TIMBER FRAMING

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Number 101, September 2011

The Gwozdziec Synagogue

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NUMBER 101 SEPTEMBER 2011

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On the front cover, timber framers and students pose during the Gwozdziec Synagogue roof reconstruction workshop at Sanok, Poland. Photo Ed Levin. Below, Polish and American students in Krakow display their decorative painting work on the assembled west ceiling boards and three zodiac panels. Photo Handshouse Studio. On the back cover, detail of Lordship Barn, ca.1440, about 30 miles from London. Photo David Leviatin.

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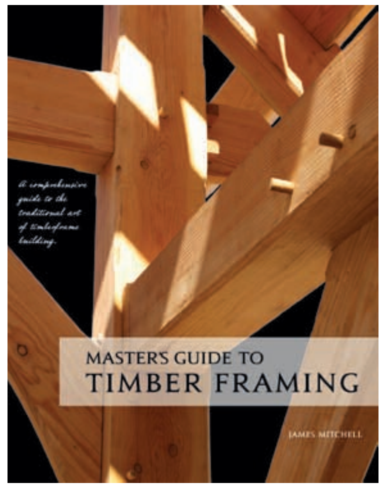
1985

BOOKS

Timber Framing Manual

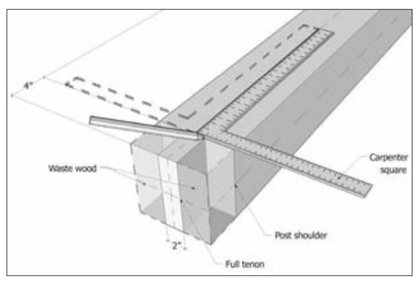
Master's Guide to Timber Framing: Project Post & Beam, Project Hammer Bents, by James Mitchell, with drawings by Eric Clark. Gabriola Island, British Columbia, Canada V0R 1X7, J. D. Mitchell Publications, 2011. 8½x11, 239 pp., profusely illustrated. Embossed hardcover, $79.95.



JAMES MITCHELL'S new guidebook, *Master's Guide to Timber Framing,* opens with a dedication to "all my students past, present and future" and states a clear intention: "This book is designed to progress in skills development from simple to the complex." And indeed it does. From the table of contents to the final glossary there is much for the student and seasoned practitioner to embrace and appreciate in this carefully laid-out and well-illustrated book. In addition to the abundant drawings, an eight-page color photo insert set between the two project sections of the book adds that extra dimension of proof to the pudding. Along with a planned companion book, *Master's Guide to Log Building,* this new work draws on 30 years of study, teaching and direct application (and refinement, the author suggests). It's part shop manual, part history book and a thoroughly encompassing journey through the fundamentals and varied complexities of timber framing.

A six-page table of contents describes the comprehensive scope that the author, who has previously written *The Craft of Modular Post and Beam* (Hartley and Marks, 1996), has laid out for his reader through the format of two distinct projects, each in six chapters, followed by four appendices.

Brief at four pages, a preliminary chapter, "A Post & Beam Perspective," is nonetheless a captivating read as one is taken from Stonehenge through Europe and Asia to the colonization of the New World to the Industrial Age to Sears & Roebuck mail-order catalog houses—right through to the concept of the new hybrid designs experimented with today.



In the first part, "Project Post & Beam," the author carefully lays out a successful map to a basic orthogonal (no compound joinery) 24x32-ft. timber frame structure. His mission, which he never hesitates to restate, is to impress upon the reader the vital logic and pleasing simplicity of centerline layout (example inset below left), as opposed to face-and-edge layout. Methodology, terminology, good planning, a remarkable list of joint designs, helpful math, pegging and drawboring tenons and finishing the timbers, all are covered clearly and concisely before carrying on to roof and wall systems. The illustrations that accompany the text are crisp, sharp and clear. The figures are close to their explanations, not pages away.

Mr. Mitchell places importance on well-presented shop drawings and careful grid-based labeling. He explains in straightforward fashion how to organize a useful spreadsheet inventory of a timber frame's component pieces. He treats the spreadsheet as an essential tool in the timber framer's toolbox and provides a fine template that allows the entire timber frame job to be cost-analyzed logically.

The discussion on preparing and laying out timber joints, perhaps the heart of what a budding timber framer might wish to embrace (or fast-forward to), is presented in chapter four of the first part. The author's observations on the idiosyncrasies and nuances of unsquare timbers and dimensioned objects is refreshing in its approach and proposed solutions. The discussion of centerline vs. virtual square-rule layout is levelheaded and easy to follow.

The second part takes the reader, presumably now comfortable with the completion of the first project, to one of more detail, sophistication and complexity. Chapters one through four in both parts follow similar paths with identical titles: "The Plan," "Joinery Design," "Shop Drawings" and "Timber Joinery."

Chapters five and six of the first part move from the orthogonal simplicity to common-rafter roof framing (with a nice look at the Pythagorean theorem), and then wall infill systems. In the second part, the final two chapters cover frame raising and wall and roof systems. The frame-raising chapter in the second part is one of the best outlines of procedure I've observed to address the entire preparation of a timber frame structure for raising. Volume and weight, center of gravity, lifting tackle loads and the discussion of forces are all clear and logical. Aspects of the outlined procedures read, perhaps, a little too much like an assembly manual, but the precision and repetitiveness may be necessary to carry home the objective.

Appendix I describes an adequate list of timber framing tools. Appendix II is a fine discussion of wood structure, drying, shrinkage and timber defects, treatments and finishes. Appendix III deals with defining and calculating loads and beam sizes. Appendix IV offers up a good presentation of the concepts of load distribution, forces in equilibrium, strength of materials and structural properties of wood. And finally, the glossary is an exhaustive list of timber terminology A through W (no X, Y or Z entries—or Q).

While I did not read this book word for word, and so may have missed these things (there is no index), I saw no mention anywhere of working with recycled timber, a fairly important topic these days. Only three species of wood appear to be mentioned at all, and only two of them (Douglas fir and Western red cedar) are cited in the allowable stresses table in Appendix IV. The third, oak (all oak apparently) is mentioned under "Patina" in Appendix II. A discussion of different wood species for timber framing and their behavior, weight, strength and how their fibers behave with edge tools (cutting mortises, etc.) might have been of value.

But everyone interested in timber framing and the exacting craft that it is will appreciate this work. Ideally, we never cease to be "students future."

—Jake Jacob

Jake Jacob (jake.thw@mac.com) has been a marine engineer, a timber framer and a specialist in engineered treehouses, cofounding TreeHouse Workshop in 1997 and lately Treehouse ARTZ. He was a member of the Guild's board of directors 1992–94 and 1995–98.

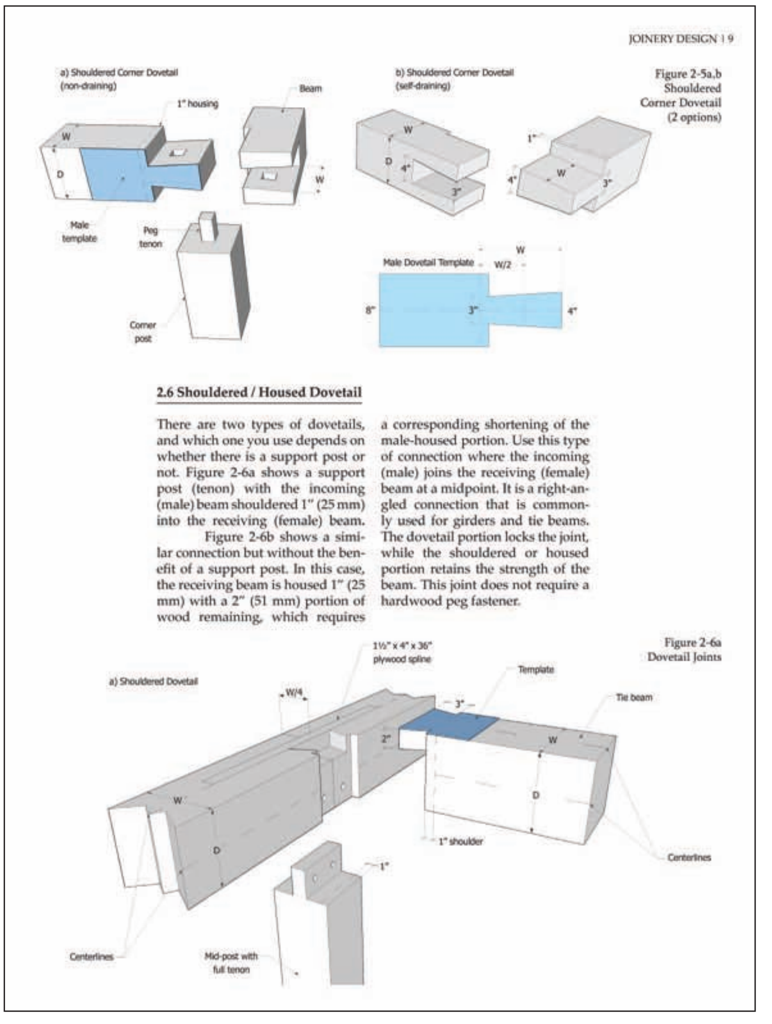

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Figure 2-5a,b Shouldered Corner Dovetail (2 options)

2.6 Shouldered / Housed Dovetail

There are two types of dovetails, and which one you use depends on whether there is a support post or not. Figure 2-6a shows a support post (tenon) with the incoming (male) beam shouldered 1" (25 mm) into the receiving (female) beam. Figure 2-6b shows a similar connection but without the benefit of a support post. In this case, the receiving beam is housed 1" (25 mm) with a 2" (51 mm) portion of wood remaining, which requires a corresponding shortening of the male-housed portion. Use this type of connection where the incoming (male) joins the receiving (female) beam at a midpoint. It is a right-angled connection that is commonly used for girders and tie beams. The dovetail portion locks the joint, while the shouldered or housed portion retains the strength of the beam. This joint does not require a hardwood peg fastener.

Figure 2-6a Dovetail Joints

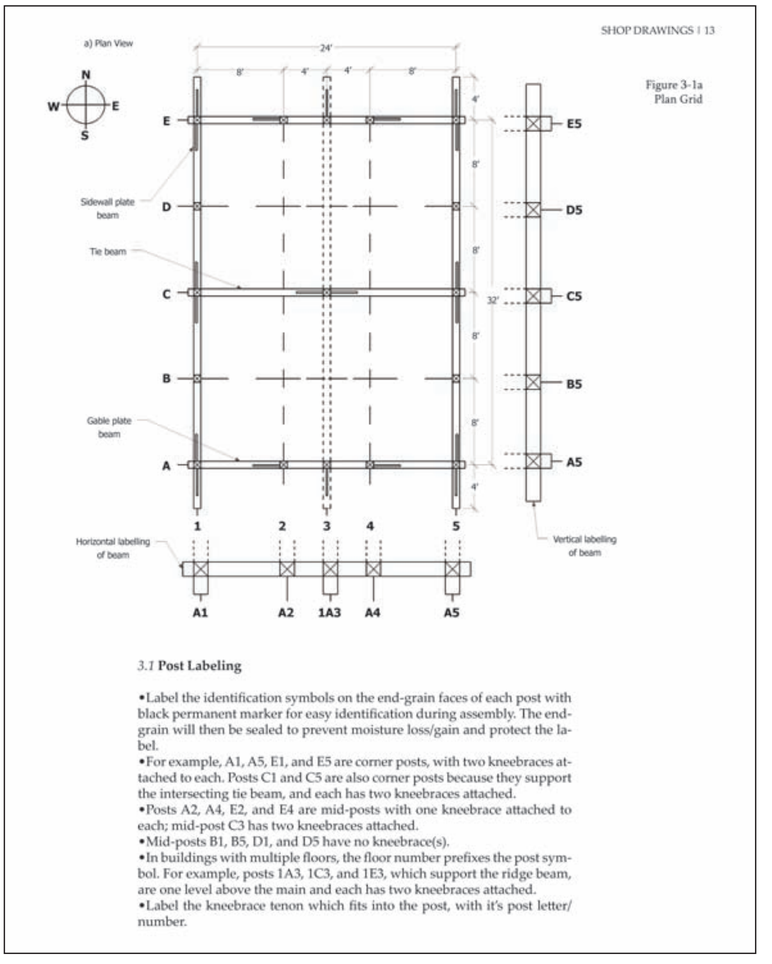
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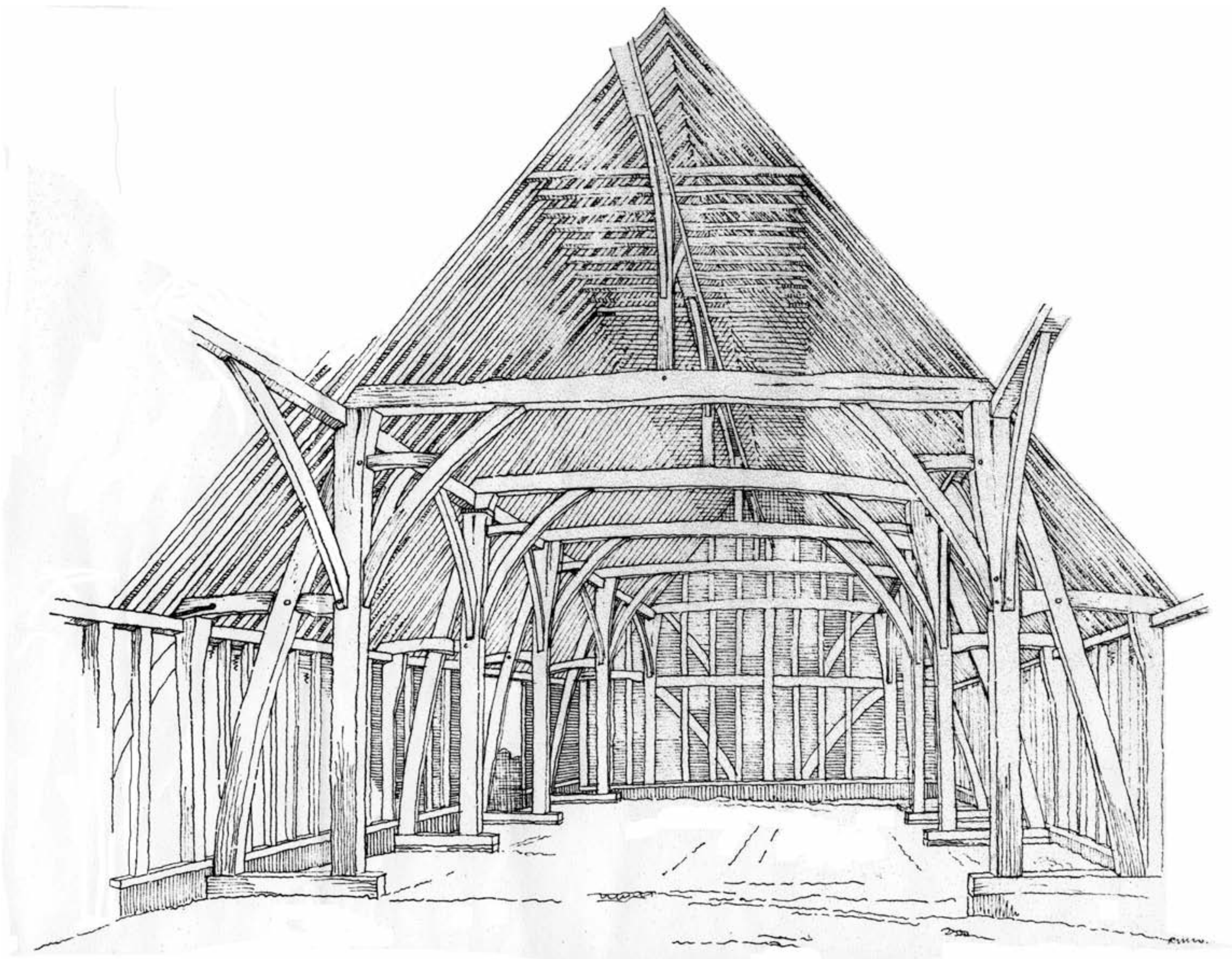
Figure 3-1a Plan Grid

