck on transverse floorbeams between two parallel trusses. The floorbeam ends rest on lower chords and the chords are suspended from posts at regular intervals. The lengthwise distance to be spanned and the weight to be carried dictate the number and spacing of posts. As the posts themselves have to be supported, they in turn dictate the struts, bracing and spacers required in one or another configuration. The results can vary from the simple kingpost to complex multiple-arched arrays of diagonals in and under the truss that intersect with the posts to transfer their loads.

When considering the inclined truss, it would have been clear from the start that the steep pitch would require significant modification from the usual horizontally laid truss. Inclining a standard truss without modification would be feasible for minor inclines, but at some point in tilting the truss further the suspended posts would reach a degree of incline where they would start to act inefficiently in the structure. Meanwhile, the struts would transmit more or less force according to their new angles, in some cases requiring new dimensioning to remain efficient.

Loose sheet engraving, probably Italian, 19th century, artist unknown

2 Upper end of Erlenbach roof, with substantial overhangs. Roof battens are not square to trusses. Sling braces are sawn not bent.

3 Historic model kept in Meissen, Germany's town archives shows largest span of covered bridge (1668–1757) over river Elbe.

4 Covered bridge over river Kander, south side of Lake Thun, Switzerland, 1746. Steeply banked cut offered ideal natural buttresses for strut system under bridge.

The joints would have to be reconsidered as members changed their state from tension to compression or vice versa. Only in the case of a heavily over-dimensioned truss could the incline angle be more than minor.

An alternative would be to consider a truss designed specifically for a steep incline, which could be based on a trellis such as the Town lattice or a simpler form using multiple St. Andrew's crosses (X-braces) either in horizontal mode (with longer braces or struts and shorter counterbraces) or rotated to the incline and varying dimensions of the now postlike braces. Both the St. Andrew's cross and trellises had been used by framers in roofs and half-timber framing for centuries before, and they would have been known to a skilled framer thinking about a new truss design.

There would still be the problem of how to roof the bridge (Fig. 2). Inclining a standard truss with vertical post roof members and rafters also has its limitations. While the majority of Central European covered bridges are horizontal, a number were built or designed with an incline of some sort, and of course normal cambering against sag amounts to inclining a bridge upward to its center from each end or each pier.

