TIMBER FRAMING

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An Open Timber Roof in Denmark

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On the front cover, open house for friends and family of the building crew at an extensive project in Stubbegaarden, Denmark. The big hole in the wall is the beginning of a walk-in fireplace, which on the day of the picture reportedly acted more as a walk-out fireplace. All masonry is laid in lime mortar. Open timber roof is made of Danish-grown Douglas fir. Photo by Jesper Lau Olesen. Story, page 16.

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1985

BOOKS
Green Oak

Green Oak in Construction, by Peter Ross, Christopher Mettem and Andrew Holloway. High Wycombe, Bucks, UK, Trada Technology Ltd., 2007. 8⅛x10⅝ in., 184 pp., copiously illustrated. Paper (Smythe-sewn), $110 fromS ummerbeam Books.

LIKE London buses, we'd say—no books for decades on new timber frame construction in the UK, and suddenly two turn up almost at once. Hard on the heels of Rupert Newman's *Oak-Framed Buildings* (reviewed TF 81), we have this most welcome addition produced by three figures well known to UK oak framers: Peter Ross, formerly of Ove Arup, consulting engineers; Christopher Mettem, of Trada Technology; and Andrew Holloway, founder and proprietor of The Green Oak Carpentry company in Hampshire.

It's important to set the publishers, Trada Technology, in context. The Timber Research and Development Association (Trada) is a not-for-profit membership organization, internationally recognized for its work on the specification and use of timber and wood products. In the UK, those from the oak world may think of the Trada of old, known primarily for being deeply concerned with plywood and fire doors. It's important to recognize that Trada has broadened its outlook and embraced the world of oak. Trada Technology, the publisher of the present book, was until 1994 wholly owned by Trada, but is now part of the Chiltern Group of companies, though it remains Trada's "appointed provider" for research and information programs.

As for "green" oak, it merely means unseasoned. Green oak is very fashionable in the UK these days, and we find more and more "construction professionals" specifying it—and finding novel ways to do so. Recently I had a request for "Green Oak kiln-dried to 12 percent moisture content."

First, a summary of the book's early chapters. A brief and effective introduction, coupled with some photos of a modern cruck and stainless steel building (more of this later), proceeds to green oak past and present, Chapter 2 showing a wealth of traditional English black-and-white houses and concluding with some of the better examples of modern-day oak framing. Chapter 3 deals fairly briefly with the supply of green oak and concludes that it is a cost-effective, sustainable and environmentally friendly material. Chapter 4 covers the properties of oak, with some very good stuff on drying, shrinkage and movement. Chapter 5 covers design of green oak structures and does a good job in the space allocated,

Erratum

Douglass C. Reed, of Preservation Associates, Hagerstown, Maryland, was incorrectly represented as Douglass Reid in the TTRAG 2007 Proceedings published in TF 84. The editor regrets the error.

though the topic really ought to have a book of its own or even a series of books. Certainly it's impossible to cover the subject thoroughly and make everybody happy within the space of a short chapter. Chapter 6, on the green oak framing process, opens with some sound thoughts on timber selection and use and goes on to make the very sensible (but often overlooked) point that "powered tools are essential to complete the work economically and within an acceptable timescale." The actual process of framing up is distilled to its essentials in three fairly concise paragraphs.

The next section briefly treats automation, and here I must comment. The Hundegger K-2 joinery machine at our own company (T. J. Crump Oakwrights in Herefordshire) is pictured in the book, and familiar clichés are dragged out to accompany it—the timber has to be better quality and has to be planed true and square on four sides, the joinery doesn't use drawboring (offset pegging), and "turned dowels are often preferred for jointing, sometimes from kiln-dried furniture-grade white oak from North America." In fact, we routinely use a 2mm drawbore and we prefer turned pegs for their enlarged diameter at one end, useful for sealing the pegholes on surfaces exposed to weather, as our frames mostly are.

If you build traditional English house frames with weatherproof infill panels, timbers exposed inside and out, 6x6 oak studs on 2-ft. centers and midrails at waist height, that is a lot of carpentry over a substantial proportion of the timber faces, which in turn means that opportunities are slim to hide defects in the timber where they won't affect weathertightness (at the very least). This better explains why much of the timber we use has to be fairly good.

It may not be apparent to North American framers reading this review that a vocal portion of oak framers in the UK advocate for the worst available timber quality (above composting grade but not quite good enough for firewood) and that it should never be planed, nor should it ever be remotely square or straight, and that pegs should be wrought by hand from off-cuts of timbers too good to make frames out of.

It can be argued that most technological advances are evidence of the dumbing down of the construction industry, and it's tempting to point the finger at the UK's oak garage market, where most UK Hundeggers are employed. One then falls into the trap of depicting the machines as dumbed-down weapons of mass production, spewing out trimber-framed country-style buildings. At the same time there are also people who grasp the nettle of advancing technology and harness the power of these computer-run machines to do things that you wouldn't sensibly contemplate doing by hand. (For instance, we have a previously undreamed-of scarf joint under university testing.) If it's true that "powered tools are essential to complete the work economically and within an acceptable timescale," the Hundegger is nothing if not a big kit of powered tools. Where do you choose to draw your line? There are plenty of people in the UK who hate the Hundegger yet wax lyrical about their collection of *portable* cellulose-modification machinery.

Our approach to oak framing also means that 80 percent of the grunt is done by the machine. There are 14 framers (more than when the machine arrived here five years ago) in two workshops who do the (much-maligned) cleaning up after the machine; they also do embellishment and decoration, plus most curved work and its scribing to the frames—sling braces into a wide truss, for example. Our methods allow us to employ a group of people of widely different ages and not wear them out. By using the Hundegger, combined with overhead cranes or gantries plus lots of forklifts, we have virtually eliminated bad backs (except, perversely, in the office). We have five people on the shop floor who are over 50 and one approaching retirement age at 65 who has asked if he can work on. Computer Numerical Control as embodied by Hundegger is the industrial revolution for timber framing, and I'm sure that its implications should not be dealt with so lightly as the Trada book does.

WHEN we oak framers started out, we learned from people who reconnected us with the idea that wood was a natural product, not some extruded material. The oak that we used came from local mills and the scale of our operation didn't give us a lot of clout when it came to purchasing. So we were happy to get what we got, when we got it, and we made the most of it.

This involved getting the timbers onto the sawhorses, then rolling them or spinning them end for end and shuffling the joinery up and down the available length to avoid the worst of the defects, all the while taking account of the need to orient the heart against the weather (heart up and out for a top plate, and out and down for a sill) and the crown of horizontal members up, and getting the sapwood turned up into compression for spanning members. We also had to make decisions about a timber's ability to take the loads and stresses in service and to predict how it might behave as it dried, hoping it wouldn't embarrass us in years to come.

If these often-conflicting requirements didn't work out, we might swap the timber for the one on the opposite side, or for its cousin at the other end of the frame. And in the final allocation any further latitude in the timber orientation allowed us to hide the faces with the most unsightly defects. With the small numbers of people involved in the process, we could choose to make more radical swaps, changing section sizes or even the general arrangement of timbers in the design to make the best use of the timber available. This whole process was often challenging but at the same time enjoyable. Given my Scots upbringing, I was ecstatic when a seemingly hopeless case could be found a place in the frame where its shortcomings were not too detrimental.

In the days when we had the luxury of doing things this way, our engineer generally didn't do any calculations. He just looked at the proposed arrangement of timbers and their sizes and said Yes (or sometimes No!). He then wrote a letter saying that he had looked over the drawings and, having satisfied himself that the design would work, certified it to be fit for purpose. This process relied on a fair degree of trust between carpenter and engineer. He had to know that we were going to behave rationally not just in terms of the choice of timber, but also in the selection and quality of the joinery.

In an ideal world it would all scale up. But even with the best will in the world, it doesn't scale up as companies and organizations get bigger. It would be a long inquiry indeed into why a successful process whereby the framer has a very close relationship with the frame, the materials and the client can't be made to scale up as the company gets bigger and employs more people. But we do know that over time we have had more government intervention, more required standardization, more calculations. And as people became more and more protective because of their liability, our local authorities, guardians of building standards in this country, hired third-party structural engineers to check the workings of the appointed engineer, adding to the pressure to adopt and adhere to the recognized building code. These third-party checking engineers generally knew less than not very much about green oak frames. It's not surprising that guys working for an engineering practice that double-checks the workings of other engineers are not radical, broad-minded, lateral-thinking, can-do problem-solvers (like us), and are not going to rubber-stamp anything that they can't get to conform to a published British standard.

Some relief on materials at least may be at hand. The information in Chapter 6 of *Green Oak* on timber selection has been well thought through and supports proposals for grading . The authors propose a system of three grades (and I assume a failing grade), much better than the two extremely silly grades we have now: THA, far too good, and THB, absolutely no good (T= Temperate, H = Hardwood, A = A grade, B = B grade, all relating to British Standard BS 5756). British Standard Code of Practice CP 112 and

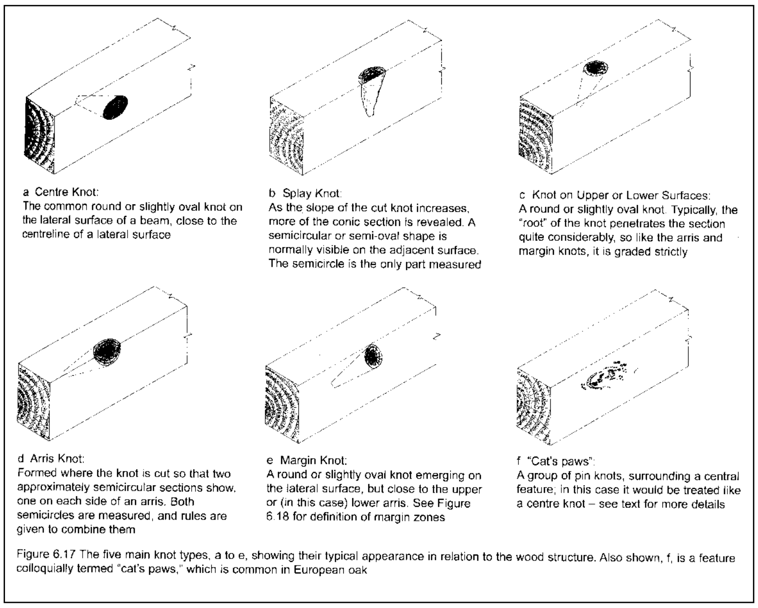

Fig. 1. **Green Oak** *Figure 6.17, a depiction of knots in connection with strength grading. Arris and margin knots lie outside middle half of timber and so affect strength values more than knots near neutral axis.*

its associated allowable stress classes 55, 65 and 75 have been around in various forms for 50 years. Despite being superseded by the THA-THB nonsense, these earlier grades are still referenced for allowable stresses by those engineers who have a good grasp on how it all works.