3.1 Post Labeling

- Label the identification symbols on the end-grain faces of each post with black permanent marker for easy identification during assembly. The end-grain will then be sealed to prevent moisture loss/gain and protect the label.
- For example, A1, A5, E1, and E5 are corner posts, with two kneebraces attached to each. Posts C1 and C5 are also corner posts because they support the intersecting tie beam, and each has two kneebraces attached.
- Posts A2, A4, E2, and E4 are mid-posts with one kneebrace attached to each; mid-post C3 has two kneebraces attached.
- Mid-posts B1, B5, D1, and D5 have no kneebrace(s).
- In buildings with multiple floors, the floor number prefixes the post symbol. For example, posts 1A3, 1C3, and 1E3, which support the ridge beam, are one level above the main and each has two kneebraces attached.
- Label the kneebrace tenon which fits into the post, with it's post letter/number.

Representative shop drawing and joinery design pages from *Master's Guide to Timber Framing.* Drawings by Eric Clark.

The Lordship Barn and Regulating Line Technique



R. M. Westgate

1 The Lordship Barn, Essex, UK, ca. 1440.

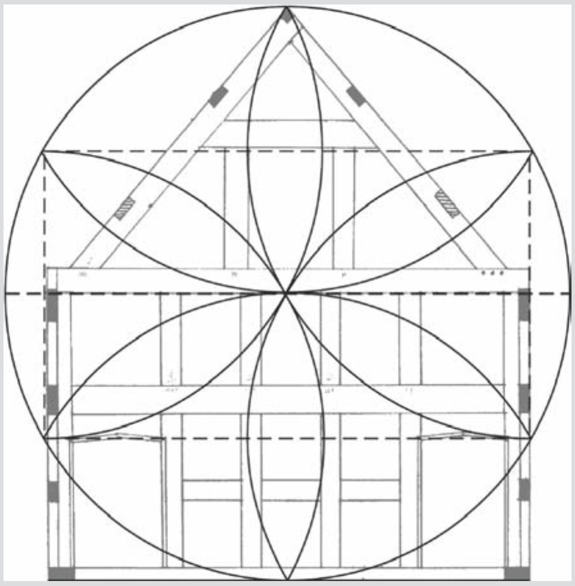
THE word *Renaissance* does not bring to mind the East Anglian county of Essex, its county town Chelmsford, the remarkable tithe barn located on the town's outskirts or the unknown English carpenter who designed and built the barn almost 600 years ago.

Maybe it should. The legacy left by that unknown carpenter, a timber frame masterpiece known as the Lordship Barn, gives shape to the ideals of Renaissance humanism (Figs. 1 and 3). The simplicity of the barn's design and the harmony of its construction demonstrate the value of an enlightened (and unfortunately forgotten) way of thinking and doing. The course of progress has resulted in our having replaced breadth of knowledge and understanding with the tyranny of specialization. Fortunately, the timber chords of the barn's ancient frame continue to resonate, reminding us who we once were.

In 2008, I was given the key to the 15th-century Lordship Barn, standing 14 miles southwest of the iconic 13th-century barns at Cressing Temple in Essex. The Lordship Barn was built in the 1440s as an addition to the grounds of a palace and hunting lodge constructed for King John in 1211. A relatively undisturbed jewel, the barn has been overlooked but it is not unknown. Drawn and discussed in detail by Cecil Hewett in his *The Development of Carpentry, 1200–1700* (1969, p. 123), the barn has been for many years part of the campus of Writtle College. It stands proud, a survivor, an anomaly, a memory of a different way of doing things.

I was given the use of the barn as a workshop in exchange for teaching courses at the college on the conservation and construction of historic timber frames. For three years, I cut frames and taught courses in the barn, always inspired by the ingenuity and quality of its design and construction and overseen by the ghost of

Daisy Wheel Analysis of Building Design



Laurie Smith

2 Laurie Smith's geometric analysis of the lower end truss at The Hall, Llanfyllin, Montgomeryshire, Wales, originally 1500–1550. The vertical vesicas of the daisy wheel define the frame's height from floor to ridge, while connection of the remaining four vesica tips generates the planes of the outer walls, the base of the collar and the doorhead level. The circle's horizontal diameter defines the base of the tie beam.

its master carpenter. I often borrowed joint details and dimensions from the barn and incorporated them into my own frames. It always seemed to be these borrowed details that made my frames stand out. I resolved to undertake a thorough survey to figure out what made the barn work so well. What was its secret?

It was Laurie Smith's recent work on compass geometry (Fig. 2), which appeared in the US in TF 70 and TF 95, that I had in mind while hanging off ladders and crawling across tie beams in my effort to uncover the Lordship Barn's secret. No one who has followed the work done with compass geometry so far can fail to be impressed. Seeing drawings of historic timber frames fit neatly beneath a series of overlapping circles is remarkable; seeing actual frames made using the technique is inspiring (such as the Gardener's Shelter built by the Carpenters' Fellowship at Cressing Temple or the small barn made in Massachusetts for the Guild's Saratoga conference, both in 2009). Watching the process unfold is captivating, widening the eyes of believers and furrowing the brows of skeptics.

While recording measurements, dimensions and joint details, I kept an eye open for daisy wheels. I didn't find any; perhaps they remain well hidden or maybe they have faded over time. What I did find, in several recurring numbers and dimensions, was another design system.

The Span A timber frame building's structural integrity and aesthetic harmony, its design, manufacture, construction and cost can all be determined by one carefully conceived line, the *span*, measured outside top of wall plate to outside top of wall plate. Get the line right and it will generate a building that sings.

It appears that the carpenter who built the Lordship Barn in the 1440s used a version of what 500 years later the Swiss-French architect Le Corbusier would call a *regulating line*. The secret of the barn's design and construction, its regulating line, represents a forgotten way of building—a way well worth rediscovering.

Innovative and imaginative problem-solvers, medieval master carpenters served simultaneously as architects, engineers, designers, craftsmen and businessmen. With so much to organize and coordinate, these "Renaissance men" would likely have sought to protect and transmit (to the chosen few) a simple system of design and construction that was reliable and efficient, easy to remember and replicate, precise yet adaptable, portable, secure, impervious to bad weather, suited to site layout, frame layout and the drafting of scaled drawings. They needed a *standard*. The standard, or regulating line, used to build the Lordship Barn probably wasn't developed overnight but rather as the result of centuries of intellectual insight and practical effort.

Before discussing the line's history, let's see how it might have been used to design the Lordship Barn. First, we need to know the barn's vitals: 33 ft. wide and 110 ft. long, the barn is aisled and, with seven cross-frames, divided into six equal bays. The roof has a rise of 18 ft. 5⅜ in. Here's what the 15th-century Essex carpenter might have done to arrive at that design:

David Leviatin

3 Lordship Barn, with crown-posted, common rafter roof, passing shore timbers at arcade posts.

Start with the building's span of 33 ft.

Divide the span into six sections by successive bisections.

Separate those sections into six lengths, yielding a cutting list.

5 ft. 6 in. Wall ties

8 ft. 3 in. Collars and lower rafters

11 ft. Wall posts

16 ft. 6 in. Arcade posts and upper rafters

22 ft. Tie beam

24 ft. 9 in. Total rafter length

Use the six lengths and the span length to draw at small scale (and later to lay out at full scale on the framing floor and on the site) the barn's theoretical and actual framing elevations (Fig. 4):

1. Start with the 33-ft. span.

2. Find the center of the span.

3. Position the 22-ft. tie beam on the span.

4. Establish the pitch and total rafter run by dividing the line into quarters using compasses, and then pitching a three-quarters line in place. Roof pitches (rafter length over span) either three-quarters of the span or the full span are commonly found in ancient buildings. Probably they worked well in the weather for their imbricated or thatched roof coverings, as well as for anticipated live loads. They were also easy to remember and lay out.

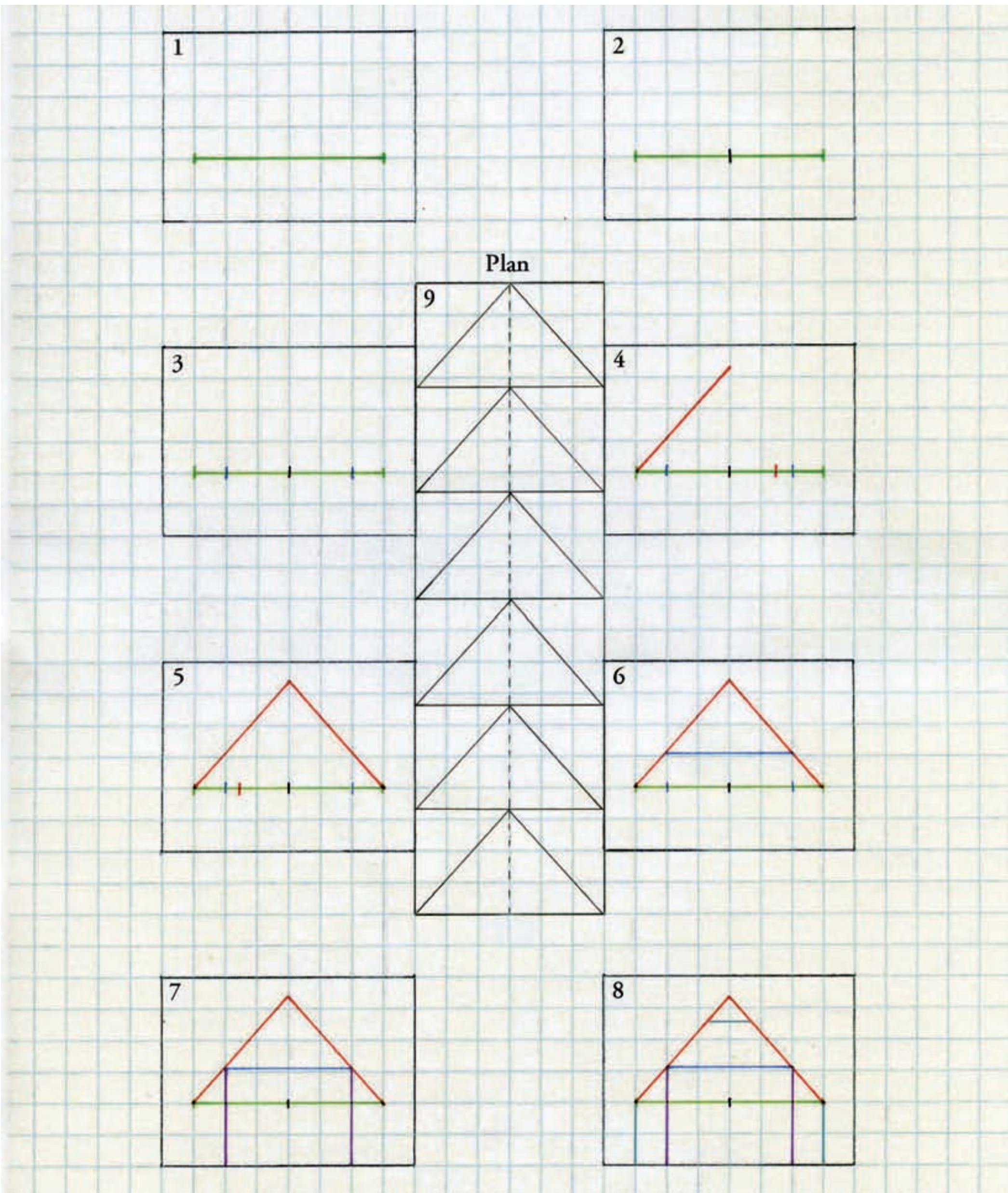
5. Repeat step 4 for the other side of the roof.