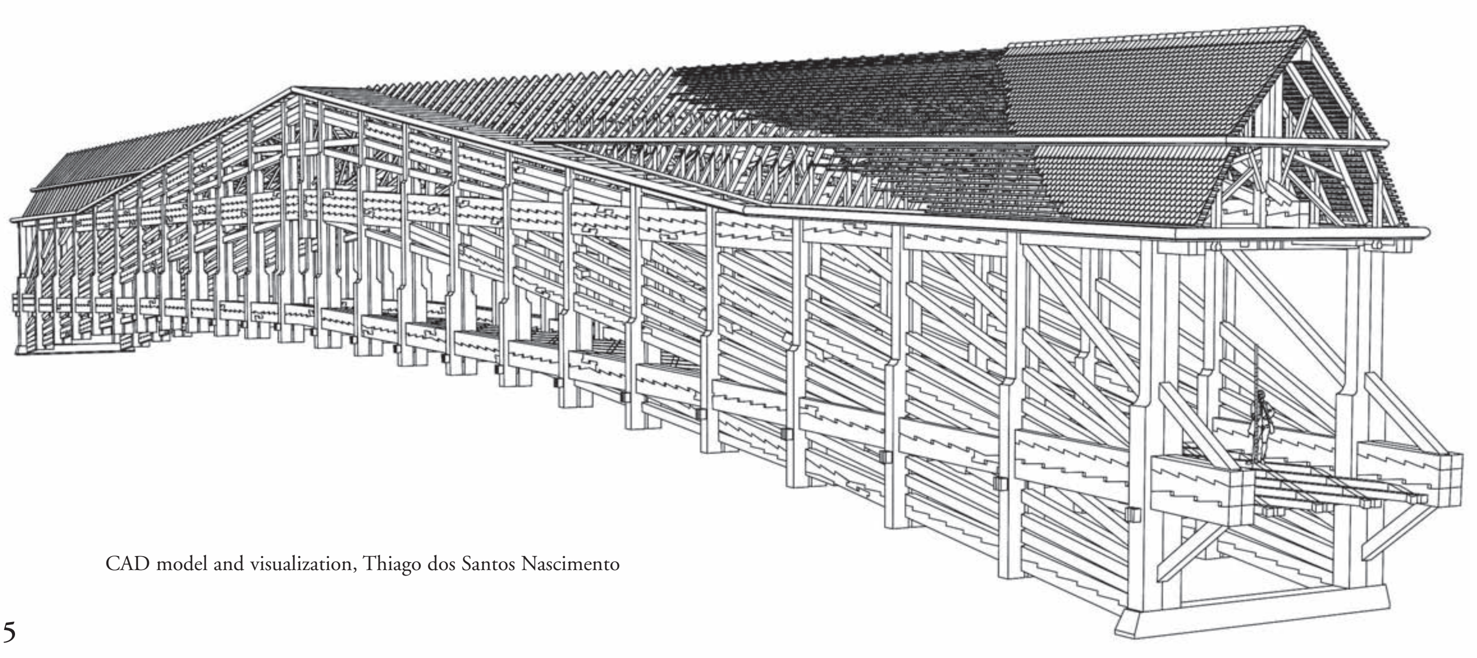
Inclined or cambered wooden truss designs in the 18th century show vertical posts despite increasing pitches. Christian Gottlob Reuß discusses the camber and design of the polygonally arched lower chords of two theoretical bridges in his treatise *Anweisung zur Zimmermannskunst* (instruction in the art of carpentry), published in Leipzig in 1764. He was designing and building a similar span over the river Elbe in Meissen at the time. As the inclines of the polygonal arch chord change at the junctions with the vertical posts, skilled setting out is required. An original model of his design still exists in the town archives in Meissen. Measuring the members revealed a 5-degree incline at the ends of the arch (Fig. 3).

J. C. Kraft's *Plans, coupes et élévations de diverses productions de l'art de charpente exécutées tant en France que dans les pays étrangers* (plans, sections and elevations of different examples of the art of carpentry in France and foreign countries), published in Paris in 1805, shows the famous Kandar Bridge, built in 1746, with all its construction details. While the deck is only very slightly inclined, the relatively flimsy structure gets its main support from a series of struts below that project up into the truss at 29 degrees from the horizontal (Fig. 4).

The design drawings of Hans Ulrich Grubenmann's famous unbuilt single-span road bridge over the Rhine in Schaffhausen from 1756, spanning a 390-ft. opening, show that the camber required a rise at the center of over 5 ft. 6 in. The lower chords sweep down from the horizontal and intersect all the vertically arranged posts at varying angles along the way (Fig. 5). Admittedly the greatest incline (at either end) is only 2 degrees, but the design keeps the posts vertical and does not arrange them as radials from the origin of the camber radius. When notching the posts and a bottom chord, both would have had to be marked very carefully to account for the constantly changing angles.

These structures show how, despite inclines, vertical posts were considered preferable. The Erlenbach trusses built in 1816 follow this tradition. The posts are vertical and intersect the upper and lower chords at an angle between 28 and 29 degrees. Diagonal intersecting of posts with struts and the like was well known to framers and so would pose no real problem for construction.

In viewing the Erlenbach bridge design as a series of transverse vertical frames suspended over struts or stood on piers and linked by upper and lower chords, it is easy to find parallels in local and



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5 Hans Ulrich Grubenmann's design for single-span road bridge over the Rhine, Schaffhausen, Switzerland, 1756, 390 ft., never built.