Like most UK oak framers, we buy a lot of timber from France, where the European Organization of the Sawmill Industry observes a common grade QPA (our translation: "Almost Good Enough"), largely okay for barn-style building save for items like purlins and unsupported tie beams. Certain attributes (like spiral grain) make it not quite good enough for traditional English infill panel frames. Spiral grain is one of the most devastating overlooked defects in timber, and continental timber also suffers from ring (or cup) shake, which has a nasty habit of not revealing itself until very late in the game. Rarely, we do upgrade purlins or other critical members to THA. We struggle with our own in-house grades ("Good Enough" and "Not Good Enough"), which are similar to some other UK end-user grades. I like the idea of the rational system proposed in the book, backed up by detailed analytic information (Fig. 1), and I'd like to see it working.

CHAPTER 7, enclosing green oak structures, brings me to my next gripe. Hold on just a moment. Enclosing green oak structures? What about infilling? For many (I dare say most) people, oak construction in the UK is typified by the half-timbered black-and-white traditional English cottage or the H-shaped manor house. This book, however, really does not say a lot about this popular method of construction. There are plenty of photos of historic frames but nothing in particular about new infill panel construction save for a fairly generic drawing (Fig. 2).

After garage builders (the majority of green oak frames built in the UK are garages), the two biggest oak frame builders in the UK specialize in these traditional English half-timbered oak frames. Ironically, these two oak framing companies are the only ones to have their entire process and systems successfully assessed by Trada (the book's publisher, remember) and who are thus able to meet the warranty requirements of the National Home Building Council. The ability to get NHBC approval is vital to many clients to secure mortgage funding and to get the 10-year warranty without which it is virtually impossible in England to resell a house less than 10 years old. The Trada assessment process is lengthy, comprehensive and thorough (and, I should add as a Scotsman, expensive). So why is the most traditional and the only approved-by-Trada system of green oak frame construction skimmed over?

Chapters 8 and 9 deal with exterior uses of timber, with good stuff on detailing bridges, and case studies. Now what is it about gridshells that gets a certain constituency of the oak framing world very excited? I don't see the attraction and I have never grasped why gridshell construction and traditional heavy structural carpentry should have any sort of affinity. I'm not sure how many enclosed gridshells there are in the UK, probably fewer than half a dozen. Certainly Andrew Holloway (one of the book's authors) has mastered the art with two very well-known examples that have won bucketfuls of accolades, awards and prizes (Fig. 3).

Having built a fistful of much smaller examples at the Earth Centre in South Yorkshire, I have a good appreciation of the skill required to overcome the difficulties in erecting these buildings. What I don't have is much respect for the buildings themselves. They are not really practical or economical to frame or to clad and close in. Again we find that the cost of the fastenings, and the labor involved eradicate any financial savings. Once you get over their groovy shape, they don't have a lot going for them. Since most of them seem to be located at visitor attractions, however, maybe nobody hangs around long enough to get bored by them. As novelties they deserve mention, though I do question whether green oak is the most appropriate material for their construction—and in a book about things being constructed from green oak in the UK, why is there nothing about garages? In numbers of buildings or even in value of buildings there are far more garage-type outbuild-

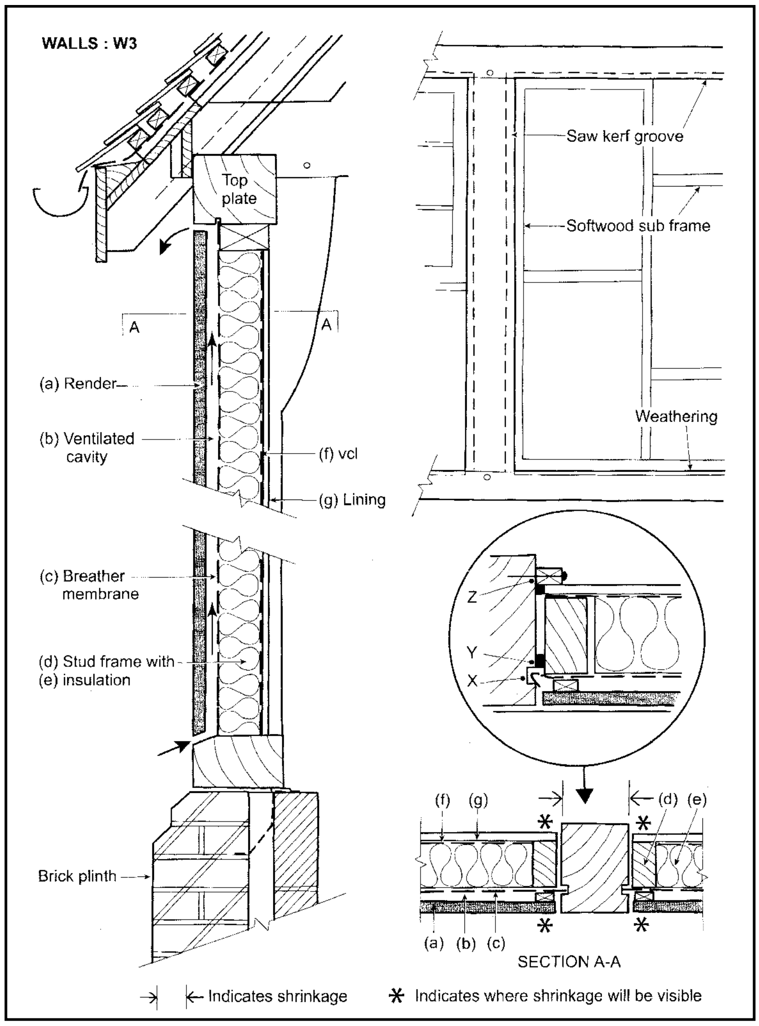

Fig. 2. **Green Oak** *Figure 7.43, "Wall Construction in plane of frame," specifications for one system of infilling timber frame wall, with appropriate warnings about shrinkage and direct air infiltration.*

ings built than houses, and far more garages erected in any one week than the total number of gridshells erected in the last 20 years. Plainly the public have an affinity for oak-framed garages, and this book might have provided a good opportunity to improve the quality of framed garages for hundreds of people each year.

HAVE people become tired of repeating the same old mortise-and-tenon projects? Some practitioners who have been around a while and have ceased to be challenged by traditional frame construction are happy to embrace whatever the current architectural whim. In doing so, they ignore the newer workers in the field who are tasked with making it actually happen on the shop floor. I have lost count of the times I've had to reassure a disgruntled worker complaining that he signed up to make oak frames with mortises and tenons, not to be a spanner monkey.

And, unless cursed with an affection for the latest architectural fad, people instinctively attracted to timber frames don't really want big lumps of cold hard steel in the middle of their living space. Steel doesn't really do much for the ambiance and is certainly not child-friendly. One house featured in the introduction is pictured showing the base of a substantial cruck amputated at about 30 in. above floor level in favor of a stainless steel fabrication running the rest of the way to the floor (Fig. 5). It just looks so wrong, so uncomfortable, a complete disconnect. I am told that this architecture is supposed to challenge and provoke. But why would anyone want to be challenged and provoked at home?

In the UK most external finishes are of masonry and we don't often see timber used as cladding or siding. In recent years designers have been specifying it on fairly well-known public buildings. Aided by engineers in dealing with the classic issues of movement and corrosion of fasteners, the designers' new approach has led to a fair amount of reinventing the wheel. It has to be said that there are one or two well-reinvented wheels as a result, and the book gives them a fair showing. Buildings clad with timber acting as a rain screen invariably look really attractive, and anything that gets more timber into everyday use has to be a bonus (Fig. 4).

Photos by Buro Happold and Weald & Downland Museum from *Green Oak in Construction*

Fig. 3. Double-layer gridshell at Weald & Downland Museum, Sussex. Edward Cullinan Architects with Buro Happold, engineers, built by Green Oak Carpentry Co., about 49 ft. by 164 ft. in plan, 33 ft. high.

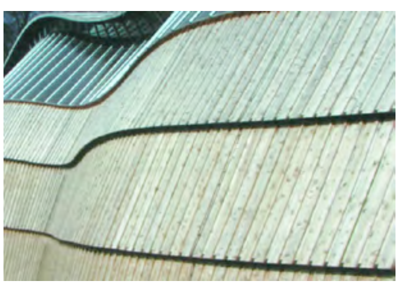

Fig. 4. Gridshell construction details. Above, assembling and bolting together a node with patented system of plates. Above right, European larch glulam arch over entrance. At right, cladding of UK-grown red cedar. Boarding is laid to account for expected cupping.

Photos by Ian MacNicol from *Green Oak in Construction*

Fig. 5. Composite waterfront house framed in oak and stainless steel, designed by Bl@st Architects and framed by Carpenter Oak & Woodland.

I SUPPOSE the biggest hurdle any individual buyer of this book will face is actually putting hand in pocket and stumping up the cash. Though I've bought three copies for the office and the design loft, even with the Trada members' discount the book is painfully overpriced. I have no doubt that institutions and architectural or engineering practices will buy it without experiencing any pain. The authors say in their introduction they hope the book will interest clients thinking of commissioning a green oak frame. Given the choice available for the casual reader, the cost of this book (at $110 some four times that of *Oak-Framed Buildings*) will probably see it left on the shelf. There is a wealth of good information in *Green Oak,* especially illustrated technical stuff. Sadly, the price will severely limit the book reaching a wider audience outside of the timber fraternity. —Bill Keir

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HISTORIC AMERICAN TIMBER-FRAMED STEEPLES

II. Restoration Strategies

This article is second in a series to discuss the form, function and joinery of selected historic American timber-framed steeples. The series was developed from original research under a grant from the National Park Service and the National Center for Preservation Technology and Training. Its contents are solely the responsibility of the authors and do not represent the official position of the NPS or the NCPTT.