6. Put the tie beam in place between the two rafters, keeping it parallel with the span. This line represents the top of the arcade plate height. (The tie drops down 1½ in. when framed in.)

7. Draw in the arcade posts at half span length.

8. Draw in the wall posts at one-third span length and collars at one-quarter span length.

9. Generate the barn's length in plan by multiplying the length of the tie beam by 5 (22 ft. x 5 = 110 ft.).



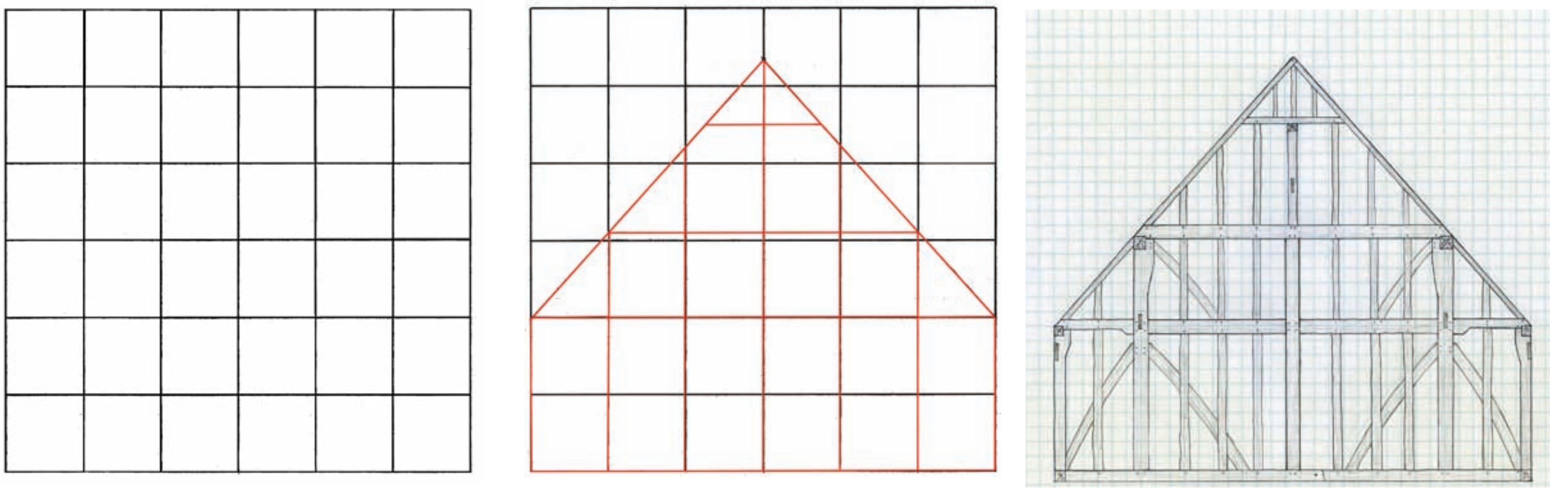
Drawings David Leviatin

4 Sequence of design for cross-section and plan of building.

THERE you have it. One of England's great medieval tithe barns, sound in construction and beautiful in appearance, plausibly the result of a single line thoughtfully conceived and carefully divided. As a system of design and manufacture, the regulating line technique is simple, elegant, accurate and reliable. It is also relatively easy to grasp in theory and apply in practice, if you know a few rules and understand some of the regulating lines' long history.

The first thing our 15th-century carpenter knew was that in building a wide barn, its span would be based on the longest unscarfed timber obtainable for the tie beam. Along with one other timber size, the arcade post section, the tie beam would pretty much determine all of the barn's dimensions. The master carpenter generated the barn's span of 33 ft. by first establishing a central aisle width of 22 ft. This length was determined by the length of timber available (we rarely find timbers longer than 26 ft. in ancient English buildings) and by a few other factors, some of which he was probably aware of and one he probably wasn't.

He was probably aware of the special properties of the so-called perfect or master numbers like 11, 22, 33, 44, 55, 66, 77 and so on. Working well individually and together (for example, in the design of cathedrals built two centuries earlier), these numbers were then perhaps invested with sacred symbolism. The carpenter



5–7 Development of cross-frame and gable-end elements of the Lordship Barn on 1:6 scale grid, with frame drawing of one gable end.

was also likely aware (as builders are today) of the Pythagorean 3,4,5 triangle. When a line two tie beams in length (44 ft.) is pulled at a right angle from one end of the barn's 33 ft. span, the diagonal is 55 ft. or half the length of the barn.

The 15th-century carpenter was definitely aware of the practice, common in medieval times, of using the human body and its various parts as units of measure to record and quantify distance, area and volume. This practice, also used as a means of establishing the harmonious proportion and symmetry of buildings, came down from the Greeks and Romans. According to Vitruvius in *De Architectura,* Book I, Chapter 2, "Just as in a human body the nature of its harmony is modular and derives from the forearm, the foot, the palm, the finger and other small parts, the same happens when it comes to the construction of buildings." Measurements of medieval English skeletons have shown that the average height of an Essex man in the 15th century was 5 ft. 6 in. (see *Death and Burial in Medieval England, 1066–1550,* by Christopher Daniel, 1998). The dimensions of the barn and the dimensions of its structural members are all multiples of 5 ft. 6 in. Viewed this way, the barn's span is 6 men; its length is 20 men. The wall posts are two men long, the arcade posts three men long, the tie beam four men long. Probably it's no accident that the *rod,* in its sense as a linear measure, is a threefold multiple of an average medieval Essex man's height. The close relationship suggests that measuring distance, area and volume all have their roots in the measure of man.

Our carpenter was aware of the 16-ft. 6-in. length of the rod, a fundamental unit of land measure formally standardized in the early 17th century but in common use long before. The barn's span is 2 rods; the total rafter run is 1½ rods; the tie beam is 1⅓ rods; the arcade posts and the upper rafters are half the barn's span or 1 rod; the wall posts are two-thirds of a rod; the lower rafters and the collars are half a rod; the wall tie is one-third of a rod. The barn in plan covers one-twelfth of an acre (an acre being 4 rods by 40 rods). If the barn is filled to a height of 12 ft., its volume (12 ft. x 33 ft. x 110 ft.) equals 1 acre-foot (66 ft. x 660 ft. x 1ft.). A handy vessel for measuring tithes!

The carpenter probably wasn't aware that the dimensions of the barn's principal structural members replicate almost exactly the notes of the Greek harmonic series. The span is the open string, the arcade posts and upper rafters octaves, the tie beams perfect fifths, the wall posts third notes, the collars and lower rafters quarter notes, the wall ties sixth notes. This actually isn't surprising given that Pythagoras is said to have based his principles of practical geometry on the harmonious construction he discerned in music. It does perhaps explain why the barn is so good to look at.

Vitruvius elsewhere in the same chapter observes, "In the case of sacred buildings, their modular systems are derived either from the diameters of columns or a triglyph." The base of each of the arcade posts in the Lordship Barn, what Vitruvius would have called the barn's columns, is 11x11 in. Eleven is the barn's base unit, the key to understanding its modular system. I divided the barn's three principal dimensions and the lengths of its structural timbers by 11 in. The result is whole units, easy to record and remember. Length works out to 120 units, width to 36, height 32, rafter 27, tie beam 24, arcade post 18, wall post 12, collar 9 and wall tie 6.

The barn appears to have been drawn based on units of 11 in., then scaled up six times. Renaissance painters created such grids to assist them in accurately depicting perspective, as shown in the inset. Start with a square 66x66 in. Divide it vertically and horizontally into six 11-in. sections to obtain 36 squares, each representing 66 in. or 5 ft. 6 in. square at full scale (Fig. 5).

Albrecht Dürer, 1525. Wikimedia Commons

Two squares up from the bottom and six squares across is the span at wall plate height. Three-quarters of the span, the total rafter run, is four and a half squares. Swing arcs this long from the wall plates to find the peak. After the rafters are drawn in at three-quarters pitch (remembering that pitch is defined as rafter length over span), the tie beam at the top of the arcade plate height (before being framed in at 1½ in. lower) can be put in place. The tie length is four squares (Fig. 6, red lines).

Voilà!

The arcade posts are in place (red lines), as are the wall posts, the wall ties and the crown post. All that needs drawing in is the collar. At the gable ends, the vertical line in the center of the grid indicates the central post. The vertical lines on either side of it are two of the eight studs that help carry the two rails at wall plate height. Further division of the 66-in. squares yields the remaining studs on 33-in. centers. Fig. 7 depicts the actual timbers following the underlying scheme at one gable end.

In the Lordship Barn, all the timbers at 1:6 scale are multiples of 11 except for the collar and lower rafter at 8 ft. 3 in., which is an obtainable fraction of 11 (8 ft. 3 in. = 1½ x ½ x 11). It appears that the classical admiration of symmetry is not only present in the barn's design but also in the numbers used to conceive and realize that design: 11, 22, 33, 44, 55, 66, 77, 88, 99. . . . These numbers, in feet and in inches, can be found throughout the barn. Mirrors and reflections, these numbers, beautiful in themselves, resulted in a harmonious and structurally sound building. —David Leviatin

David Leviatin (dleviatin@yahoo.com) operates Boxed Heart Timber Frame (boxedheart.com) in London and Essex, UK, specializing in conservation of historic English timber frames and new construction in historic style. A longer version of this article appears in the autumn number of The Mortice and Tenon, *the quarterly journal of the Carpenters' Fellowship (UK).*

Timber Grading, or "Select" Timber Has Knots

ACCORDING to page 7 of the National Lumber Grades Authority *Canadian Lumber Grading Manual*, "The art of lumber grading can be defined briefly as the separation of the products of the log into grades according to quality and intended use." The art part of lumber grading results from the fact that no two pieces of a natural product are the same.

So why have a grading system? Grading rules provide accepted standards and a common language such that people distant from one other can know what to expect before the truck rolls in with the timber order. A grading system has a set of objective criteria that allow for engineering, design and manufacture of wood products. Grading rules allow buyers and sellers to use a common language to accurately discuss the different grades of lumber appropriate for the end use intended.

What is a lumber grade? According to the New England Lumbermen's Association, it's "a grouping of pieces, all slightly different, with regard to the end use for which the grade was intended. The purpose of the grading rule is to describe as accurately as possible the pieces which may be accepted in specific grades. Each grade description lists major characteristics [*knots, splits, rot, etc.*] which may be accepted and usually limits them as to location, type, area, size, or number. When characteristics are not listed [*now we get into the art of grading*], they are appraised in relation to the characteristics permitted or limitations prescribed for the grade under consideration and are allowed, if judged by the inspector to be equivalent to those listed. Grade is determined visually by measuring the number, size, type and position of knots, shake, wane or other visible characteristics" (NELMA 2006).

Here is a request-for-quote I received recently:

"Good afternoon. Thought you could quote this in Doug fir.
I have a couple of gazebo roof trusses we need to build here ASAP.
8 – 8x4 – 18 ft.
4 – 8x7 – 26 ft.
8 – 12x7 – 10 ft.
2 – 8x8 – 10 ft.
4 – 5x6 – 10 ft. [etc.]
Give me a call with any questions."

Questions? Where would I start? First of all, how about desired grade, surfacing, boxed heart or free of heart center, green or dry? I called back and found out that a price was needed in 24 hours, the foundation had been poured on this modest 10,000-sq.-ft. home and the general contractor was raring to go. (Incidentally, the project had been awarded to the GC three months before.) The timber grade had not been specified. I asked if #1 Structural FOHC would work. Pause on the other end. "Well, okay. . . . Is that a higher grade than #2 & Better?" Help me, Rhonda! After a few minutes, we worked out the timber specs for this job.