6 Wynigen bridge, Burgdorf, over river Aare, 1776. Bridge was moved a few feet upriver in 1959 to make way for concrete bridge able to carry heavy traffic.

other Bernese contemporary covered bridges with horizontal trusses. A bridge over the river Emme in the town of Burgdorf, a bridge over the river Trueb near Sidelen and two in the town of Langnau im Emmental over the river Ilfis, all within 30 miles as the crow flies, are relatively close in age and could have served as design prototypes.

The oldest of the four, the Wynigen bridge in Burgdorf (N47°03.521′ E7°37.832′), over a small side branch of the river Emme on the edge of town, was erected in the same year that the United States declared its independence, 1776, some 40 years before Erlenbach (Fig. 6). The bridge (now load-rated for pedestrians) consists of four identical 37-ft. spans and was built by master carpenter Johann Jakob Staehli. Each span consists of two queenpost and strutted trusses, set parallel 14 ft. apart, from which the transverse floor beams are suspended. The four trusses on each side of the roadway are linked together by continuous

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upper and lower chords. Posts at the piers and abutments are naturally in compression, supported at their lower ends. But the intermediate queenposts are in tension as they are hung from main braces and horizontal straining beam that form the upper chord of the truss.

Above deck the similarities to Erlenbach are obvious. There are no continuous tie beams at plate level spanning between the two truss assemblies. Instead a three-sided transverse polygonal arch, a *liegender Stuhl*, connects two opposing posts and supports the roof framing at every principal crossframe, increasing the height of the main passage into the roof space above the upper chords (Fig. 7). Below deck, unlike the bridle joints between posts and transverse floor beams at Erlenbach (to be seen later), the Burgdorf floor beams rely on iron straps and bolts to suspend them from the lower chords, rather than carpentry (Fig. 8).

8

The liegender Stuhl comprises a pair of inclined struts, a straining beam and straight diagonal braces lap-jointed over the posts and straining beam. In this case the braces pass the straining beam (as well as the collar beam just above it), cross each other and extend to the rafters on the opposing sides, forming an integrated scissor truss. Given the two structurally rigid solid triangles at purlin level, the abundant bearing of the passing lap joints and not least the contribution of the scissor, the only part of the rafters remaining subject to deformation would be a short stretch above the plates, and for this the designer had a thorough solution too.

The Stuhl is mortised into stub (or interrupted) tie beams apparently notched over the upper chord passing through the joint of the compound posts. To achieve rigidity here, curved sling braces tenon into respective mortises in the inner wall post and the inclined strut of the liegender Stuhl. Bolts hold the sling braces in position (Fig. 9).

9

This remarkable sling brace device joining post and principal

10

rafter and allowing an open roof can be seen in several other local bridges. The Ramseren bridge (N46°55.446′ E7°49.155′), two miles southeast of the town over the river Ilfis, was erected in 1793, 23 years before Erlenbach. The bridge is 95 ft. long in a single span, still open to motor vehicles, and rated at 4 metric tons. The trusses are divided into eight bays, with compression posts at the ends and a suspended post in tension at the junction of each bay, making seven suspended posts per truss. The suspended posts are divided into an inner and an outer post in order to clasp the main braces.

There are four systems of braces, three of which each form a single queenpost system and one kingpost system, one stacked above the other with space in between and each transmitting its portion of the load to a different section of the truss (Fig. 10). The fourth system is formed by the simple struts at either end and the top chord as the straining beam. Again the transverse floor beams are suspended using iron braces instead of a carpentry solution.

The open roof uses the same liegender Stuhl construction as in Burgdorf, but the detailing is different. The straight diagonal braces at the upper angles of the liegender Stuhl are short and smaller in section than at Burgdorf. They do not extend to opposite rafters. The ends are notch-lapped with decorative curved edges to the tenons. Wooden pegs hold them in place. The junction of the liegender Stuhl with the stub tie beams is as at Burgdorf, but here the sling braces are not mortised but lapped over the rafter, liegender Stuhl, stub tie beam and inner post. The lower ends of the sling braces are similarly decorated with curved tenon edges (Fig. 11).