THE difficulty of repairing a church steeple has as much to do with the problems of vertical access, scaffolding and rigging as with any esoteric carpentry involved. The architectural design, framing and finish work it supports, often the most elaborate, showy and prestigious in town, might include octagons or cylindrical forms, tall tapering spires and several telescoping stages, all located on a compact plan but 70 to 200 ft. above the ground (see Part I of the series in TF 83). Repair work can be carried out either from tall scaffolding surrounding the steeple or from ground level on sections of the steeple that have been brought down for easier access. Which method to use depends upon the condition of the steeple and how it was originally built—how amenable it might be to dismantling and re-erection in stages (Lewandoski 1995).

For example, at the 1839 Community Church in South Woodstock, Vermont, the shocking deterioration and failure of much of its three stages as well as truss problems below the steeple left no choice but to dismantle, and the lodged telescoping stages encouraged and permitted this approach and the fitting of a temporary roof (facing page). At the 1799 Town House in Strafford, Vermont (page 12), on the other hand, timber needing replacement was limited to the middle and upper sections of the semi-detached tall tower, while the 68 ft. of belfry, lantern, spire and vane above were in good condition. Furthermore, the specific site of the Town House on the crown of a steep mound left no level area for the placing of telescoping stages in the surrounding yard. Consequently, the work was carried out from scaffolding, in this case structural scaffolding that not only provided us access to the steeple but also formed the basis of rigging to lift the upper 68 ft. of steeple off its bearing in the tower and keep it there safely for two months.

Regardless of the chosen access strategy, our goal should be to understand the original design of the steeple well enough to never cut through framing members, but rather to detach them at their joints, to repair or remake members as needed and then insert them back into their positions.

SOUTH WOODSTOCK COMMUNITY CHURCH. The Community Church at South Woodstock, Vermont, built in 1839 in the Greek Revival style as the South Woodstock Congregational Chapel, provides an example of a structurally deteriorated and failing steeple restored with the intent to reuse or repair the maximum amount of its historic material.

Many timber elements from the 1792 South Woodstock Meetinghouse, then recently torn down, were included in the frame of the new 1839 structure. Most of the roof frame came from the previous church, reconfigured to a fashionable lower pitch and recut using the square rule layout method, which generally replaced the older scribe rule method of timber layout around the turn of the 19th century. The latter requires the laying of timbers against one another, and preassembly; the newer method allows the remote cutting of joinery and no preassembly. Signs of the scribe rule method such as unaccompanied marriage marks and empty joinery on kingposts and chords indicated timber reuse and the change in layout method.

The first two telescoping levels of the steeple, however, were made of new spruce timber combined with hardwood bracing that carried the marriage marks of the 1792 scribed frame. The eight turned butternut columns that form the belfry level were from the previous church and carried the remains of elongated, steeply pitched joinery and relict hand-forged bolts that once fastened tall spire rafters. In our repairs, we managed to reuse parts of six of the original columns.

The 1839 church appears in 19th-century photos with its current more modest short cone of a spire; no historical accounts suggest any alteration of the original. Typical for the period, the steeple is fully engaged in the body of the church. Posts 15 ft. tall emerge through the roof to form a square tower. These four posts tenon directly into tie beams in the roof frame rather than tenoning into sleepers (or distribution timbers) that cross two or three truss tie beams, the more common technique at the time (Fig. 1). The front of the tower was well supported by the front wall of the church but the rear stood over an open choir with an unsupported span of 42 ft. In an attempt to bridge this distance stiffly, the builders used the tower's two rear posts as queenposts in the first roof truss, with principal rafters as main braces.

The second square stage of the steeple rises from sleepers resting on girts 6 ft. down within the first tower (Fig. 1c) and carries the heavily framed bell deck 18 ft. above (Fig. 1a). The bell deck is in the form of a low-angle kingpost truss, the kingpost a short octagonal block of hemlock, 14 in. across the flats and with eight small mortises to accept the hip and principal rafters, the latter acting as four main braces for the truss (Fig. 2).

Some 8 ft. below the plates of the bell deck, four sleepers lodge diagonally across wall girts and carry eight butternut columns that surround the bell and support the short conical spire over the belfry (Fig. 1b). The 18-ft. butternut columns are notable for having been turned between centers to a tapering cylinder for their visible upper 10 ft. but left as debarked logs for their concealed lower 8 ft. The columns, thus rough and irregular for about half their length, nevertheless tenon into the sleepers in a regular layout governed by the central axis of their upper visible portion and the octagonal form implicit in the diagonal sleepers.

An original gin pole base, still in place across one of the corners of the second stage when we began work, suggested that the columns were brought up one at a time through openings in the bell deck. The lack of any joinery between the columns short of the spire framing, and a general lack of space, suggested that the upper octagon was not brought up from below as a whole, as was often the case in the erection of steeples.

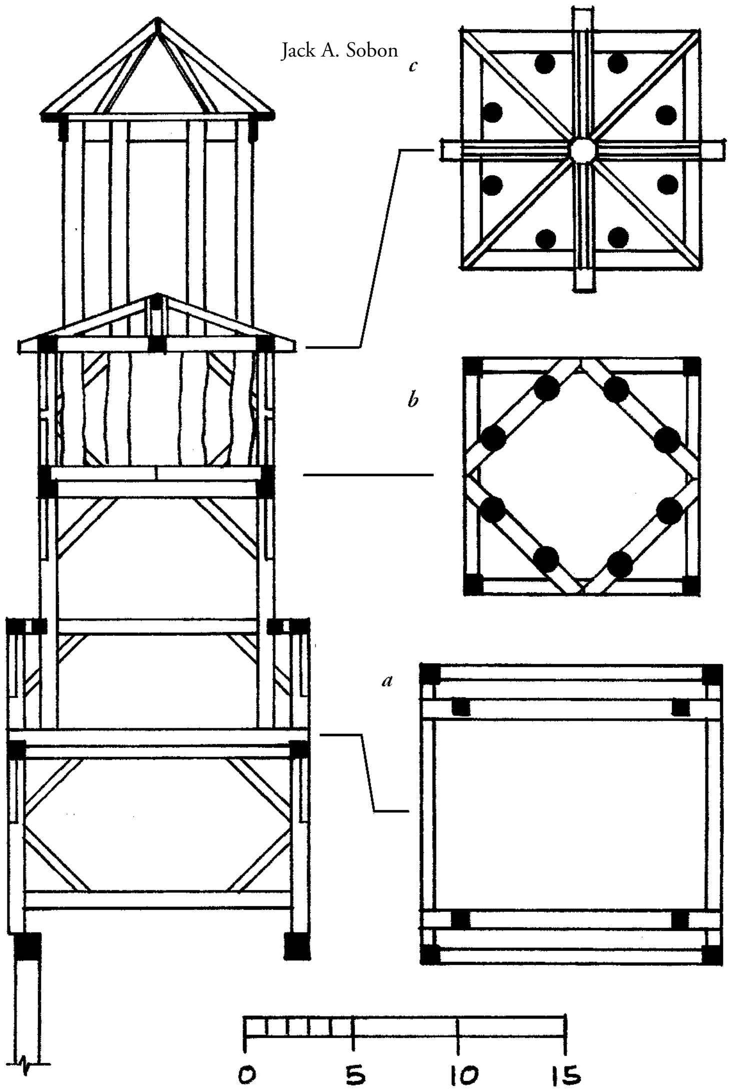


Fig. 1. South Woodstock steeple frame section seen from inside looking toward eaves of church. To form first stage, tower posts rise from tie beam in front wall of church (at left in drawing) and tie beam in first roof truss. To form second stage, posts rise from sleepers resting on girts 6 ft. down within first tower (plan view a) and reach bell deck (plan view c) 18 ft. above, intersected about halfway by horizontal framing (plan view b) to support feet of eight columns surrounding bell. Original columns were lathe-turned where they could be seen in belfry, left in the rough where concealed. Compare Fig. 14 on page 11.

Fig. 2. Original South Woodstock bell deck. Since belfry is open to weather on four sides, deck must be framed and sheathed to shed water. Rafters measure 4x4½, hips 3½x5. Short kingpost is 14 in. across flats.

Fig. 3. Steeple of South Woodstock church before repairs. Compound tilt, somewhat unusual, includes typical backward lean from overloading of the first interior truss combined with sideward lean from rotting posts and sleepers along the south side of the tower.

All photos Jan Lewandoski

Fig. 4. Greek Revival façade of South Woodstock Community Church after removal of steeple upper stages and capping of tower with light temporary roof. Church was built in 1839 as South Woodstock Congregational Chapel and took its present name in 1957.

Fig. 5. Original column butt with turning center and regularly offset tenon. Crescent section perched on top is from another column.

Fig. 6. Original mortise in sleeper, skewed as necessary to follow regular octagonal pattern. Ghost reflects hewn clearance reduction of column in Fig. 5.

Fig. 7. Layout for tenon on repaired column. Pierced hole at upper left crossing of lines represents reference center.

THE keys to dismantling, restoring and re-erecting any steeple are to understand its structural system and to interpret the original framer's intent, then to assess which failures are ascribable to avoidable decay over time and which ascribable to original design flaws or undersized materials. It's not uncommon to be confronted by framing that seems inadequate or baffling as to why anyone would do it that way. If the framing shows no evidence of stress other than decay or insect damage, however, it should be retained or reproduced in kind, regardless of odd joinery locations, small dimensions or low design values of the wood species.

Fig. 8. Distinctive scarf joint in progress between new column bottom and old column top. Mostly rebuilt bell deck in the background.

Quantitative engineering of historic wooden steeples is of limited use since no convincing analytic models exist for their performance. Often the exercise is better avoided entirely. While a calculation can be made of a steeple's overall weight, the effects of wind, and thus the impact on the sleepers or trusses that support it, looking for deflection or shear failure in the trusses or timbers can tell you as much or more. Quantitative analysis might suggest that a bearing member is overloaded or a vertical member is in danger of buckling failure but, if visual examination and measurement find no confirming evidence, you are wiser to have confidence in the thing itself rather than a theoretical model with excessively simplified assumptions about connections and load paths, and design values that may not accurately reflect the precise species or quality of wood or the snow and wind loading specific to the microclimate of the site.