On another occasion a timber framer advised his supplier that the architect was "upset, concerned and uncomfortable" about the presence of knots in the Select Structural beams and timbers that the framer had confirmed and ordered. The supplier had made it clear at the point of sale to the timber framer that Select Structural allowed knots. Apparently the information was not passed on. This makes a case for putting the grade rule on the order confirmation or sending a copy of the grade rule (WCLIB Section 5, ¶130-a, Select Structural Beams and Stringers) for the designer to initial. Evidently a basic knowledge of timber grades is lacking among many timber framers and architects. Anyone who specifies or buys timber should be fluent in lumber standards and grading rules.

Grading rules allow you to describe timbers explicitly. The standard terms and definitions objectively state, for example, the slope of grain and diameter of knots allowed in the grade. Subjective descriptions such as "nice-looking" don't help you clearly communicate with mills, engineers, architects or building inspectors and, most important, with customers. Grading terms can be misleading to the novice. For example, the term "Select" is used in the grade descriptions for Select knotty cedar siding, Select Structural Douglas fir timbers, Select railroad ties and other surprising items that permit knots.

So, how to become fluent with the grading rules?

A professional certified mill grader can grade a timber in 20 to 30 seconds, eight hours a day, five days a week. A professional grader's course takes two to three months at a cost of up to $800. The course covers details of tree anatomy, lumber manufacturing, safety, efficiency and quality control. The closed-book written and practical final exam is four hours. Sometimes in the exam (and in everyday mill production), the grading rules do not always provide a single solution to a grading problem. Senior graders can pick a piece apart on several levels and still not agree. It's an interesting academic exercise, like being in a room with three economists who come up with seven opinions.

Short of taking the official grading course, and learning the role of judgment, obtain a grading rule book for the species you work with. You can get them online or order hard copies from any grading agency to put in your tool chest.

All of the regional grading authorities like the West Coast Lumber Inspection Bureau (WCLIB) or NELMA maintain a broad program of standardization of grades and manufacturing practices, in conformity with the basic provisions of the American Lumber Standard (US Department of Commerce 2010). ALS is the overriding authority and the source for all North American softwood lumber grading rules.

The American Lumber Standard Committee (ALSC) promulgates standards for the regional grading authorities and lumber inspectors. In Canada and the US, the wording, terminology and intent of every regional grading agency's rules are based on ALS sizes, terms and definitions. Grade limits for knot size, slope of grain, rot and most other defects are, with minor differences, essentially the same across the species.

Note that what you see in the grading book are the maximum allowable defects. You won't get all the maximum defects characteristics in each and every piece. In addition, "Any piece with a combination of characteristics which are judged to be more severe than the maximum characteristics permitted in the grade, even if taken individually is permitted, shall be excluded from the grade" (NELMA 2006 Standard Grading Rules General Provisions, Section 5-5).

Regional grading authorities concentrate on local species like Eastern white pine, hardwoods when used as structural timbers, and, on the West Coast, Douglas fir. Minor variations do not really affect our conversation about structural timbers at an introductory level (WCLIB ¶130, NELMA ¶25, WWPA ¶70, NLGA ¶130).

Structural timbers Structural lumber and timbers are graded for strength and all structural grades permit knots. In ascending order of nominal size, we have Structural Light Framing (2 in. thick x 4 in. wide), then Structural Joists and Planks (3 in. thick x 4 in. and wider), then the big stuff that most interests timber framers—Structural Beams, Stringers, Timbers and Posts. When the grade name includes structural, you are going to get some knots!

There are three main grades of the big stuff: Select Structural, #1 Structural and #2 Structural. We will ignore Dense Select Structural and Dense #1. Dense grade is useful for demanding engineering applications, but a close reading of WCLIB ¶204-c shows that as few as four rings per inch are permitted as Dense under certain circumstances. If you want fine appearance, you probably can't count on Dense to provide it, but you don't have to get involved in technical interpretations of density and rate-of-growth rules. If your goal is better appearance, then there are simpler ways to achieve that. For example, specify the minimum number of rings per inch, restrict wane or reduce knot size as part of the order confirmation. *It's okay to write your own custom grade as long as both buyer and seller agree.* If you are literate with the official rules, this becomes pretty easy.

Can you grade Eastern hardwoods under the softwood grading rules? I'll exaggerate to make a point, but any species of wood can be graded under the structural grading rules. The knot sizes, holes, slope of grain, skips, and all the characteristics listed apply when visually grading the timber if the species is being used as a structural timber. Engineering stress tables by species will then complete the story and indicate if the timber may be allowable for a particular end use in the timber frame. Two Eastern hardwood species are in fact listed in NELMA Section 1-1: maple and oak (maple ¶14, mixed oak ¶16, red oak ¶17, and white oak ¶19).

In structural timbers, which are graded only for strength, the number of knots is not limited, merely their size and placement. The idea is to allow only small knots in the middle and larger ones at the ends. Structural timbers are also graded from the worst face, such that the most serious characteristic that affects strength determines the grade. Most of the timbers you get will be certified and on grade, but it never hurts to do a grade check.

Squint at the wood soon after the truck delivers the order. Some version of a speedy check list will get you in the right ballpark for sorting a timber order into three general grades. If you order #1 Structural and you see lots of knots the size of your palm, for instance, then trouble is a-brewing.

Rough and dirty grading Make a simple table to compare the four or five major characteristics (defects) in a grade (WCLIB ¶130).

Table 1 Quick Grading for Structural Beams & Timbers

Defect	Select Structural	#1 Structural	#2 Structural
Knots	20% of face or edge	30%	50%
Rot	No	No	Scattered, small spots
Holes	No	No	Same size as knots
Slope of Grain	1:15 Middle third	1:10 Middle third	1:6 Full length
Splits	0.5 width	1 width	2 widths

Speed grading In a different approach, wouldn't it be nice just to glance quickly at a timber as you flip it over and get a good idea of what grade it's close to?

For *knot size*, here are three easy hand gauges to apply to a 10-in. or 12-in. face. (Don't worry about the middle third of the length reference in the rules. This tactic will get you close enough.)

Thumb-finger O, about 2 in. average dia. Select Structural
End of fist, about 3 in. average dia. #1 Structural
Top of palm, about 5 in. average dia. #2 Structural

For *rot*, if *any* is visible, immediately grade as #2 Structural or lower.

For *slope of grain*:
1:6 #2 Structural
1:10 #1 Structural
1:12 Select Structural

For *splits*:
Splits through #2 Structural
Halfway through #1 Structural
One-quarter through Select Structural.

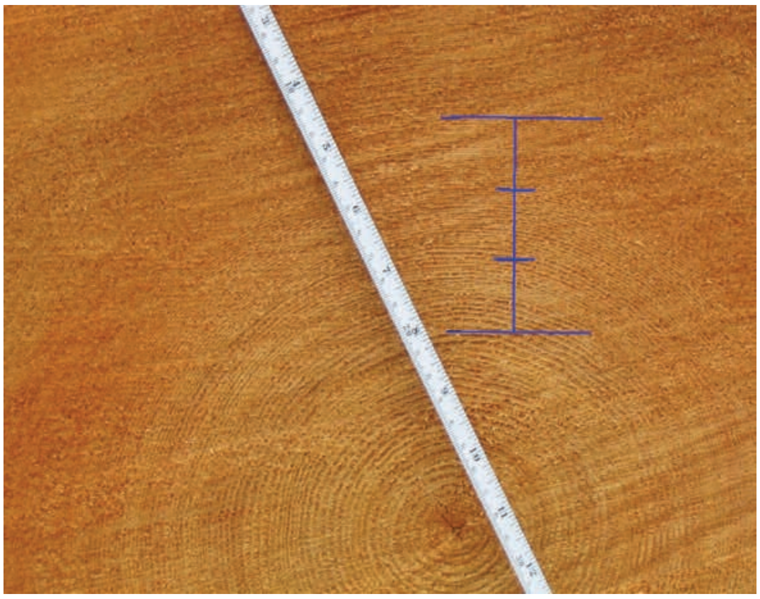
Not all splits or fissures (shake, end check, surface check—in general, any separation of the wood fibers) are of the same structural importance. They will require a second close look with your rule book in hand, but these proportions will get you started. If all the other prior defects easily meet the grade requirements, but you have a significant fissure, get your grading shoes on and grab your tape measure.

Alternate speed grading Here's a third checklist.
Visible rot — #2 Structural (at best)
Knots—What's the largest knot as a percentage of width of the face being graded?
25 percent Select Structural
35 percent #1 Structural
55 percent #2 Structural
Slope of grain below 1:8—solid grade of #2 Structural
Slope of grain below 1:6—falls out of #2 and into Utility
Splits in depth as a percentage of width of face being graded:
60 percent #2 Structural
40 percent #1 Structural
25 percent Select Structural

These three quick grading procedures get the timber *generally* in the right pile. If you order #1 Structural and you find you are putting 30 to 50 percent of the sticks in a #2 Structural pile for knot size, holes, slope of grain or rot, then you need to consult with a lumber grader. Go get the lumber expert in your tribe to check things out, take pictures, and immediately put your supplier on notice of a possible complaint. For serious unresolved grade claims there are formal reinspection procedures in the rules. Anyone can call for an official reinspection, but the loser pays ($1500 or more). It's best to try to work things out before it comes to that (WCLIB ¶300, NELMA ¶5).

Sometimes a few sticks, maybe 3–10 percent of a load, cause concern or are borderline because of harder-to-measure defects like splits, shakes and checks. These may have developed after the timber was cut and shipped because of timber movement, drying, or seasoning in transit. Be aware that the grade rules allow for 5 percent defective pieces—that is, below the invoiced grade—in a shipment of timber. Five percent should seldom happen but some percentage will. These are good arguments for ordering extra pieces.

Rate of growth measurement Boxed heart (BH) Douglas fir, the most typical cut and usually from second-growth or younger



1 Fine-grained salvaged dry larch, with about 25 RPI.

2 Slope of grain is apparent from surface checking.

forests, often displays a coarse rate of growth, with four to five rings per inch (RPI). Free of heart center (FOHC) timber generally comes from larger, more mature logs with closer rings. FOHC generally has less sapwood, is more stable, and develops less split, warp, twist and crook as it dries. To get visually tighter grain, the easiest solution is to specify a minimum of 8–10 rings per inch as part of the specs in the order confirmation. It should be measured radially or nearly so on the endgrain along a 3-in. line, a varying distance from the heart according to the width of the piece (Fig. 1).

Slope of grain measurement Slope of grain is the deviation of the splitting plane of the wood fibers from a straight line parallel to the edges of the piece. It's easiest to see when a surface check has developed. The correct way to measure slope of grain is to lay a straightedge along the direction of the grain. Choose a 5-ft. baseline parallel to the edge of the piece to overcome any local grain deviations (Fig. 2).

Clear does not mean clear There are various grades and levels of "Clears." Clears are graded not for structural qualities but for fine appearance from the best face of timber. Compared with structural timbers, the number of knots allowed is strictly limited. For example, C Clear (WCLIB ¶151-c) allows only two small knots in a piece 8 in. wide by 12 ft. long. More knots are allowed upon an increase in surface area of the face graded. A piece 16 in. wide by 12 ft. long may have four small knots (Fig. 3 is almost D Clear).

Characteristics affecting appearance such as stain, sapwood and holes are restricted. The reverse face in many grades may be one grade lower and often allows 50 percent more knots. If as a timber framer, you wish to have more than one face of a timber to be clear or to have restricted knots, then write that into the order confirmation. It's accepted to write custom grades as long as both parties agree.

"Clear" lumber under any of the rules is usually grouped into three grades. The names vary from agency to agency. The intent of the top grade is to be virtually knot-free in most of the pieces. The middle grade may have one to three knots. The third grade of "clear" may have anywhere from four to six knots on the best face with 50 percent more on the back. In larger clears like beams and posts, the best wider face determines the grade and the reverse or back face may have more defects. But if (as is common for exposed timbers) two or three or perhaps all four of the surfaces will be seen, and it matters how they look, then you can write the requirement into the confirmation of sale. Something "B & Better [the highest possible appearance grade, not a mixed grade] No Knots Three Faces" should do the trick. Best practice when ordering is to include the grade and paragraph number as part of the spec. But beware—not all agencies use the same grade names (see Table 2), and names vary depending on size, surface and form of the product! Look in the book or consult a knowledgeable supplier or local grading agency.