Four years later, a similar bridge to Ramseren's was erected by local framers two miles downstream on the outskirts of Langnau. The Moos bridge (N46°56.276′ E7°47.934′) has a smaller 64-ft. freespan but identical eight-bay trusses with multiple queenpost

11

7 Wynigen bridge, Burgdorf, Switzerland, 153 ft. in four spans, 1776. By omitting tie beams, useable height is notably increased.

8 Transverse floor beam at Burgdorf is not joined to posts but attached with straps and bolts as is common for such bridges.

9 Wynigen's sling braces, slightly curved, terminate in stub tenons. Bolts attach the braces to the *liegender Stuhl* and post. Some posts lean out, suggesting frame was insufficiently rigid to resist thrust.

10 Ramseren bridge, Langnau im Emmental, Swizerland, 85-ft. span, 1793. Doubled main braces on shallow incline, increasing horizontal thrust component of truss, lead to heavy sections.

11 At Ramseren, suitably curved grain produces almost perfect sling brace, lap-jointed to four timbers to form solid tie.

12 Moos bridge, Langnau im Emmental, 64-ft. span, 1797. Heavy main braces pass through built-up posts. Rhyme celebrating building of bridge is painted on upper chords and records Christen Habbegger as master carpenter. Bridge carried local traffic for 177 years until 1974 when it was moved upriver to serve pedestrians and replaced by concrete.

13 Pedestrian entrance to Moos bridge. Note decorative portal framing.

14 Substantial doubled iron straps support floor beams, which stiffen post lower ends via upcurved braces.

arches and a kingpost system, all built of European spruce (*Picea abies*). The liegender Stuhl roof construction is identical and copies the Ramseren bridge in its detailing (Figs. 12 and 13).

The light floor deck (for pedestrian traffic only) reveals more of the lower ends of the posts, where it can be seen that curved braces were employed to stiffen the posts by connecting them with the underslung transverse floorbeams (Fig. 14). (The same detail is found in the Ramseren bridge.)

The youngest of these local bridges with similar details is the Siedelen bridge over the river Trueb (N46°56.254′ E7°52.471′), near the village of Trub (Figs. 15 and 16). This small bridge was built by framer Peter Bächle in 1808 and moved downstream to its present location in 1977. The bridge is only 47 ft. long with double-queenpost trusses but sports all the details of the Ramseren and Moos bridges. In the early 1800s, this is how covered bridges were built in this part of the canton of Bern.

15–16 Siedelen bridge, Trub, Switzerland, 47-ft. span, 1808, refurbished 1977 and moved downstream. Still open to motor vehicles, its roof frame bears plaque with historical information including reference to framer Peter Bächle.

17–18 Neubrügg over river Aare near Bern, Switzerland, 302 ft., 1535, third "new bridge" built to replace earlier failures. Unique not just for its old age, but also because it is not straight. Last span bends off axis. Deck is 17 ft. 6 in. wide.

The design, however, is much older and can be traced back to the 16th century. The Neubrügg bei Bern (New bridge at Bern, N46°58.428′ E7°25.687′) over the river Aare was erected in 1535. It's the oldest known of this type and is still open to traffic (Figs. 17 and 18). All the elements previously described are present. The tie beams in the roof are probably a later addition. The kingpost trusses are much simpler and more robustly built than their 18th- and 19th-century counterparts.