Rather than opposing engineering analysis, I am recommending here the use of engineers, consultants or contractors experienced, or at least interested, in historic timber framing and willing to spend the time physically examining the artifact in great detail, not merely running the numbers. The appropriate form of engineering analysis for these frames that have endured the vicissitudes of existence for 100 to 250 years is qualitative. Analysis should proceed by looking for stressed joinery and excessive bending or buckling of beams and columns, or other evidence of progressive failure not attributable to water or insects, nor attributable to the unconsidered removal or severing of steeple structural elements by tradesmen, or to modifications made to the audience room below the steeple, such as the removal of galleries, columns or braces.

Fig. 9. Author smooths one of two new replacement columns, laid out, sawn, shaved and planed rather than turned as were originals. Bully surface where left rough suggests difficulty of finding good butternut today.

Fig. 10. Repaired columns using original lower ends, shortened to remove decay, in one case leaving enough sound wood for an integral half-tenon. Pale wood indicates free tenons.

At South Woodstock, the key to understanding the steeple was to observe that the three stages are not interconnected but merely lodged on sleepers within each other, attached by no more than the nailed small lumber and flashing of their skirting roofs. Furthermore, while the first and second stages are rigidly framed in themselves, the butternut colonnade has no column-to-column joinery connections, although it picks up some rigidity where it passes through the boarding of the bell deck.

Consequently, our pulling away the flashing allowed a crane to lift off the conical spire, then the eight columns separately (they all needed repair or replacement), and then the entire second square stage, setting all in carefully prepared frames on the ground. On the same day, a light temporary roof (Fig. 4) was placed atop the first square stage (the tower), which would be worked on in place since large portions of the church roof still depended upon it.

Restoration required copying the dimensions, species and joinery of the various members and reassembling them. The in-place tower called for extensive free and slotted tenoning since it couldn't be fully pulled apart. We were free to rebuild the second stage, however, as it was originally built. The butternut columns were elaborately repaired and two replaced, although finding reasonably straight and sound 13-in.-dia., 18-ft. butternut logs was difficult because of the present diseased state of the species (Figs. 8–11).

With the columns on the ground, we discovered the original turning centers, 2-in.-dia. holes 2 in. deep, giving us reference points for correctly locating tenons on the bottom of restored or replacement columns. An octagonal layout had been superimposed upon the diagonal sleepers, and mortises cut at eight regularly spaced points. We were able to cut (or insert) tenons on the bottoms of the columns at a regular offset from the turning centers to engage the sleeper mortises correctly to hold the columns plumb (Figs. 5–7, 10).

Fig. 11. Reconstructed bell deck admits scarfed and new columns (two at left) through the boarding to appear in the belfry as tapered cylinders.

Fig. 12. Structural stage inside church paired with another on the porch outside (see Fig. 4) provided base for lifting elements within tower.

Fig. 13. Tower required numerous scarfed repairs and whole-member replacements, using structural staging as jacking base for insertions.

We made structural improvements only where excessive stress was observed. The truss supporting the back of the steeple was not stiff enough to help carry the weight of all the stages above in addition to its own significant roof load, and had sagged noticeably when we began work, a problem endemic to steeple supports of the period. (The resulting backward tilt of many 19th-century steeples is a common sight today in New England.) At South Woodstock, this problem was amplified by extensive water infiltration into the two tower sections and resultant rot.

We strengthened the truss incorporating the rear posts of the lower tower by adding another set of queenpost main braces and another straining beam, parallel to the originals, as shown on the facing page. We installed these when the entire truss was lifted to level on structural scaffolding and the original truss connections, now relaxed, could be wedged tight as well. The structural scaffolding rose from the main floor of the church and from the inset front porch floor, with cribbing below the floor in the crawl space to bring the load to ground (Figs. 4 and 12).

Each pair of scaffolding towers carried large built-up beams passing through the second floor windows of the front gable of the church. Screwjacks atop these lifted the sagged truss chord to slightly above level so that the additional queenpost elements could be installed and then loaded. We also increased the sleepers for the octagon columns from 7x9 to 10x11 inches in response to sagging observed in the originals. After completing repairs to the tower (Fig. 13), we lifted the ensemble, stage by stage, back into position.

The question of how much you can recamber any truss depends not only on the weight and stiffness of that truss and any superimposed load such as a steeple, but on what else in the church you might be trying to drag upward with you. At South Woodstock, the front gable and the next truss in from the one we were improving were cambered slightly below level, so this set a limit to how far we could lift the truss located between the two. If screwjacks that have been readily lifting a frame element abruptly become much more difficult to turn, don't merely add more jacks at that location. Look to see what you are pushing or pulling with you, and either jack those adjacent elements individually or accept the level you have achieved.

Dismantling a steeple for the purpose of frame and flashing repairs also offers the opportunity to uncover changes in its form and finish that occurred over time. Decisions can be made (though not lightly, and with the participation of all vested parties) to return some portions of the steeple to an earlier configuration. In the case of South Woodstock, joinery for tall spire rafters existed, but the rafters may have been on the previous 1792 meetinghouse where the butternut columns had a former life. No images or descriptions of a former spire on the 1839 church existed, so any restoration would have been hypothetical and none was undertaken. On the other hand, the 1950s layer of white cedar shingles on the second tower level was found to cover a mostly sound finish of clear pine boards, 12–22 in. wide, hand planed, tongued and grooved, and mitered at the corners. Such flush boarding was typical of the Greek Revival and survived on the tympanum of the church. Since we had the artifact still in place, and 75 percent reusable, we left the shingles off and returned to flush boarding in our restoration.

STRAFFORD TOWN HOUSE. The Town House (1799) at Strafford, Vermont (Fig. 15, page 12), was built at the end of the period when New England town and church still shared financial and architectural resources, and the meetinghouse was used by both. With its steeple appended to the front gable of the building, not rising from the roof, the building's design was also conservative, what Edmund Sinnott calls Type II in his 1963 survey *Meetinghouse and Church in Early New England.* Sinnott's Type I is the square, hipped-roof meetinghouse of the 17th century

Jack A. Sobon

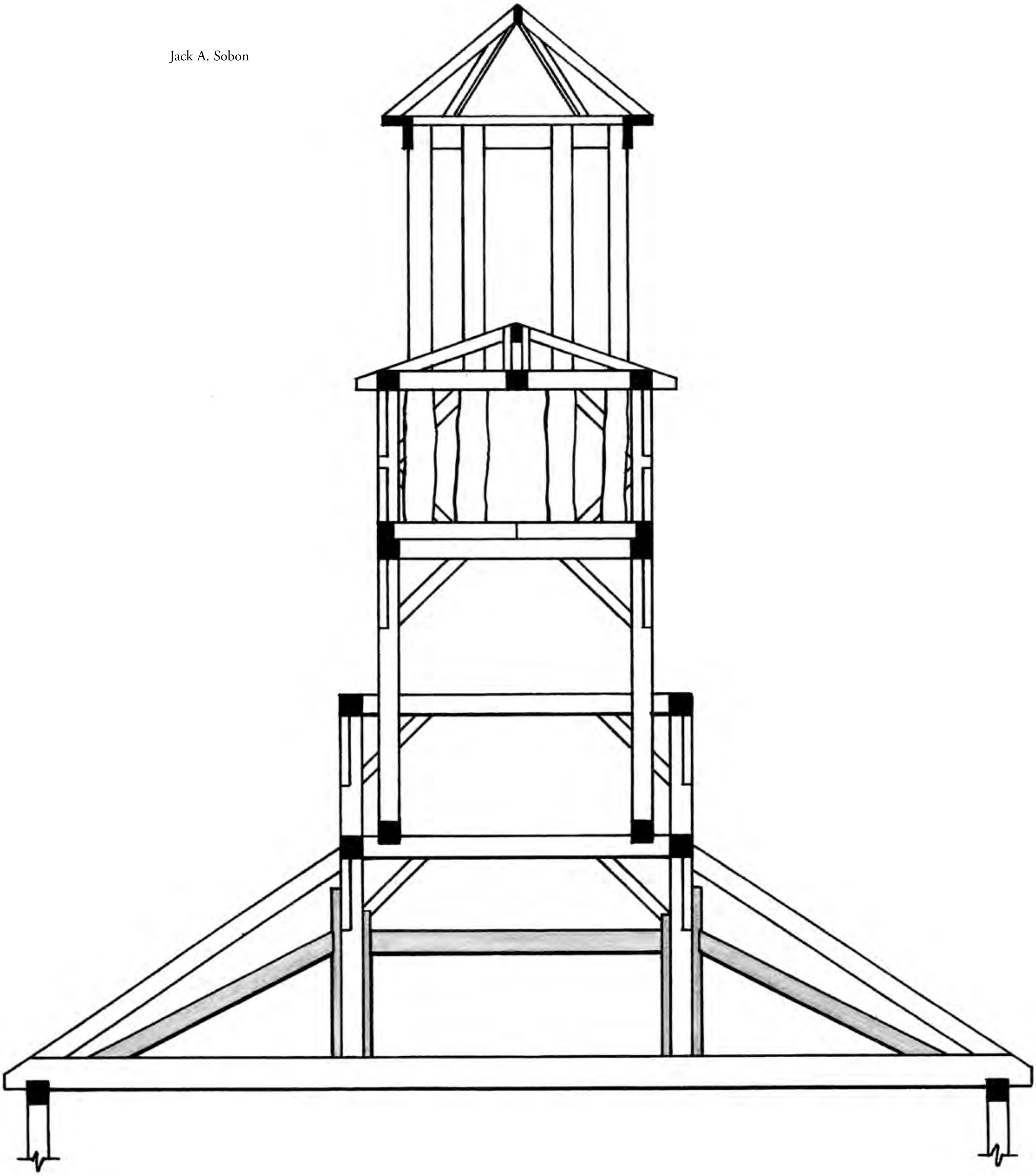


Fig. 14. South Woodstock steeple frame section seen from inside looking toward back of church, showing queenpost truss formed by rear tower posts and truncated principal roof rafters. Shading indicates stiffening elements added during repairs. Posts rising to hipped bell deck are continuous.

that sometimes carried a small turret or cupola at its center, but no steeple. Type II is the oblong meetinghouse of the 18th century with a semi-detached steeple rising from the ground at one gable end. The mostly postrevolutionary Types III and IV show the steeple moved onto the body of the church, rising from the roof and portico or the roof alone, and are distinguished only stylistically as Federal or Greek Revival.