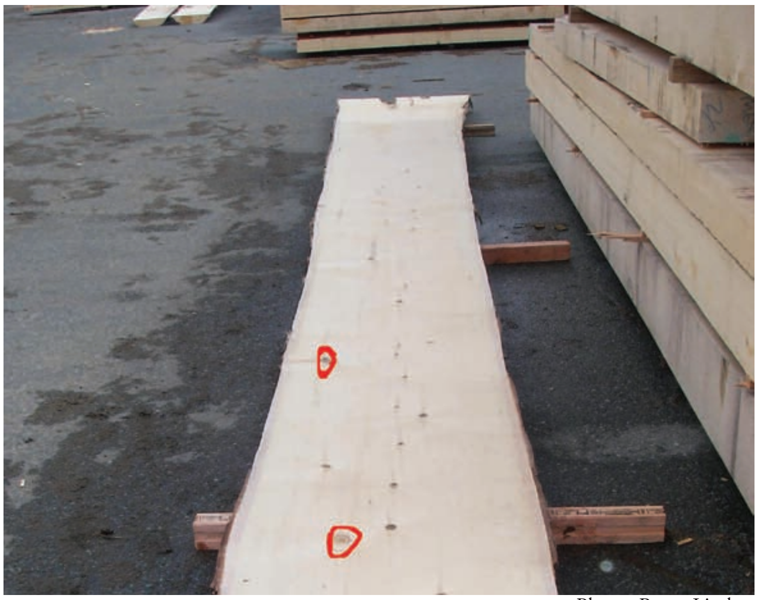
Table 2 Multiplicity of "Clear" Grade Names

Top Grade	Middle	Third	Agency
B & Better	C	D	WCLB
A	B	C	NLGA
#1 & #2	#3 Clear	#4 Clear	Export R-List
Select & Better	#2	#3	NELMA

Cut-outs in clear grades A cut-out is defined as a crosscut 3 in. wide, 3 ft. from the end in a piece 12-ft. or longer. They are generally permitted in C Clear and D Clear grades. This provision assumes the user will be cutting the material into shorter pieces and allows for a few pieces, otherwise very good looking but with some isolated defect, to meet the grade. It's a shame to reject a 20-ft. long clear piece with one large knot more than 3 ft. away from an end, so the rules allow cut-outs in 5–10 percent of 12-ft. or longer pieces. Cutting out the defect gives you two shorter clear pieces.

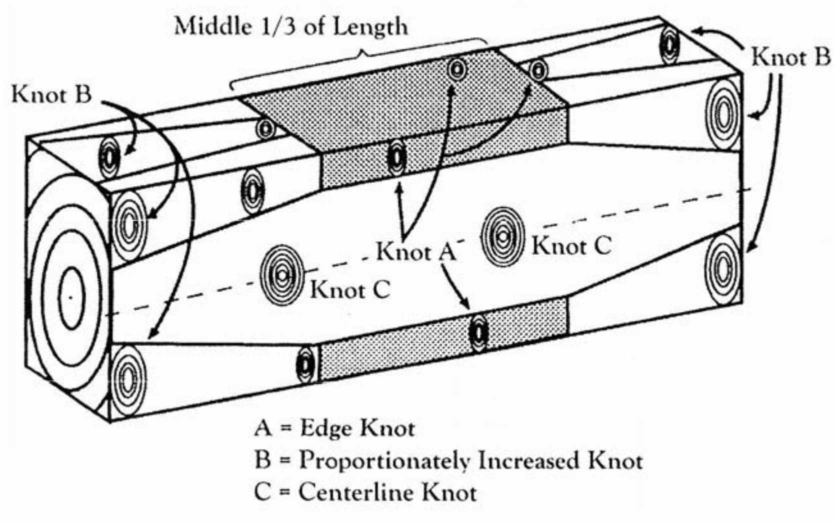
If you have no use for short 3-ft. to 6-ft. clears on your job, the solution is to specify "No Cut-outs" on your order, but realize that this will increase the price (Cedar WCLIB ¶149-c cut-out allowed in 10 percent of the pieces; NELMA ¶6.1.2. Eastern white pine, D Select, 5 percent).

Mixed grades Specifications like "#2 & Better" or "D Clear & Better" are vague and can be trouble. The first thing a lumber inspector will say is that such a grade does not exist. It's not in the book. If you can accept a mixture of grades, best to quantify the grade, for example "85 percent C Clear & 15 percent D," or "25 percent #2 & 75 percent Better." The price will generally indicate the quality of mixed grades and the actual amount of "Better" left in the grade. Some mills have a whole range of products, such as J Grade Export, lamination stock, millwork, scaffold plank, boat



Photos Bruce Lindsay

3 Almost D Clear yellow cedar. Nonconforming knots are circled.



National Lumber Grades Authority

4 Proportionate increase in allowable knot size from middle third of the timber toward ends of piece. Allowable centerline knots and end knots are equal-sized and larger than edge knots.

lumber and machine stress rated (MSR) lumber (which has been nondestructively tested by mechanical stress-rating machines to indicate bending strength). You may find that much of the "cream" has been picked out of the grade, and a shipment of #2 & Better is mostly #2, with perhaps an occasional piece of borderline #1. It is prudent when ordering to ask if there is prior selection for Select Structural or if higher export grades have been picked out of the grade. I've generally found it better to order specific grades rather than blended grades. In an order of #2 & Better, if you get all #2 and virtually no #1, you really have no recourse to the supplier.

For casual timber grading, you will need to be familiar with only about 35 percent of the grade book. Many products in the book we will likely never use, from casket stock to furniture parts to railroad ties. But the definitions in NELMA ¶700 and glossary will come up in any grade discussion, so refer to them often. General grading provisions, methods of knot measurement, definitions and standard sizes are common to all lumber grades and products covered in the rule books.

Advanced grading in structural timbers can get quite complex. "In structural grades of Beams and Stringers, the size of the knots on the narrow faces and at the edges of the wide faces are the same. They may increase gradually from the size permitted in the middle one-third of the length to that permitted at the ends" (NLGA grading course manual, 1972, page 75. For proportionate increase of knot size, see NELMA ¶41.0, NLGA ¶320-c, WCLIB ¶201-a). This is advanced grading and really looks at the science of assessing knots (Fig. 4). Read all three rule books to see the different approaches to this subject.

Grade descriptions always include descriptive adjectives such as "occasional," "large," "small," "short." These adjectives are defined and quantified explicitly in the ¶700 definitions. These apply to all grades listed in the rule book. For example, "Occasional" is defined as not more than 10 percent of the pieces in a shipment. A "medium knot" may not be over 1½-in. dia. A "short split" may not be longer than the width of the piece. So a short split in a 10x14 WCLIB 149-b "B & Better" Clear will be not longer than 10 in. The use of common definitions applying to all grades in the book is efficient and keeps the grading book to a manageable size. You will be flipping constantly from timber grades in the middle of the book (NELMA Section 6 ¶25 or WCLB Section 5 ¶130) to Definitions & Abbreviations (¶700 in the back).

The lessons to be learned are many. If you are not confident about a verbally expressed grade, have a copy of the rule sent to you. Put the grade rule and paragraph number on the job specification and the order confirmation. In cooperation with a grader, when necessary write your own grade rule speaking in "plain language, no code." Call your local grading inspection authority for guidance. Or pay for a grader to come to your office to give your team a brush-up lesson on the grade that interests you. Have a grader as one of your team.

When you and your team become literate with the grading rules, you'll avoid a lot of heartache down the road. Timber grading rules show us how to choose the right timber for the job and know in advance what to expect. By knowing the syntax, grammar and terms of the rules you will demonstrate a competency and professionalism that will serve you well. This knowledge will keep your shop running efficiently and allow you to meet and exceed your customers' expectations. —Bruce Lindsay

Bruce Lindsay (brucelindsay@shaw.ca) runs Evergreen Specialties Ltd., a timber brokerage, in North Vancouver, British Columbia.

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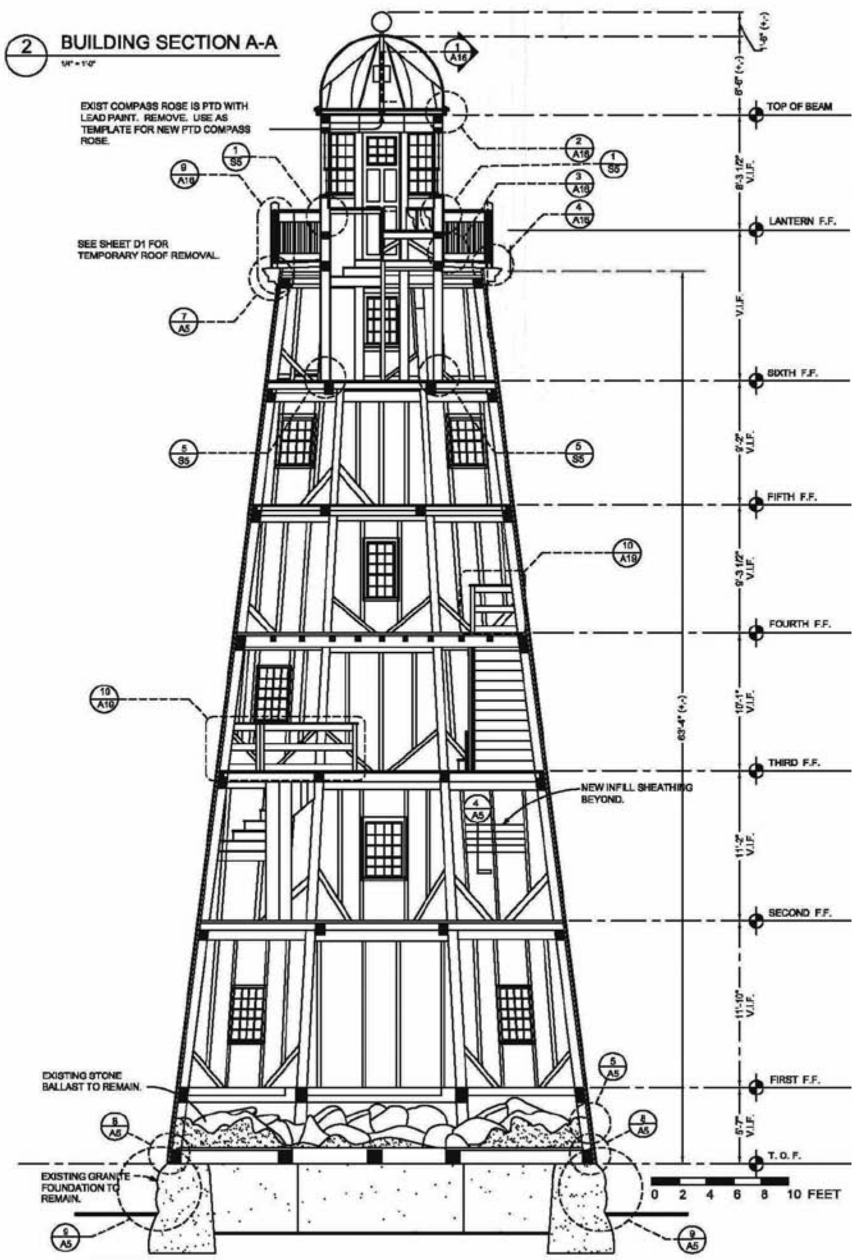

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TTL Architects

The Portland Observatory

TIMBER framers have long recognized the links between the nautical and timber framing worlds. One example of this shared tradition is the Observatory in Portland, Maine (Fig. 1). It's not a lighthouse but a marine signaling tower, the only known one left in the United States. It was designed by a ship captain in 1807 and let a merchant know (literally) when his ship came in.

Owned by the city and located on its tallest point, Munjoy Hill, the Observatory is unique, drawing some 7000 visitors each year, and was added to the National Register of Historic Places in 1972. In 2006 it became a National Historic Landmark and was named a National Civil Engineering Landmark by the American Society of Civil Engineers.

The tower is substantially built. Captain Lemuel Moody (who got a taste of all aspects of sailing, including being captured by pirates) knew a thing or two about the overturning forces of wind when he planned the 86-ft. structure. Like a lighthouse, the eight-sided tower is purposefully tapered, its walls sloping a bit over 7 degrees. In plan, it measures 30 ft. at the base and 16 ft. at the sixth floor across the flats of the octagon.

An unusual detail the Observatory shares with ships can be found in its base, which is filled with stone ballast. The tower is not physically anchored to its foundation in any way but is kept steady by 122 tons of large granite boulders stacked within the spoked-wheel configuration of its massive sills and girders (Figs. 2 and 3).

The perimeter of the structure is formed by eight canted (or cant) posts, continuous 65-ft. five-sided timbers (Fig. 4). These hewn posts taper like the Observatory, measuring some 14 in. square at the base and about 10 in. square at the top. They were cut and roughly squared for the contracted sum of $12 each in the nearby town of Windham. Like ships' masts, they were hauled by oxen some eight miles to the Presumpscot River and floated over a set of falls to the sea as far as the Portland peninsula, arriving finally at the Observatory site on Munjoy Hill.

Photos Don Perkins unless otherwise credited

1 Far left, the Observatory, 86 ft. tall, Portland, Maine, 1807.

2 Left, adapted detail of architect's elevation section, 1999. Note boulders to stabilize base of tower.

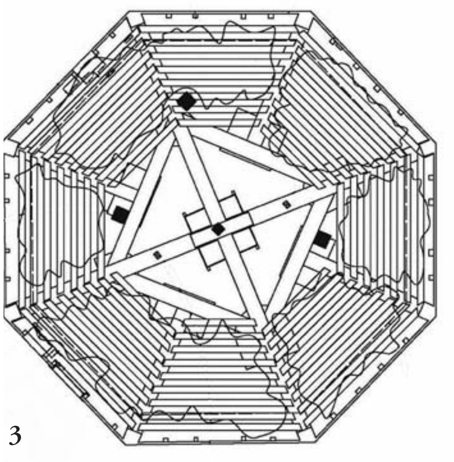
3 Below, adapted architect's plan view (scaled to elevation view) of base framing, 1999. Boulder ballast indicated by wavy lines.