19 Erlenbach bridge portal lower end with date carved in cross beam.

20 Erlenbach floorbeam is set plumb, rather than in plane of deck, with resulting compound connections to X-bracing.

21 Queenpost system lies in chord plane of lower truss, kingpost system is offset inward.

HAVING seen the framers' tradition in some detail, we can now look at the Erlenbach bridge construction in a new light (Fig. 19). The posts and open roof frames in Erlenbach follow this tradition, but no liegender Stuhl support structure is fitted to stiffen the roof transversely. Given the diminutive size of the Erlenbach pedestrian bridge compared to the road bridges discussed, and supposing the builder assumed that snow would quickly be shed from the steep compounded pitch of the roof, the lighter design was an efficient solution.

The lower ends of the suspended inner posts finish in bridle joints trenched across the underslung transverse floorbeams and secured by a bolt with split pin (Fig. 20), which also supports the floorbeam. The two Erlenbach freespans are not identical. The lower span truss is divided into four bays, the upper into three (Fig. 22). To keep the post braces in the trusses at practical angles, the upper truss is constructed as an asymmetrical kingpost with both braces at almost identical angles. The upper brace traverses just one bay, the lower two. The braces are offset from the centerline of the chords toward the inside of the bridge (Figs. 21 and 22), which is unusual, and it's not clear why this is so, possibly to leave room for the queenpost truss to bear on the lower chord in the lower, longer span (Fig. 21). The longer, lower brace is lap-jointed over a suspended post and was obviously added after the post had been put in place, but did that happen as part of the original erection process or are the braces an afterthought?

The lower truss uses a compound kingpost and queenpost assembly over the four bays. As in the upper truss, the lower kingpost system uses two similar angled braces, both set to the inside of the bridge. The lower brace is extremely long and crosses two suspended posts before passing through the floor and becoming a strut directly supported by the abutment. Again these braces must have been added at the end of the assembly sequence.

The queenpost system is set in the chord plane. It too is asymmetrical. Being in the same plane as the chords, it must have been integrated in the truss with the posts and not added later. There is no discernible deformation in the trusses, so the idea worked and continues to do so.