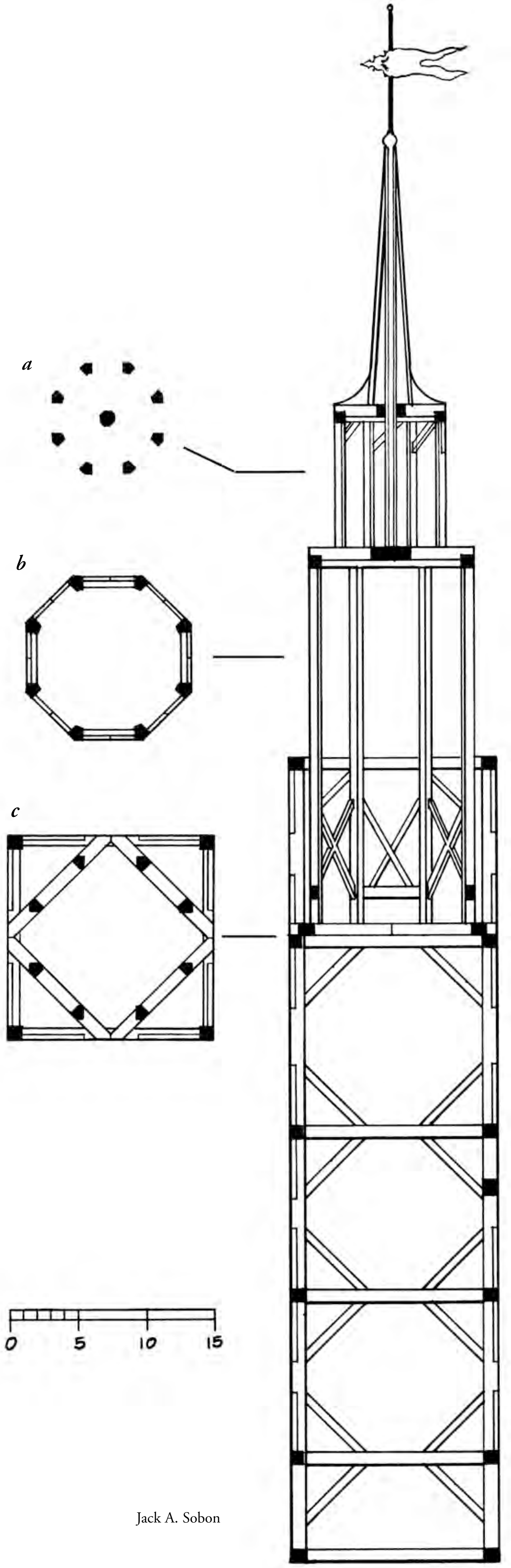
The Town House frame, its joinery laid out by scribe rule, is in a remarkable state of preservation. Even substantial areas of sawn white pine clapboard on the tower we found to be original, affixed with handmade nails, and in good condition. The trusses of this building have been discussed elsewhere (Lewandoski et al. 2006) and the entire history of the building, including design and construction, in Gwenda Smith's *The Town House* (1992).

Fig. 15. Strafford Town House, Strafford, Vermont, 1799. Author used structural staging to lift and internally hold 68 ft. of steeple while repairs were made in place to supporting tower girts threatening failure.

The steeple of the Town House comprises a 59-ft. tower, an octagonal colonnaded belfry rising from within it, a smaller octagonal lantern atop the belfry and 19 ft. of tapering spire exposed above that, capped with an ornament and weathervane (Fig. 15). Overall height is 115 ft.

The framing of the tower telescopes where exterior design allows. Belfry posts rise from diagonal sleepers 14 ft. below the roof of the tower (Fig. 16c). That tower roof is the bell deck as well, so that the weight and dynamic loads of the bell are borne first by cambered bell girts that cross the tower plates and then by the heavily braced framing of the tower below (Fig. 16). A horizontal timber crab (a frame with eight radiating legs) sits on top of the belfry posts, providing a base for the eight wall posts of the lantern and footing for the mast (Fig. 17). The mast, a 12x12x30 timber, rises through the lantern and offers a center for the spire and anchorage at the top for the weathervane (Fig. 16).

The framing of the Strafford steeple is very heavy and of thoroughly mixed species. The front tower posts, which go to the foun-



Jack A. Sobon

Fig. 16. Strafford steeple section seen from inside looking toward back of meetinghouse. First stage (tower) begins at grade and rises to bell deck, identical with tower roof. Second stage (octagonal belfry) begins on sleepers 14 ft. down in tower (section c) and rises to belfry roof (identical with base of octagonal lantern). Third stage (octagonal lantern) rises to base of spire. Spire mast is footed in belfry roof.

Fig. 17. Mast for Strafford spire is footed in eight-legged crab in belfry roof, which also forms base of octagonal lantern.

Fig 18. Structural staging supports cribbing to carry steel I-beams that lifted upper stages of Strafford steeple off supporting tower girts.

dation, are 11x11x59 single sticks of chestnut. The rear tower posts of beech drop 30 ft. from the tower plate to tenon into the front gable tie beam of the meetinghouse. The horizontal tower girts, typically 10x11 and 15 to 16 ft. long, are of spruce, white pine and beech while the bracing and studs are mixed hardwoods including sugar maple, yellow birch, red oak and beech.

One level of tower girts carries the four belfry sleepers, 10x9 pine timbers, set diagonally across the corners of the tower, each with mortises for two belfry posts with lower through tenons, unpinned (Fig. 16). These belfry sleepers lodge on the tower girts, as is typical, neither lapped in nor affixed in any way. Today's engineers, architects and contractors are usually shocked by this lack of a mechanical tiedown between telescoped stages, but my examination of 100 and more steeples indicates that uplift is not a problem at this location. Stages are better left only lodged, the intent of their historic engineering.

IN carrying the belfry sleepers and posts, the tower girts also carry the lantern, spire, vane and all 68 ft. of framing and finish above. The main problem to be remedied at Strafford was the failure of tenons on three of the vital tower girts. The cause of this failure was twofold.

First, water infiltration at the front of the bell deck had run across the tower plate and down the posts. All being chestnut, they suffered little harm. The same water entering the mortises for the tower girts of spruce, pine and beech, however, caused their tenons to be weakened by decay, though not totally destroyed.

Second, the braces and studs under the tower girts supported the outer 4 in. of a 10-in.-wide timber while the load of the 68 ft. of structure above was delivered by the sleepers to the inner edges of these timbers (because load always goes to the first point of stiffness). Meanwhile, the tenons of these supporting girts, 2 in. thick, 11 in. tall and set 2 in. from the outside face of the frame, unassisted by any bearing housings for the girts, took the entire eccentric load.

With few exceptions, American scribe and square rule framers from the 17th through the 20th centuries located tenons a framing square's tongue (1½ in.) or blade's width (2 in.) from an exterior reference face, almost ritualistically and regardless of the tenon's relationship to the forces it was expected to resist. At Strafford, with the weakened condition of the tower girt tenons, the eccentric loading and the absence of resistant bearing housings where the girts met the posts, rotation of the girts began to bend and break the tenons, threatening to drop the upper levels of the steeple.

Other problems at Strafford included a horizontal tower girt (not directly bearing upper steeple loads) rotted for half its length and needing a scarfed timber repair (Fig. 22 overleaf). The bell deck was leaking and in need of a new covering as well as replacement of some of its structural members, including two hip rafters.

Since the belfry, lantern and spire were to be left in position at Strafford, the rigging problem was how to lift these upper stages off the tower girts that were failing under load. The solution was to erect 42 vertical ft. of tied-together structural scaffolding around all three sides of the tower, footed on good gravel. On top of the scaffolding at two opposing sides of the tower we established framed cribs, each composed of two levels of stacked 8x9x17 hemlock timbers spread 5 ft. apart by tenoned 6x6s (Figs. 15 and 18).

The cribs would allow us to locate and freely move steel I-beams with which we would transfix the tower, rather than having to posi-

Fig 19. Eight 20-ton screwjacks (three visible here) push up under belfry post positions to lift Strafford's upper steeple stages.

tion them over the panel points of the scaffolding. From this high platform we carefully removed the original clapboards and wide sheathing boards, saving them and their wrought nails, to expose the girts we would replace and to provide a space for the steel to be slipped through. The 12x12 I-beams, 25 ft. long and weighing about 2000 lbs. each, were lifted by crane and beam tongs and guided into the tower to rest on wooden rollers over 3-in. planks (Fig. 18).

By counterweighting the load from within the tower, we could slacken the crane's lift line to free the beam tongs and shift them progressively outward, thus sending the steel inward. In this fashion we were able to slip three I-beams through the tower from crib to crib. At one point, the opening for the steel was so constricted by a sound diagonal brace we did not wish to remove that we moved an I-beam on oiled steel plates rather than 1-in. rollers, this small difference allowing us to get through the desired opening. A fourth position was too constricted entirely for the 12-in. steel, so we inserted a 7x13x20 yellow pine timber instead and, once it was in place, bolted on a 2¼x16 laminated veneer lumber (LVL) plank for further stiffness.

We placed heavy cribbing spanning the I-beams and 20-ton screwjacks atop these, pressing on 4x10 hardwood blocks under the belfry post positions on the belfry sleepers (Fig. 19).

Turning these eight jacks at first deflected the I-beams a couple of inches and then readily lifted the approximately 20,000 lbs. of upper steeple off the girts. At this point we were free to cut out the damaged girts and replace them with new timbers (spruce of very high quality), free-tenoning one end to engage the fixed frame, and then repair or reposition the diagonal braces that rose to the girts.

Resistance to the fatal inward roll of the girts, as well as support for the free-tenon ends, were provided by bolting 4x9 hardwood studs to the corner posts right under a girt joint to the post and at two additional locations under a girt where belfry sleepers bear (Fig. 20).

The same rigging and shoring we used at Strafford could be used elsewhere if horizontal sleeper timbers and post tenons were in need of replacement, as is often the case. Crossing steel I-beams with a grid of substantial plank or LVL lagbolted to the belfry columns will generally allow picking a belfry off its bearing sleepers

Fig. 20. New spruce tower girt supports diagonal sleepers carrying upper stages. Bolted 4x9 sisters at each end relieve 2-in. splined tenons of shear forces; long braces and median posts stiffen middle of girt against bending. At girt center, nutted iron rod (old but not original) runs back to tie beam of second interior roof truss.

if the pick points are reinforced above by blocks bolted to the columns or jammed against any upper girts between columns.