4 Above, cant post. Builders hewed a prow on the outside face to conform to the octagonal plan, but the sides of the posts do not face each other for normal connections to girts and braces.

5 At top, mix of 1807, 1939 and 2000 work, with errant peg. Tenoned and pegged ring girt to right is original; ring girt to left is a 1939 replacement.

6 Above, oversize mortise and packing piece indicate brace was fitted after tower's erection.

7 At left, untenoned replacement ring girts fitted from inside into diminished housings in 1939, with cover patches to fill out original post section.



3

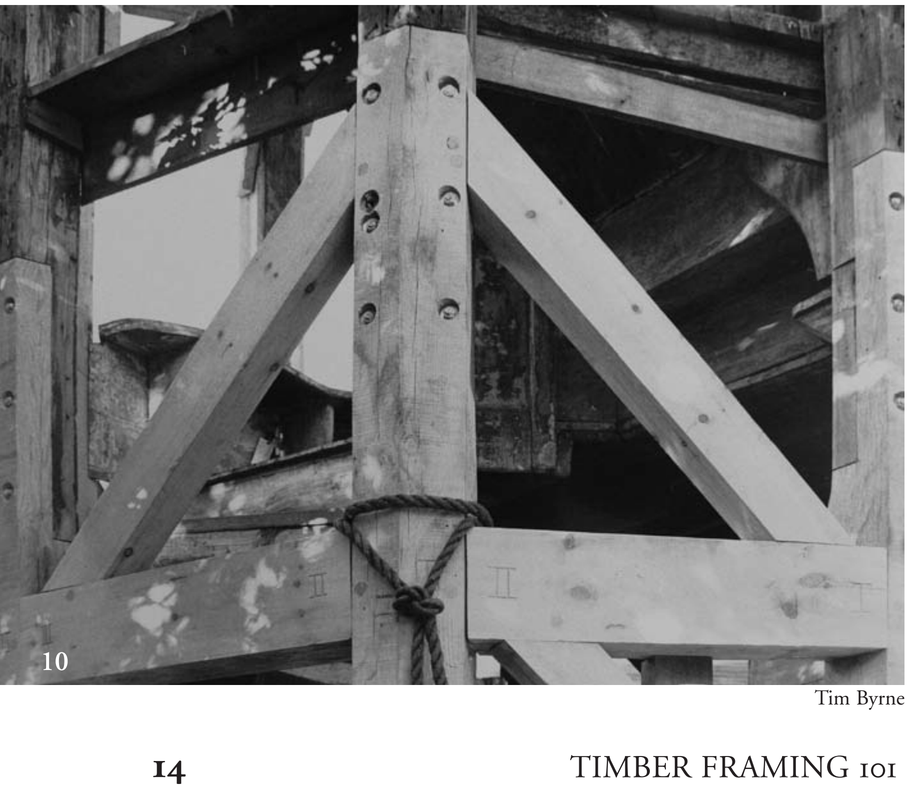
TTL Architects

The Observatory is unfinished inside, affording a fine view of much of the joinery. The structure went through two restorations: 1939 saw the replacement from inside of almost half of the ring girts with sawn material and a coat of dark stain applied to the interior. The new girts are untenoned, supported instead on shoulders cut into the posts (Fig. 5). A more accurate and thorough overhaul in 1999–2000, at a cost of $1.28 million, removed all sheathing boards and dealt with a powderpost beetle infestation. While the lantern was removed, the tower frame was not disassembled; according to Julie Larry of TTL Architects of Portland, the firm in charge of the restoration, the architects and contractor feared they "might never get it back together again."

The frame and boarding of the tower are of Eastern white pine, with the exception of the 8-ft.-dia. oak lantern deck, the uppermost dome where Captain Moody would gaze through his telescope identifying various ships approaching Portland Harbor. Once a ship was spotted, a specific flag was raised for any merchant who had contracted with Moody. The eight 7½x7½ lantern deck posts (also five-sided) are white oak and about 19 ft. 6 in. long. These are anchored into summer beams below via threaded rods, with housings for the nuts concealed by wooden plugs.

Towers are difficult, and the layup, scribing and assembly must have been daunting, not to mention the raising. (Think 60-ft. gin poles.) As the elevation drawing shows, the tower is not comprised of platforms stacked atop one another; the 65-ft. posts are unbroken. But Moody and early-19th-century builders in a port town were familiar with setting ships' masts and might have felt right at home with such tasks.

Some original timbers evidently were put in place after the cant posts were fixed into position. All braces, for example, were inserted into chase mortises (Fig. 6), with the resulting gaps filled with packing pieces. One oddity of this structure is the small triangular patches ¾ in. thick and nailed over the numerous replacement ring-girt connections (Fig. 7).



Tim Byrne

As to the natural question of how this tower was raised, Tom Thomsen of Woodard Thomsen Co., Portland, who did the 2000 restoration, speculates the posts might have been assembled on the ground in pairs, four opposing "ladders" or bents of a sort, which were raised with their ring girts pegged in place and their feet tipped into place in the octagonal sills. Once these bents were up, spread somewhat from their final position, they could then be linked together progressively higher via the remaining ring girts. This theory would seem to be contradicted somewhat by the fact that all the original braces are fitted to chase mortises with packing pieces. (The theory would be strengthened if four opposing pairs of posts were found to have been braced internally to their ring girts in blind mortises.)

In 2000, more ring girts were replaced. Since the frame was not disassembled, the contractor used slip tenons to fit new girts in place, between the fixed posts, but no evidence of this method appears in the original connections. Perhaps (to suggest an alternative to Tom Thomsen's theory) Lemuel Moody's 1807 builders set all posts individually into the sills, outside a network of staging, with ring girts in position at appropriate heights of the staging, and crew at each joint guided the tenons into place as the whole structure was tightened with ropes.

The summer beams alternate direction at each level, all set atop ring girts (Fig. 8). Summer beams tenoned directly into the cant posts at ring girt level would have required excessive mortising and removed too much material from the all-important posts.

During the 1939 repairs, the first four floors were fitted with stacked center posts, presumably to correct sagging (Fig. 9). The latest repair work is readily apparent because it lacks the dark stain applied during the first renovation. No builder's marks are evident inside, but the framing of the lantern deck, photographed after removal and repair in 2000, displays Roman numerals on the outside surfaces of replacement timbers, likely copying what was found on the originals (Fig. 10).

There are many irregularities within the timbers themselves as well as in joinery details, especially at the post mortises, because of the repair method chosen in 1939. While original ring girts are hewn, replacements are sawn, in some case bandsawn, misleading the lay visitor to suppose they might have been up-and-down sawn, like the original boarding. Other elements from the 1939 work, such as the center posts, are circular sawn. Original ring girts vary somewhat and measure about 8½x10, with 3-in. tenons. Some at random are smaller in cross-section. All secondary joists and wall scantlings are vertically sawn, measuring a nominal 3x4.

The Observatory was lucky to be spared the great Portland fire of 1866, along with the ca.-1828 Abyssinian Meetinghouse (see TF 93) just a few blocks away, which also escaped the flames. Observatory staff say men stationed with buckets of water at the tower's windows likely saved this monument. The Abyssinian was saved by a dedicated firefighter, who covered that structure's wood-shingled roof with wet blankets. —Don Perkins

Don Perkins (don@ourbarns.com) is a writer and barn enthusiast living in southern Maine. The Portland Observatory (portlandlandmarks.org/observatory) is open between Memorial Day and Columbus Day. There are one hundred four steps to the lantern deck.

8 Summer beam for floor joists supported on replacement ring girt. Adjacent girt is original.

9 Braced center post added in 1939 to resist floor sag. Post above is turned 45 degrees.

10 New and repaired lantern framing during 2000 restoration, with half-lapped, bolted connections to old framing.

All photos Studio Perini Associati

1 SS. Pietro e Paolo at Marilleva 1400 (Trento), in Italy's Sun Valley, finished 2006. Design and engineering by Studio Perini Associati, Trento, with architectural design by Lorenzo Perini, engineering by Luciano Perini. Engineered larch and fir framing by Holzbau, Bressanone (Bolzano). Footprint about 750m^2, cost €2,000,000. Large stained glass display stands just inside north-facing glass.

Church in the Trentino-Alto Adige

MARILLEVA in Mezzana is a mountain village in the Trentino region of northern Italy, facing on the Val di Sole, an Alpine valley rich in conifers and rivers. Built at altitudes of 900 and 1400m beginning in the 1970s, Marilleva is still one of the most interesting projects in Italy's favorite region for ski tourism and summer holidays. Nevertheless, an absence of controls made possible such runaway construction of concrete seasonal houses—for a total of about 20,000 beds—that Marilleva became environmentally one of the least exemplary tourist destinations in Italy. Serious landscape damage resulted from thousands of buildings built in the woods without a precise plan.

When SS. Peter and Paul was built in 2006 at Marilleva (Fig. 1), it represented the first sign of sustainable and systemic planning in the valley for more than 40 years. The choice to use local wood as the primary building material and to orient the church on the Val di Sole has started a new relationship between architecture and *genius loci.* New architecture built since the church has preferred timber over concrete, and more integration into the surrounding woods.

Architecture Designed on an irregular plan to follow the lines of the obtainable lot, the building's similarly irregular roof inclines contrary to the slope of the mountain and suggests something ready to fly away under a strong wind, or to slide down under heavy snow—light architecture, temporary, seasonal. But its framing elements look appropriately heavy to resist the strong visual nature of the mountainside.

Perhaps the most innovative design is the inside of the roof, with a symbolic sun spreading wooden rays in its sky (Figs. 2-5). The clerestory windows at the top of the perimeter walls give light, recalling the Schreiner House (1959–1963) by the late Norwegian architect Sverre Fehn. The orientation is uncommon: traditionally facing east, here the apse faces north (to keep the parishioners from being dazzled by direct sunlight, according to the designers), its huge window fitted on the inside with a spectacular display of abstract stained glass intended to resemble watercolor.

Framing All exterior framing members are larch glulams, including the round pillars and long braces. The 36cm-dia. pillars, spaced about 6m apart around the perimeter, are doubled, the lower facing inward to support the wooden floor of the church and the higher facing outward to support the roof. Supporting glulam fir beams for the interior floor (Fig. 2) are 16x73.5cm (main frame) and 18x56cm (secondary frame), sheathed in plywood 42mm thick covered by about 25cm of light concrete.

2

3

The roof system (Figs. 2–5) is divided into nine different pitches as steep as 50 degrees and includes a cupola and a cantilevered free-span on the north or apse end of about 6m. The framing inside may be compared to a complex of wooden trusses with rafters and kingposts all converging to one point, forming a truss with 60mm radiating steel cables as tie rods. The laminated fir rafters are sized variously according to the different loads they might carry, with an average depth of about 60cm. Most connections, visible or concealed, are steel-finned and cross-pinned or bolted to the wood.

Over the rafters, the layers are plywood 42mm, vapor barrier, 10cm (5+5) of polystyrene panel insulation, free ventilation 5cm, planks 24 mm and copper sheet roofing. Walls have 18mm plasterboard inside, 20mm larch cladding outside, and between them 5cm of free ventilation on both sides of a sandwich of 18mm OSB panels protecting the inner 16cm of rock wool. —Thomas Allocca

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

2 At top, construction photo facing north toward the apse, showing finned connections for joists and steel tie rod truss system. Compare Fig. 4.

3 At left, construction photo facing south, showing repeated use of curved elements to resolve problem of converging timbers. Compare Fig. 5.

4 At right above, large array of stained glass, protected by clear exterior building glazing, evokes water colors.

5 At right, clerestory at top of walls brightens body of church. Service rooms to the rear.


4


5

Ed Levin

1 Short log wall and base of synagogue roof to be installed with remaining elements and finished interior in 2012 at Warsaw museum.

A Synagogue Roof in Poland

THE roots of the Gwozdziec Synagogue roof project, undertaken in earnest this summer in Poland (Fig. 1), go back to the efforts of Marek Baranski, of Warsaw, who introduced the idea of reproducing the lost synagogue at Zabludow to the Guild's 2003 TTRAG Symposium in Shepherdstown, West Virginia. Later that year, Baranski organized a conference in Bialystok, not far from Zabludow, on the lost legacy of wooden synagogues. Numerous Guild members attended the Bialystok conference.

As time would prove, the most inspired were Rick and Laura Brown, artists and entrepreneurs at Handshouse Studio in Norwell, Massachusetts, and professors at the Massachusetts College of Art and Design (or MassArt). Handshouse had recently organized the building of a large 18th-century French builders crane at Norwell, working from original documents, and shown themselves adept at making a large reconstruction "a time machine for learning," as Rick Brown put it (see TF 64).

Handshouse took a deep interest in the subject of lost wooden synagogues and returned to Poland the next year leading a group of MassArt students, touring widely and looking at wooden vernacular architecture, making an extended stay in the village of Narew to document the Catholic and Orthodox churches there (see TF 70 and 75).

The Narew trip, the first of many such educational expeditions, workshops, courses and research projects focusing on the wooden synagogues of Poland, followed the Handshouse paradigm: studying history hands-on via existing artifacts and documents, and then using traditional tools and techniques to replicate vital pieces of the past now lost to us.