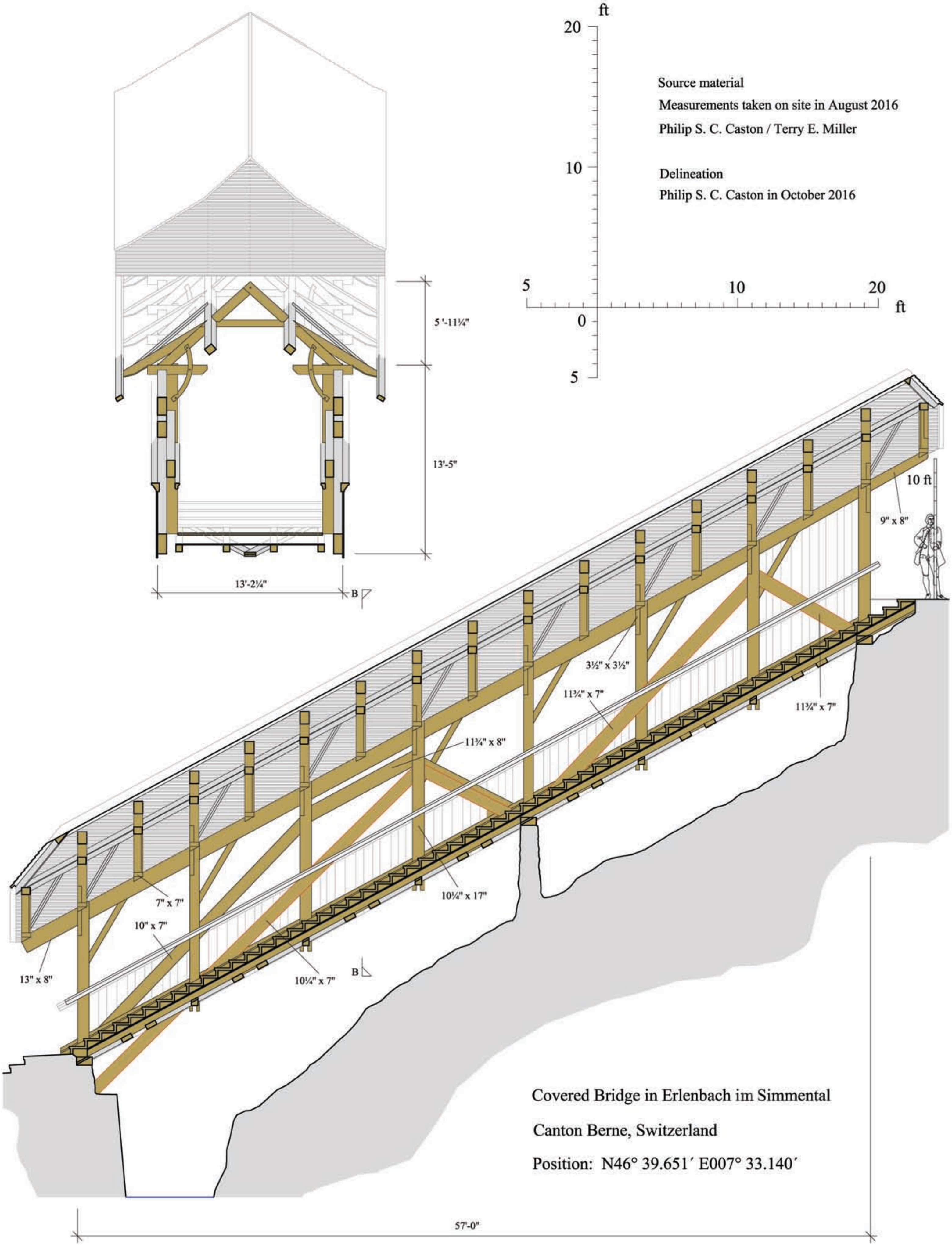
In all the roofs of the other bridges looked at so far, principal purlins join or pass through the liegender Stuhl upper angles and run horizontally along the underside of the rafters and collars. In the inclined roof of the Erlenbach bridge, the purlins instead lie flush with the tops of the rafters and join them in trenched halving joints. Since the purlins are crossing the rafters at the angle of incline, plumb cuts for the halving walls are not perpendicular to surfaces, nor are seat cuts in the rafter half, but must be laid out at the angle of incline. Collars at every rafter pair take the compressive roof load transmitted by the purlins.

One final problem that arises with the inclined bridge is the roof tiling. Overlapping flat tiles (in this case with arrowhead butts) are also limited in how far they can be inclined sideways. The solution chosen in Erlenbach was to lay the battens diagonally over the rafters and sprockets in horizontal layers with respect to the ground, so that the tiles hang normally. This poses a geometrical problem, because the sprockets fitted over the rafters are pitched slightly shallower. The sprocket plane intersects with the rafter plane roughly along the line of the purlin and it is here that the battens have to be adjusted somehow. It is not easy to determine what the tilers did.

The on-site realities are not so clearcut or demanding as a precise CAD simulation. The battens are irregularly shaped and the tiles not perfectly aligned. Any minor planar differences nearly disappear under these circumstances. Looking along the roof surface, one can see the gentle rise of the sprocket and sense a change in direction of the horizontally laid tiles.

This enigmatic and unique covered bridge posed challenges which the designer overcame by adapting traditional Bernese bridge building techniques to extraordinary circumstances. The very first impression when seeing the bridge in its setting is one of amazement. You may have seen it all before, but never like this. It is well worth going that extra mile if you are in the vicinity. Oh, by the way, Happy Anniversary! —Philip S. C. Caston

Philip S. C. Caston (caston@hs-nb.de) last wrote (TF 121) on the Wildhof covered bridge, in Ahrensberg, Germany, an example of 20th-century European use in wood of the American Howe truss.



22 Cross section and longitudinal section of steeply inclined covered pedestrian bridge, Erlenbach im Simmental, Switzerland.

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THE TIMBER FRAMERS GUILD
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