We reinstalled the several original clapboards with their original wrought nails on the east and west faces of the tower. On the south side, where more damage from sun and precipitation had occurred, we replaced the clapboards in kind with clear white pine, bandsawn with some taper and with a handplaned bevel along the top edge.

The bell deck was of great interest, with two versions still in place. The first, resting upon heavy bell girts crossing each other from the tower plates, comprised wide pine boards 1½ in. thick used in a sort of giant shingling (Fig. 21). The butt joints of these planks and the eight openings around the belfry posts had been caulked with oakum (rope fibers) mixed with tar, like the deck of a ship. However, unlike a ship's deck, no large crew would check the condition of its oakum caulking every day, so this deck failed to keep water out. Another had been built on top of it using 4x5 hardwood rafters, pine and spruce boards and painted pine shingles. Sometime in the 20th century this second deck was covered with galvanized metal. Throughout these changes, the columns were kept well flashed where they passed through the deck, a common locus of deterioration, and no problems occurred there.

Repairing the deck was straightforward. The metal and the wood shingles were removed, two hip rafters replaced in kind and the rotten boards renewed. The town had decided to try a membrane covering and a contractor laid it on ½-in. plywood so as not to attach it irreversibly to the historic bell deck. We left the original plank and oakum deck in place as a rare survivor.

—Jan Lewandoski

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Fig. 21. Old bell deck covering of thick planks caulked with oakum and tar revealed by removal of younger deck of rafters, boards and shingles.

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Fig. 22. Seth Kelley (at left) and Michael Cuba install stop-splayed and tongued scarfed repair to rotted wall girt in Strafford tower. Girt carries relatively light clock-room floor, does not support upper steeple stages. Free tenon (hidden by Kelley) allows insertion of new piece from side.

Danish Country Manor Open Timber Roof

All photos and drawings Mikkel Johansen except below

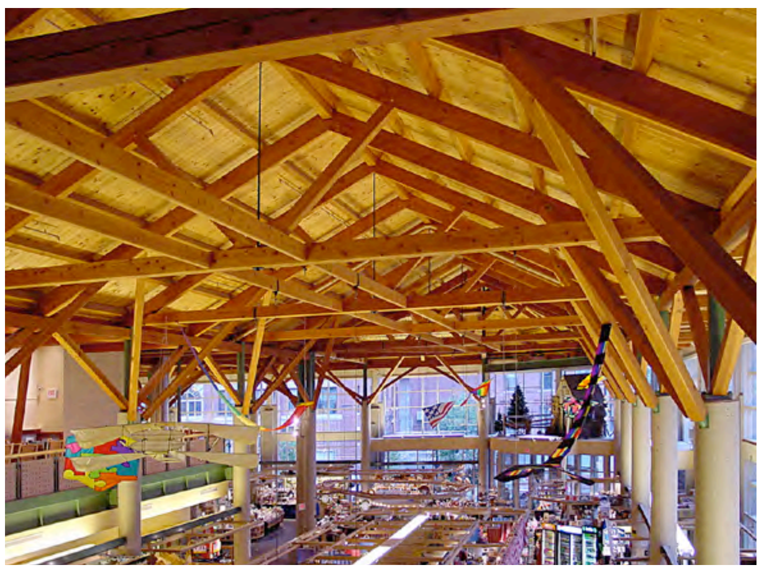
Fig. 1. Thatched house under construction at Stubbegaarden, Denmark. Great room is under tarped scaffold roof.

STUBBEGAARDEN lies 40 miles north of Copenhagen in Denmark's Northern Zeeland province. We are working there on timberwork for a large project that has really stretched our skills. Eventually it will include a horse barn and a riding area (Figs. 1 and 8).

The first phase of our timberwork, now done, was a great-room roof frame inspired in part by Guesten Hall at the Avoncroft buildings museum in Worcestershire, England. At one of the presentations there during a UK Carpenters' Fellowship conference, my attention wandered off (apologies to the lecturer), and up. The

Will Beemer

Fig. 2. Open roof over Guesten Hall, ca. 1330, Avoncroft, Worcestershire.



John Libby

Fig. 3. Open roof over the Public Market, ca. 2002, Portland, Maine.

braces in the roof plane at Guesten Hall are aligned across the bents and form nice diagonal lines across the roof (Fig. 2).

The other inspiration for the Stubbegaarden roof frame was the work of Ed Levin, who has a wonderful way of designing across the conventional *x*, *y* and *z* axes of plan and façade. He rotates timbers away from those axes and brings them away from the walls and roof. Timbers and joints become twisted, bent and skewed in a 3D approach to the framing of a space. When thinking about Stubbegaarden, the particular design I had in mind in which Levin had a hand was the roof over the public market in Portland, Maine. The posts stand under kingrod trusses, but additional uncollared rafter pairs are in the middle of the bays. Rafter braces then run on a diagonal from the posts halfway up the otherwise unassisted rafters (Fig. 3).

The initial design for the great-room roof was for six trusses with collar beams and arched braces. Braces in the roof plane rose from the rafters to the downhill sides of the purlins; additional braces rose from rotated kingposts to their undersides. The visible result would be a grid pattern weaving up and down across the roof (Fig. 4).

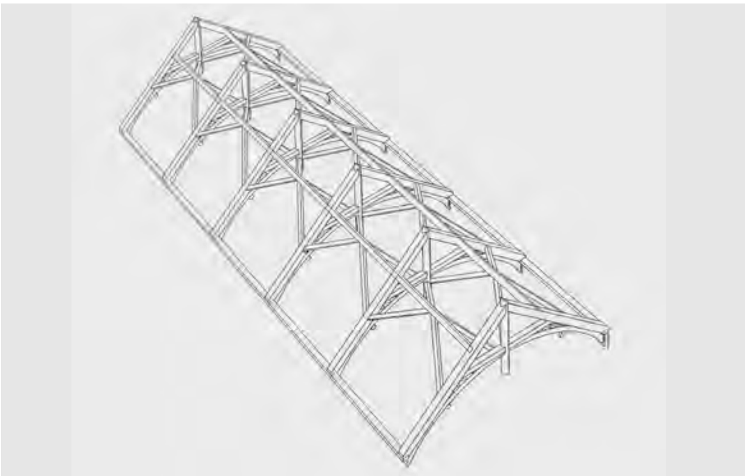


Fig. 4. First trial design for the roof frame.

That could have become a neat frame, but the placement of windows and doors dictated that I couldn't space the trusses evenly along the room. The architect and I had a couple of wonderful days of e-mailing AutoCad files back and forth, and slowly the current solution with double trusses came up (Fig. 5).

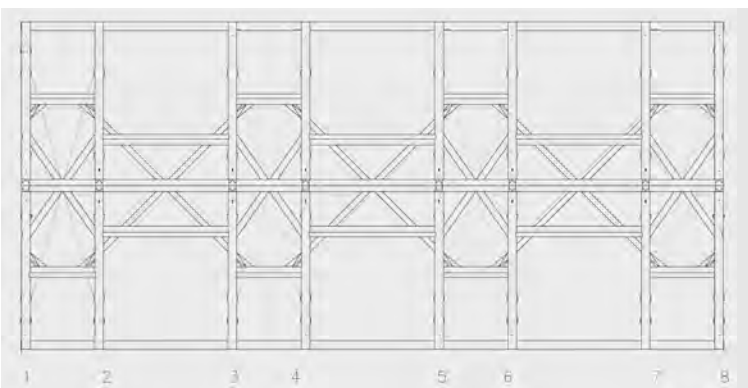


Fig. 5. Plan view of double trusses designed to reflect window placement.

I tried to compress the trusses into pairs and keep a certain geometric justification, but the rhythm was so subtle that it looked like a mistake. I couldn't keep the idea of the four diagonal braces shining out from the kingpost, but I turned it upside down so the braces now support a little stub in the greater bays (Fig. 6).

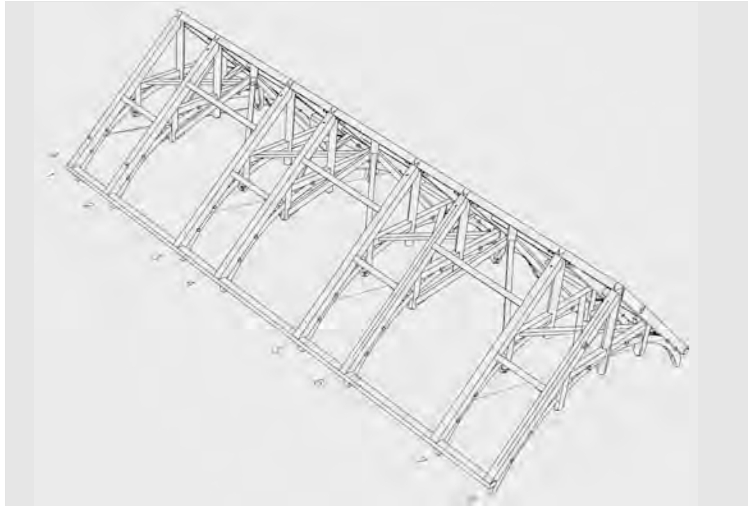


Fig. 6. Perspective view of double-trussed design as built.

Each of the stub posts will hold a chandelier. The small braces resist the lateral thrust of the long braces. To make the joint in the purlin simpler, I decided to turn the timbers 45 degrees. The joints then took about 30 hours to make. So much for simplicity (Fig. 7).

Fig. 7. Short brace is rotated to simplify connection at one end, with serious consequences at the other.

The arches don't rest on the walls. It was the architect's idea to stop the lower arch just short of reaching the wall to give the roof the impression of floating in the air. Some frames are designed for looks more than structure—and then you figure out how much steel it takes to keep the thing from collapsing. I admit this is one of those frames. The tie rods are an indispensable part of what holds up the roof, but the X configuration is an added twist.