Out of the 2004 trip, course work at MassArt and later MassArt trips to Poland in successive years, and with the help and collaboration of architectural historian and author Tom Hubka and other scholars, Handshouse put together a traveling exhibition, built initially around 1:12 scale models, first of the Zabludow Synagogue (Fig. 2), then of another that had stood at Gwozdziec (Figs. 3 and 4), with additions coming to include a full-scale *bimah* (a central, free-standing pavilion with lectern, from which the Torah is read) and log entrance, as well as half-scale paintings reproducing ceiling panels from the Gwozdziec Synagogue.

While the Handshouse crews and classes traveled, observed, recorded and built models, in Poland the Jewish Historical Institute Association was making plans for a new museum to be built in the heart of what had been the Warsaw Ghetto and to chronicle one thousand years of Jewish history in Poland. (The Museum of the History of Polish Jews is scheduled to open in the spring of 2013.) Eventually, Rick and Laura Brown encountered scholar Barbara Kirshenblatt-Gimblett, leader of the team planning the museum's core exhibition, beginning an association that bore fruit in 2011 in the Handshouse project to build and install an 85-percent scale replica of the Gwozdziec Synagogue roof, including elaborate polychrome paintings authentically reproduced on wood, as a permanent exhibit at the museum in Warsaw.

Handshouse Gwozdziec Reconstruction Timeline

2003	-	Handshouse initial visit to Poland
2004	-	Zabludow model, coursework, Handshouse workshop
2004	-	MassArt student travel documenting historic architecture of Poland
2005	-	Gwozdziec ceiling painting workshops (first of series)
2006	-	*Bimah*-building workshop
2007	-	Student travel documenting historic architecture of Poland
2007	-	Rick Brown Fulbright research fellowship
2007	-	Student travel documenting painting
2008	-	Gwozdziec model, course work, workshop
2008	-	Student travel documenting painting
2009	-	Student travel documenting historic architecture of Poland
2009	-	Student travel documenting painting
2011	-	Framing workshop in Sanok, painting workshops, with student, professional, Polish and international participation
2012	-	Museum replica painting workshops (ditto)
2012	-	Installation of timber frame, cupola and painted ceiling in Museum of the History of Polish Jews in Warsaw
2013	-	Opening of the Museum and permanent exhibition of Gwozdziec roof

Handshouse turned to the Timber Framers Guild as prime contractor for the timber structure. The work was to be done by some 30 professional framers working in tandem with crews of students (including MassArt students) from the US and Poland in a six-week workshop this summer in southeastern Poland. Once the cupola was completed, the structure would be dismantled, the pieces numbered and log walls and timber frame would go into storage pending completion of the museum building in Warsaw. The cupola sheathing boards would be measured, numbered and packed to travel to eight successive painting workshops organized by Handshouse and scheduled over this summer and next, where student painters, including many from Poland, would recreate the polychrome ceiling of the Gwozdziec Synagogue. The timber frame and painted cupola would reunite in the completed museum building in Warsaw in the fall of 2012. The Guild workshop completed the promised woodwork in July and the cupola boards are being painted in the scheduled Handshouse workshops.

History Behind the Gwozdziec reconstruction project, funded by the major gift of Irene Pletka and the Kronhill Pletka Foundation, the history reaches back to the 17th century and beyond. Our contemporary perception of Polish Jewry is typically seen through the lens of the Holocaust, but there is a thousand-year-long history of Jews in Poland. While the reality of anti-Semitism, ghettos and human tragedy cannot be denied, there is much more to the story.

Coming up to World War II, one-third of the population of Poland was Jewish, and Warsaw had the largest Jewish population of any city in the world. Back hundreds of years Poland was known as the *paradisus Iudaeorum* (Jewish paradise), a place renowned for its tolerance and acceptance, particularly through the period of the Polish-Lithuanian Commonwealth from the middle of the 16th century to the end of the 18th century. During extended periods of peace and prosperity, Jewish communities and Jewish culture flourished in Poland, leaving an artistic and architectural legacy. And most notable among the building heritage were wooden synagogues dating from the 17th and 18th centuries.

Wealthy urban congregations built stone synagogues. Village communities with limited but sufficient resources resorted to timber and produced a style of building unlike anything seen else-

Handshouse

Ed Levin

Alois Breier, Max Eisler and Max Grunwald
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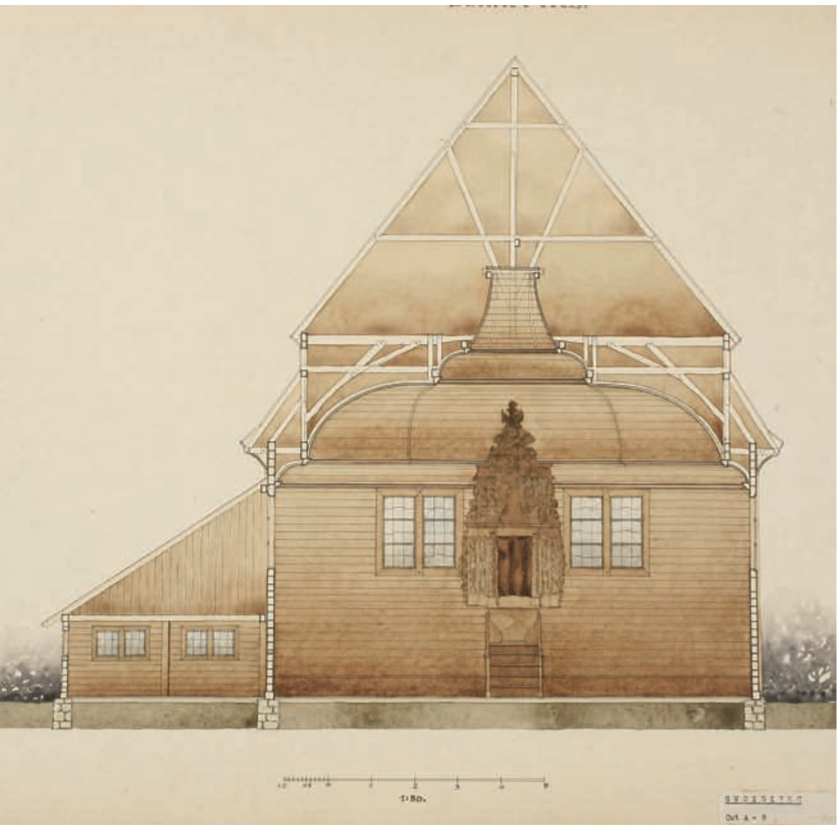
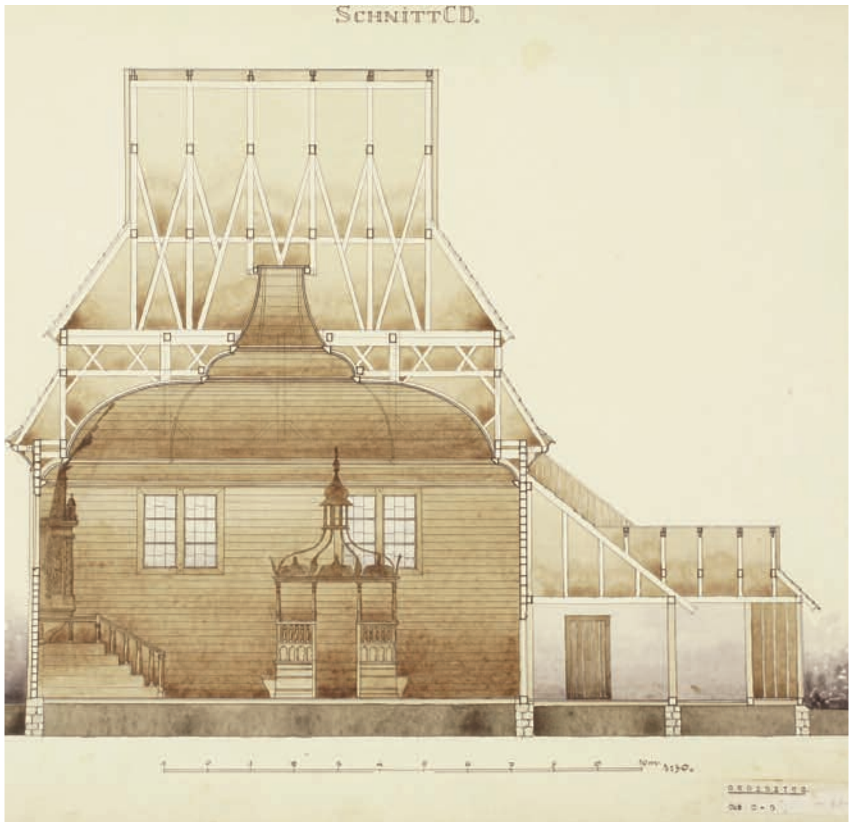
2 At top, first stage of model of Zabludov Synagogue built at Handshouse Studio in Massachusetts.

3 At middle, model of Gwozdziec Synagogue built at Handshouse, on site in Poland for reference by the builders of the reconstruction.

4 Above, photo of Gwozdziec Synagogue, ca. 1913.





Alois Breier, Max Eisler and Max Grunwald. Images used by permission Tel Aviv Museum of Art

5, 6 Breier, Eisler and Grunwald's combination section-elevations of Gwozdziec, from which roof reconstruction dimensions were scaled.

7 Facing page, view of open-air museum in Sanok, Poland, where framing reconstruction took place. Note oil derrick.

where, before or since. These structures featured tall log walls surmounted by elaborate timber frame roofs. To the street they presented more or less ordinary façades, impressive in size, but similar in style to other domestic and modest ecclesiastical buildings. But inside was a very different story. The roof frames supported (and were concealed behind) compound curved domed cupolas, with inside wall and ceiling surfaces throughout covered with brilliant polychrome liturgical paintings and religious texts.

This interweaving of two separate structures into one made the synagogues into hermetic vessels, their plain exteriors concealing interior spaces of extraordinary power and intensity. It's hard to imagine the sudden, enormous and complete transition from the secular street to sacred space experienced by congregants entering the synagogue. Tom Hubka describes the experience in *Resplendent Synagogue* (2003):

> For the Gwozdziec congregation, moving from the outside world into the prayer hall's swirling vortex of form and color must have been an intense spatial experience. Their day-to-day lives were set in a muted environment dominated by the dull browns and smoky grays of earthen streets and untreated wooden structures, broken only by points of color and texture. Against this muted backdrop, the prayer hall had visceral intensity that was literally not of their everyday world.

One other element that presumably set these buildings apart was sound. I remember my own experience in 2003 of choral sacred music in a small polygonal wooden church deep in the Polish countryside at Szczyty-Dzieciolowo. As we left the bus and walked toward the green-painted walls of the building, the air suddenly filled with music. It was an Orthodox holy day, and the congregation (mostly women in coats and headscarves) crowded the octagonal nave as their raised voices, counterpointed by the deep tones of the young priest, filled the space inside the church and spilled out into the walled churchyard and beyond. Impossible to describe the sense of wholeness inside this wooden vessel, suddenly and completely made holy by devotion embodied in song. I have no doubt that to hear the cantor singing and the congregation chanting under the domed ceiling of a wooden synagogue was an equally transformative experience, no less than the profound visual effects.

Documentation Some six dozen documented wooden synagogues in greater Poland survived into the 20th century. Exact dating is often difficult, given that the buildings and the bulk of the primary documents pertaining to them have since been destroyed. Later 18th- century and 19th-century synagogues might have been built in one go—walls, roof and cupola—while 17th-century examples typically underwent 18th-century retrofits to accept interior cupolas.

Wooden buildings are vulnerable to decay and to destruction by fire (accidental and intentional). Examples of each brought home the fragility of the Jewish architectural patrimony in Poland, and in the 1920s professors and students at the newly formed Institute of Polish Architecture at the Warsaw Polytechnic undertook to document these buildings. Because of their foresight, we have photographs and measured drawings of then-extant wooden synagogues, and books like Hubka's *Resplendent Synagogue* and Maria and Kazimierz Piechotka's *Wooden Synagogues* (1959) are possible.

In addition, we have photographs and measured drawings of the wooden synagogue at Gwozdziec, which had been destroyed in the First World War (Figs. 4–6). Alois Breier, Max Eisler and Max Grunwald documented Gwozdziec (among other synagogues) in 1913, although their work was not published until 1934 as *Holzsynagogen in Polen*. The Tel Aviv Museum of Art provided Handshouse with image scans of the Gwozdziec plates.

The *skansen* The venue for the synagogue roof build was the open-air museum, or *skansen*, in Sanok, in the southeastern corner of the country (Fig. 7). Set in the foothills of the Carpathian Mountains, with Ukraine about 20 miles to the east and Slovakia 20 miles south, the Muzeum Budownictwa Ludowego (Museum of Folk Architecture) is the largest open-air museum in the country, displaying dozens of relocated buildings representing the four ethnographic groups that inhabited the region.