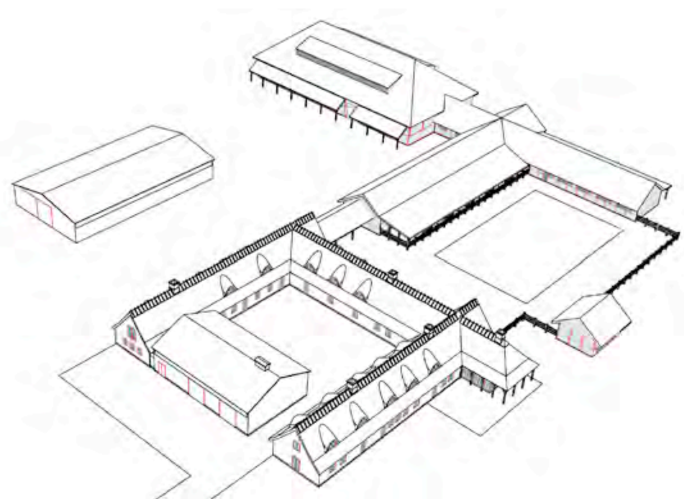


Fig. 8. Overview of compound showing extensive facilities for horses.

Fig. 9. Unloading trusses at site. Building underway is fully enclosed.

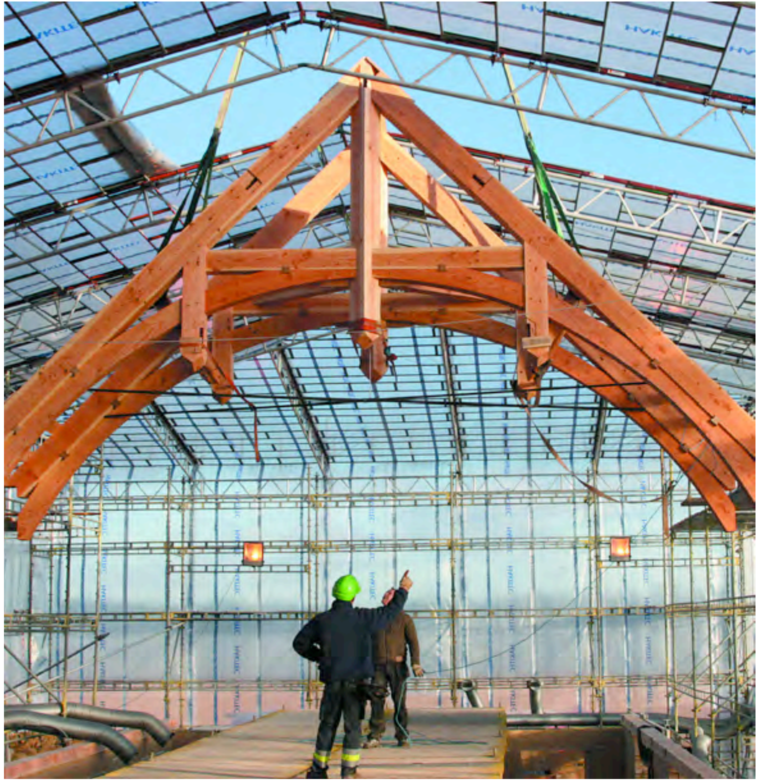


Fig. 10. Double truss of Danish Douglas fir flown in through roof.

Each double truss was preassembled at the workshop and transported with escort to the site, just four kilometers away. Since the construction of this part of the compound took place in the winter and since the brickwork was made with lime mortar that cannot cure at under 15C (60F), the whole wing had been staged and roofed in and was heated with four huge oil furnaces. In a country where there are fewer than seven hours of daylight at the beginning of January, it's useful to be able to hang floodlights in the ceiling—and we didn't waste any time messing around with tarps, snow shovels or raingear (Fig. 9).

We hoisted each double truss in through the same opening in the staging roof, then set the truss on the plate on four sets of roller skates and pushed it gently along the plate to its housings. It went remarkably smoothly. Getting the skates out of the way to set the rafters in the housings we accomplished with a pair of shoring jacks, one side at a time (Figs. 10, 11).

EVERYBODY is appropriately impressed with the roof, but there is a feeling that the kingpost pendants are a little too long. We might cut them back.

The client is very firm that the house should be built with top-quality materials, exquisite workmanship and healthy building techniques. Everything is built to last at least 200 years and a healthy indoor environment has a high priority. The exterior walls, and a lot of the interior, are double-brick walls, lime-mortared. Clay for bricks and lime for mortar are two of the few natural resources plentiful in Denmark. The mortar is cement-free, a mix of washed lime, sand and water—that's all. Mineral wool insulation 6–8 in. thick fills the wall and roof cavities (Fig. 12).

Thatched farmhouses are fairly common in Denmark and thatching has strong historical roots here. A thatched roof is typically between 10 and 11 in. thick; for this house it's 13 in. On one island in Denmark, they thatch with seaweed and the roofs can be 5 ft. thick or more! The thatch for the Stubbegaarden roof was harvested in Turkey, packed in bundles and dried outside in winter.

Thatchers lay about 100 sq. ft. of roof covering a day, then spend a couple of days at the end petting and shaping the whole roof. Before the thatch is laid, a treated fiberglass blanket goes over the battens for fire protection. (A thatched roof can burn out in about a half-hour on a warm summer day.) The thatchers sew the bundles to the battens with steel wire, then use the petting board to push, stroke and shape the thatch in place (Figs. 13,14).

Fig. 11. Stefan Hildebrand rolls truss to position on skates. Pairs of shoring jacks assisted removal of skates and final descent of truss.

The ridge is covered with crumbled oat straw held in place with chicken wire, like a hairnet. The ridge bundle is held down with what we call crowsfeet, 3-ft.-long quarter-cleft oak saplings crossed and bolted together. The crowsfeet are not tied down in any way (Fig. 15).

English thatchers preserve a strong tradition for molding thatch into decorative patterns, but the Danish tradition is very strict. There are virtually no regional variations in the thatching techniques here, and ornamentation is rare. Personally I wouldn't mind if modern architects played a bit with straw roofs.

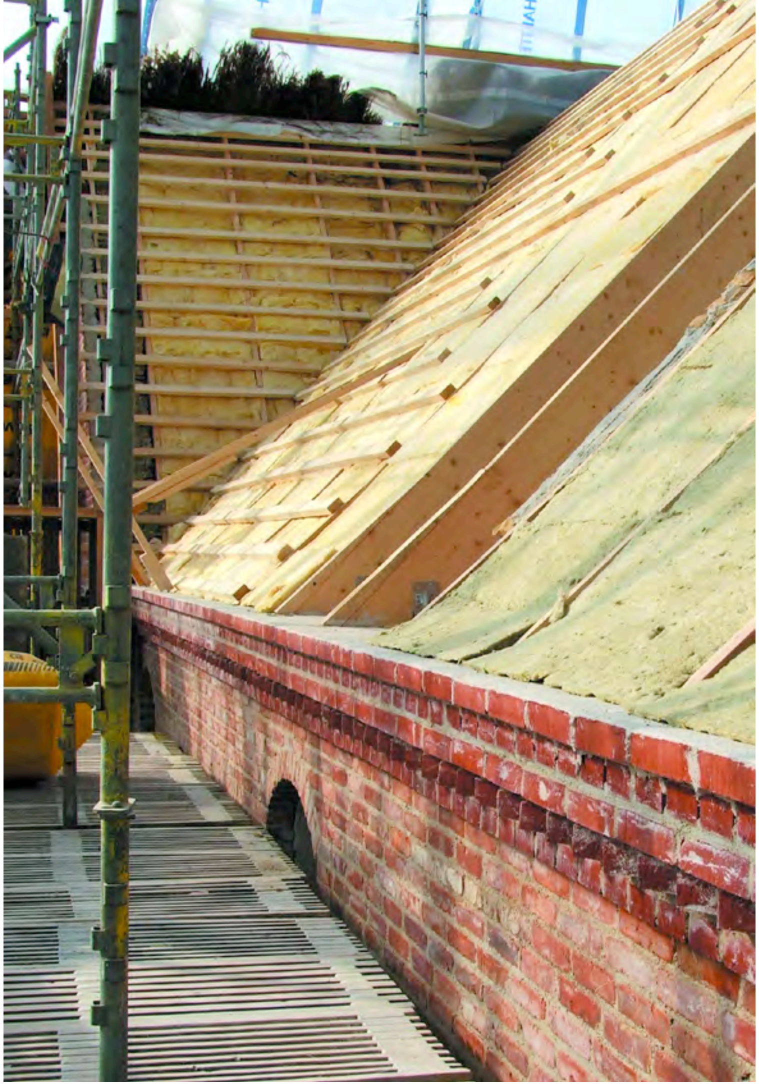


Fig. 12. Mineral wool thoroughly insulates cavities in roof and walls against air and fire movement. Treated fiberglass blanket will cover roof battens before application of thatch. All masonry is lime-mortared.

Fig. 14. Algis Kucinskis wiring down bundles between dormer windows, thatching boss Michael Jahrle just visible behind thatched dormer, Ramunas Lukasuskas busy at the far end (see also Fig. 13).

Plans for Stubbegaarden include a horse barn for 12 Spanish purebred dressage horses as well as a riding arena, both with open timber roofs. I hope to have stories to tell about those structures in due time. —Mikkel Johansen

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Fig. 13. Ramunas Lukasuskas uses petting board to stroke and shape bundles of thatch. Gloves protect hands from abrasive thatch. Drill drives long screws prefitted with two wires into roof batten below; thatcher then ties wires around bale. Heavy wire at lower right holds down entire course of bundles.

Fig. 15. Crowsfeet made of cleft oak saplings bolted together hold down thatched ridge by their own weight. Wooden boarding laid shingle fashion serves as exterior flashing under window and chimney.

The Howe Truss Goes Low-Tech

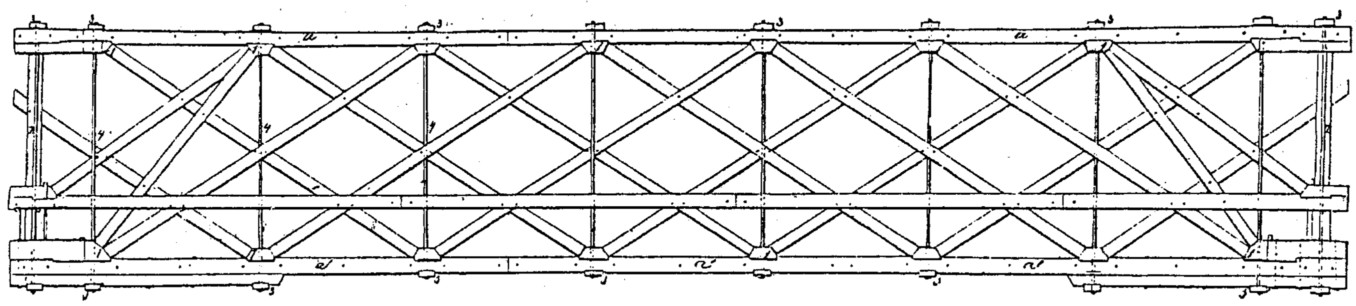

Fig. 1. Double-web Howe truss, with braces and counterbraces over two panels, from William Howe's patent of August 3, 1840, reissued in 1850.

THE Howe truss was one of several 19th-century inventions that continued using timber for bridge construction while replacing traditional joinery with standardized mass production techniques. For this reason, many timber framers may find it less interesting than other bridge trusses such as the Burr (TF 78) and the Paddleford (TF 75), which preserved the older joinery. In its late development, however, and especially in 20th-century Oregon, Howe truss builders sometimes returned to traditional details. This period of timber framing seems little known outside the Northwest.

All photos by Joseph D. Conwill

Fig. 2. The classic form of the Howe truss as widely built in the 19th century, although this example dates from 1912. Columbia Bridge over the Connecticut River just south of Colebrook, N.H., between New Hampshire and Vermont.

Fig. 3. Moose Mouth Bridge over Alces River south of Clayhurst, B.C., Canada, built in 1961. End panels are cut off such that top chords end just past last set of rods. Howe trusses built in British Columbia since the 1930s used chords fabricated from smaller sticks pinned with sections of steel pipe like treenails, with no space between sticks.

FIRST we will look at the early history of the truss. William Howe received two patents in 1840, a third in 1846 and a reissue in 1850, all for variations on a truss that could be adjusted to allow for timber shrinkage and creep. As built in practice, the truss was much simplified from the elaborate patent designs. A number of early examples had a double web, similar to the second 1840 patent (Fig. 1) but without the intermediate chord. None of the double-web kind survives in North America, but Howe's associate George Washington Whistler brought the design to Europe, where several examples are found in Switzerland.

As commonly built, the Howe truss used panels with only a single web (Fig. 2). In truss terminology, "web" describes a plane of braces or counterbraces, and there may be more than one plane per panel. But in describing Howe trusses, the web number indicates whether the braces and counters are self-contained (single web) or run past panel points to the next panel (double web), as in Fig. 1.

The truss used vertical rods of wrought iron, or later of steel. In some late Howe trusses, counterbraces were eliminated entirely in panels near the end. Also, the end panel was often cut off so that the top chord ended just past the last set of rods (Fig. 3).

Technically, the last brace completes the top chord function, and was recognized in some regions with the special term "batter brace" (or, less accurate, "batter post"). In some form or another the Howe truss was used for bridges from 1838 up to the 1960s. The name still survives as a generic description for a certain profile of manufactured roof truss, but this bears little resemblance to the historic design.

Parts for a Howe truss could be fabricated in a distant factory and shipped by rail to the bridge site to be erected by a local contractor. This procedure was later used for metal truss bridges of all types. A contractor could, however, prepare the timber locally with his own crew, ordering only the hardware from afar. Such a system offered much room for individual decisions about joinery. We even have a report of Howe truss hardware being made by a local blacksmith. So Howe truss building in practice could involve anything from local craftsmanship through industrial standardization.

The usual form of Howe truss had top and bottom chords built up of three or four parallel sticks, spaced apart and with shear blocks to prevent longitudinal shifting and to transfer stresses across joints in the sticks. In New Brunswick, a major bastion of the Howe truss in the 20th century, these blocks and other timber connections were sometimes carefully matched to the right place with marriage marks scribed in the traditional style (Fig. 4).

Fig. 4. Marriage marks on shear blocks and bottom chord, top view looking down. Tracey Mills Bridge, Carleton County, New Brunswick, built in 1936. Note angle block at bottom.

Fig. 5. Gilkey Bridge, Linn County, Oregon, built in 1939, with open sides but covered bottom chords. In the background (visible under the highway bridge) is a railroad bridge, itself once covered.

Each panel point had an angle block to receive the braces and counterbraces. The block was of cast iron, or sometimes of wood; in New Brunswick, hackmatack (larch) was sometimes specified for this use. The truss rods passed through holes in the block, and then through the chords, bearing on plates on the other side, with nuts for tightening and adjustment.

The most common plan used a pair of rods per panel point, but bridges were built using as few as one or as many as five. Sometimes rods passed just outside the faces of the chords, instead of or in addition to passing through. Most commonly there were two braces and one counterbrace per panel. Braces and truss rods usually increased in thickness toward the ends of the bridge, where their loads are concentrated, while counterbrace thickness decreased. Occasionally, rods are found in the wrong sequence, indicating either that contractors were careless or did not understand the distribution of stresses.

Howe truss bridges were built both covered and open. There is no doubt that a full, well-maintained covering is a better defense against decay than pressure-treating with creosote, the old preservation method. But the covering also reduces visibility inside the bridge and adds somewhat to wind stresses. The three strongholds of Howe truss construction in the 20th century handled the problem differently. Oregon covered its bridges, but the style varied by county. Linn County used open sides with a low sill completely boxing in the bottom chords (Fig. 5); Lane County boarded the sides nearly to the top (Fig. 6); Lincoln County used flared sides that directed rain runoff far from the chords (Fig. 7).

New Brunswick built both covered and noncovered varieties, the choice depending on traffic volume and site geometry or occasionally, it seems, on whim. British Columbia built noncovered trusses exclusively, but protected crucial timbers such as chords and batter braces by covering them with tar or, later, with sheet metal. Plans here also called for hollow angle blocks on the lower chords to be filled completely with tar to prevent water infiltration. By these ingenious methods British Columbia has managed in a few cases to get 70 or 80 years of service life out of noncovered Howe trusses. Fully covered bridges, however, can last far longer with proper maintenance.

THE OREGON CONTRIBUTION. Timber truss building saw a revival in Oregon following World War I. The wartime steel shortage led to a new appreciation for timber, which was then abundantly available in large dimensions and at low cost; extensive virgin stands still remained. The Oregon State Highway Commission offered bridge design services to the county engineers, who in turn added their own details of housing to produce beautiful covered bridges, right into the early 1950s. Over 40 remain, and many still serve traffic.

Fig. 6. Earnest Bridge, Lane County, Oregon, built in 1938. Far end opens onto curve in road; note window for visibility.

Fig. 7. Fisher School Bridge, Lincoln County, Oregon, built in 1919, with broadly flared siding.

Fig. 8. Top chord of Cavitt Creek Bridge (in fact over Little River), Douglas County, Oregon, built in 1943. Use of a log is impressive but unusual; standard practice was to square the timbers. Dimensions on near end were probably added by inspectors during load-limit calculations.

From the timber framer's point of view, one of the most interesting features of these late Howe trusses is the use of single-piece chords. This was not a new technique, but Oregon made extensive use of it. The finest example is the Pengra Bridge in Lane County, which has 16x18 bottom chords measuring 126 ft. in single sticks. Such timber was obviously too large for any sawmill carriage, so it was prepared in the old way with broadaxe and adze. Although locally cut, the timber's transportation to the site was a challenge. Some Oregon covered bridges did use chords built up of smaller sticks, but many use single-stick chords, and these are highly impressive (Fig. 8).

Since oversized timber could be obtained easily, Oregon engineers did not mind sacrificing a little section for daps, to make direct brace connections to their single-stick chords without angle blocks. Some bridges did use blocks, and many used both kinds of joints—blocks in the middle of the bridge where braces and counterbraces bore at the panel point from both sides, and daps toward the ends where the panels often had braces only (Fig. 9). With one-piece chords, engineers usually passed the rods just outside the faces of the chord sticks; occasionally they bored through instead. With chords built up of multiple small sticks, the rods could simply pass through the spaces between the sticks.

Floor systems in the older Howe trusses elsewhere most often consisted of floor beams placed directly on the bottom chords, either spaced several feet apart with stringers planked on top, or else placed closely together and planked over directly. Some older Oregon bridges used this system, but most of the surviving examples suspend the floor beams below the bottom chords from the ends of the truss rods. This gives extra clearance inside the bridge, but makes the floor beam ends susceptible to damage from flood drift or to decay if not protected by the bridge covering. Stringers are needed in such a system because the floor beams are widely spaced.

Quality of workmanship in late Howe trusses was very high. Some bridges were built by contractors, but others were built by county crews. They were designed for generous loads, either 10 or 15 tons, still sufficient today for most rural uses. But the rapidly changing economy often meant early replacement. A decision to log a tract on the far side of the bridge might suddenly bring 40-ton loads, and some modern farm equipment is too large for the limited clearance inside. So covered bridge construction in Oregon is a thing of the past. But it is a surprisingly recent past, and it did involve traditional joinery, even with a style supposedly so modern as the Howe truss. —Joseph D. Conwill

Fig. 9. Braces and counterbraces connected to top chord with an angle block. Block is let slightly into chord to prevent it from shifting. Oregon occasionally used iron angle blocks in its 20th-century covered bridges, but much more often used wood. At far right, note batter brace joint in top chord made with a dap instead of a block. Top chord is hand-hewn while braces are sawn. Hoffman Bridge, Linn County, Oregon, built in 1936.

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Pat Hakanson

Lacking only common rafters, freshly assembled 699-piece roof frame in Southern yellow pine, cut by Blue Ridge Timber Frame, Swannanoa, N.C., on a Hundegger K-2, for raising by volunteers at St. Mary's City, Md., over the nave at the 1667 Brick Chapel reconstruction. St. Mary's was established by Lord Calvert and 140 colonists as the first English Catholic colony in the New World. Roof will be closed, ceiled by a barrel vault following the framed arch. Mesick, Cohen, Wilson and Baker Architects (Albany, New York) developed conjectural 17th-century chapel and truss designs. Challenge for Blue Ridge was to design joinery for orderly and efficient frame assembly on a remote site by inexperienced workers.