Our workspace at the *skansen* was a gently sloping field adjacent to the display of early petroleum-extraction equipment (Poland was an oil-drilling pioneer). Spread out on bunks was the material for the frame, over 200 European silver fir (*Abies alba*) logs in lengths up to 40 ft. We had before us two distinct projects, first the timber frame structure of the top of the synagogue, including

John Nininger

shortened walls, and then, fitting neatly inside its roof frame, the cupola, a scaffold to carry boarding in four ascending stages, in effect a compound-curved canvas for reproducing the elaborate polychrome liturgical painting that blanketed the interior of the original prayer hall, walls and ceiling.

The Gwozdziec Synagogue was built over a square plan in three vertical stages. The drawings showed that a base of 20-ft.-tall log walls enclosed the prayer hall, 36 ft. on a side. Next a 32-ft.-square box frame, composed of double sills and plates connected by 16 posts, rose 8 ft. 6 in. above the tops of the logs. Finally, six trusses spanning the box frame plates formed the upper main gable roof, with a pitch of approximately 15:12 and a ridge 23 ft. long, allowing for lean-to roof slopes at either end spanning 4 ft. 6 in.

Echoing the upper roof was a slightly steeper lower roof (17:12), with rafters rising from a flying plate (cantilevered 2 ft. outside the log walls) up to girts set 3 ft. below the top of the box frame. Both lower and upper roofs featured hipped corners. Over time, the prayer hall had been surrounded by supplementary structures yielding yet another band to the cascade of lean-to hip roofs.

In its original 17th-century form, the prayer hall seems to have had a simple shallow barrel vault ceiling, indicated by curved inner surfaces on internal bracing shown in measured drawings done early in the 20th century before the destruction of the building. This curve appears both as a cut surface on the lower scissor braces and a dotted line on the upper scissors rising to the main tie beams. (Fig. 5). By extending and joining these lines we could extrapolate the shape of the original barrel vault.

But by the early 18th century, the space had been remodeled and the interior of the roof frame adapted to the four-stage compound cupola (the cupola ceiling painting has been dated to 1729).

The organization of the Guild framing crew echoed the vertical order of the building and a disposition of special talents. John Nininger, a skilled log builder, was in charge of the log walls. Gerald David, a trained *Zimmermann* experienced in historic framing, took charge of the box frame. Bob Smith, veteran of international framing expeditions and all problems that arise, took on the roof frame. The cupola with its multiple curves was the province of millwright and boatbuilder Jim Kricker.

Overseeing the operation were lead carpenter Mikkel Johansen, who took a "vacation" from his timber framing business in Denmark, and Guild project manager Alicia Spence, along with the overall project managers Rick and Laura Brown of Handshouse. Barbara Czoch, of the UK Carpenters' Fellowship and fluent in Polish, was our invaluable minister without portfolio, splitting her time among logistics, translation and pitsawing, of which she was the master. *Skansen* architect Arek Kryda, an expert in Carpathian log building and a vital pillar of the project since well before our arrival in Sanok, quickly made himself indispensable. For crew, in keeping with the nature of the project, we had an international team of framers and students hailing from North America, Belgium, Denmark, England and Wales, Estonia, France, Germany, Japan and, of course, Poland.

Hewing and pitsawing Before we could begin to lay up the log walls or start chopping joints for box frame or roof trusses, we needed hewn beam and post stock. I can testify from direct experience of historic replication work that the choice is typically made to take the low road in timber conversion—to use machine-sawn timber and subject it to some kind of fakery to produce hewn surfaces, a procedure that satisfies neither aesthetically nor philosophically. So it was thrilling to learn that project manager Spence was determined to keep to the high road and hew the timber directly from the log. And scantlings (smaller stock) for braces, common rafters and the like would be gotten out by dividing hewn baulks into two or four smaller sticks with a pitsaw. (The one exception would be the 3x10 stock for the 24 dome ribs, to be supplied by a sawmill.) Alicia had done the paperwork and the spreadsheets, and the project charts indicated that it could be done. But frankly it took some serious chutzpah in the face of limited time and the daunting job at hand: over 200 logs to be converted into 450 timbers—some 16,000 bd. ft. with 10,000 sq. ft. of surface area—by a crew of inexperienced hewers. And of course, that little task done, it would remain merely to scribe, cut and raise the log and timber walls and two-stage hipped roof, cut the compound four-stage curved cupola and fit the cupola to the frame.

Another challenge in store for the hewers was the timber itself. The winter-cut silver fir logs may have been handsome but, by the time we got to it, the wood was on the dry side, stringy with small tough knots. Not terrific hewing material and certainly nothing like hewing green pine or oak. There was also the matter of the relatively small sections of our timbers. The largest on the list were 6x8s and 7x9s and could be hewn out of logs with 10–12 in. dia. inside the bark. But many of our logs were actually 15 in. dia., and some larger, so there was a great deal of material to be removed,

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8–11 Clockwise from top left, deep-scoring oversize logs, joggling large chips, hewing to the line quad-teaming fashion and, at left, turning to another trade, trestle-sawing to get out smaller stuff from hewn baulks.

vastly increasing the work of scoring and joggling (removing the first large chips). With significantly oversized logs, the hewers resorted to deep scoring with two-man saws rather than felling axes (Fig. 8).

Lead carpenter Johansen had cut a deal with Gränsfors Bruks, the Swedish axe-manufacturer, for a mass purchase of felling and hewing axes at substantial discount. So we were well equipped. The crew set aside their usual framing kits, shared safety and technique briefings, picked up their axes and set to work (Figs. 9, 10).

Not knowing the numbers, I can't say that the Gantt production schedule charts were wrong. But I'm pretty sure the time and energy investment in hewing and pitsawing substantially exceeded the tabulated estimates. But then so did the rewards of doing the right thing. I can say with conviction that for this crew of framers and students, it was among the great work adventures of their lives.

For the first two weeks on the ground in Sanok, pretty much the whole enterprise was devoted to hewing. But on the other conversion front, Barbara Czoch and Leon Buckwalter put heads and hands together to make a trestle for swivel-sawing. Once enough large timbers had been hewn, the saw went into action under Barbara's direction, producing braces and common rafters (Fig. 11).

With the beam pile growing, the joinery began. Where the evolved default joint in Western European framing is the pegged mortise and tenon, in Eastern European carpentry it is the lap dovetail and its close cousin the half-lap crossing. Blind mortise and tenon joints are found only occasionally, as at the meeting of major posts and beams. Taking advantage of the larger log sizes, John Nininger was able to reduce the number of courses in the short log walls from six or seven down to five. He chose the dovetailed corner, full-scribe log method (Fig. 1), a choice supported by local historical evidence. After scribing in place, longitudinal log joints were hollowed with the so-called Harley-Davidson drawknives (handlebars the reference) to ensure tight fits at the edges (Fig. 12).

To keep the bulk of the joinery close to the ground where it was easily accessed and worked on, John prescribed that the short log walls be laid up *inverted*. The layer including wall plates and lower box frame sills went down first, then the remaining courses were scribed on one by one—the entire construction stood on its head. Meanwhile, the same trick was employed on the framed walls, with the box frame plates going down first then posts, girts and X-braces scribed upside down.

Once the log walls were complete and the box frame establishment taken as far as possible, both assemblies were pulled apart then quickly re-erected right side up with the box frame in place

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12 John Nininger, with drawknife, explains hollowing the underside of a squared log to fit neatly over the one below in a full-scribe hewn log wall. From left, Museum of the History of Polish Jews director Agnieszka Rudzińska and Gwozdziec project co-director Rick Brown.

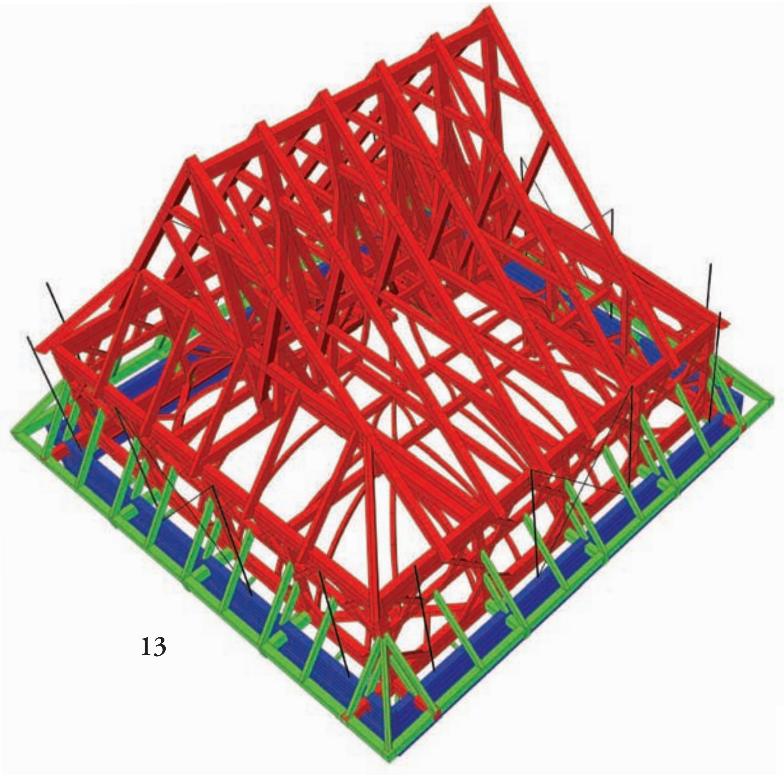
atop the log walls. Post feet were married to the box frame sills and lower braces scribed in, and flying plates were added to the outer ends of the hammer-beams to allow fitting of the lower roof.

While the intricate dance of log walls, box frame and roof proceeded, Jim Kricker's crew hewed away at the 80-odd curved ribs that carry the cupola boards. Working from the cupola profile drawings, they lofted and cut full-size Masonite patterns and used them to select and lay out the stock. Each of the major ribs of the dome was made in two parts from sawmilled, sistered 3x10s, half-lapped in the length at midspan to make up the full length of the curve of the dome and pendentives. Remaining shorter ribs for the cove, zodiac and lantern were one piece, hewn from a mixture of sawn lumber and naturally curved sticks taken directly from the nearby forest.

It was not unusual to see Jim walking off into the woods to hunt for stock, or heading out in a truck with Arek Kryda to explore a new woodlot. The results—a firewood pile to the uninitiated—were then picked over by the cupola builders, patterns in hand, and their axes and hatchets maintained a steady rhythm under the tent adjacent to the office hewing cupola curves. As a sign of progress, mockups of partial cupola stages would periodically invade the office to be checked for conformity with the plans.

Design Prime source material for recreating the frame, cupola and decoration of the Gwozdziec Synagogue was the work of Breier, Eisler and Grunwald, who had documented the synagogue in photos and drawings a few years before its destruction in the First World War. Their black-and-white photos were the primary basis for Handshouse reproductions of the Gwozdziec paintings, and their measured drawings included sections and elevations of the prayer hall taken in both directions, as well as framing plans.There are no dimensions, but all three drawings have on-board scales, a 5m scale on the plan drawing and the gable section (east elevation), a 10m scale on the ridge section (south elevation). Both scales are graduated with 1m hash marks (Figs. 5 and 6).

By bringing these drawings into a computer-aided design (CAD) drawing at scale and in correct orientation, I could trace frame elements over the original layout and create a full three-dimensional model of the timber frame and cupola, an accurate representation of the structure according to Breier *et al.* The process was not completely straightforward as there are some minor discrepancies between the individual source drawings, and not all frame members are shown. Some pieces are simply absent (cupola ribs, for instance), others appear only in one or two views, and there are dimensional differences from section to plan.



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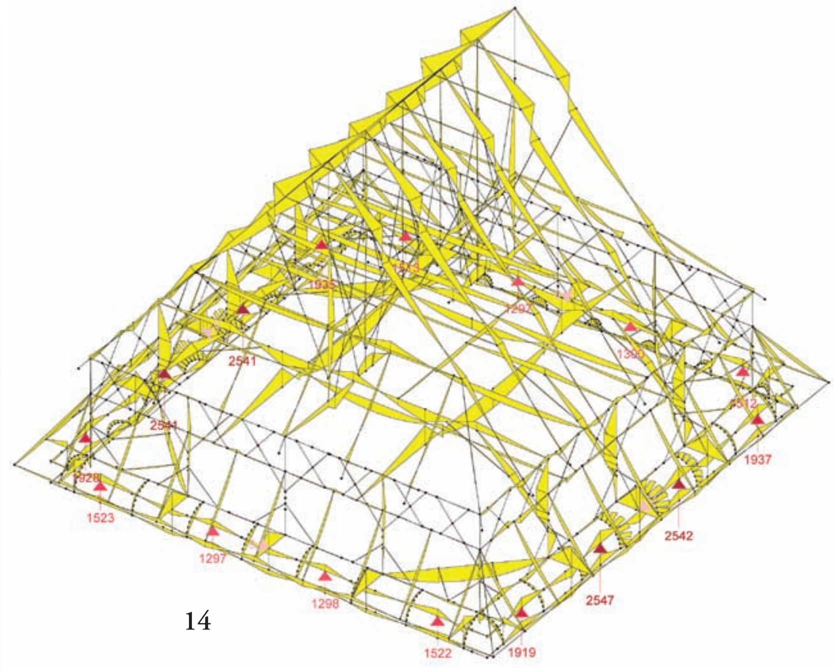

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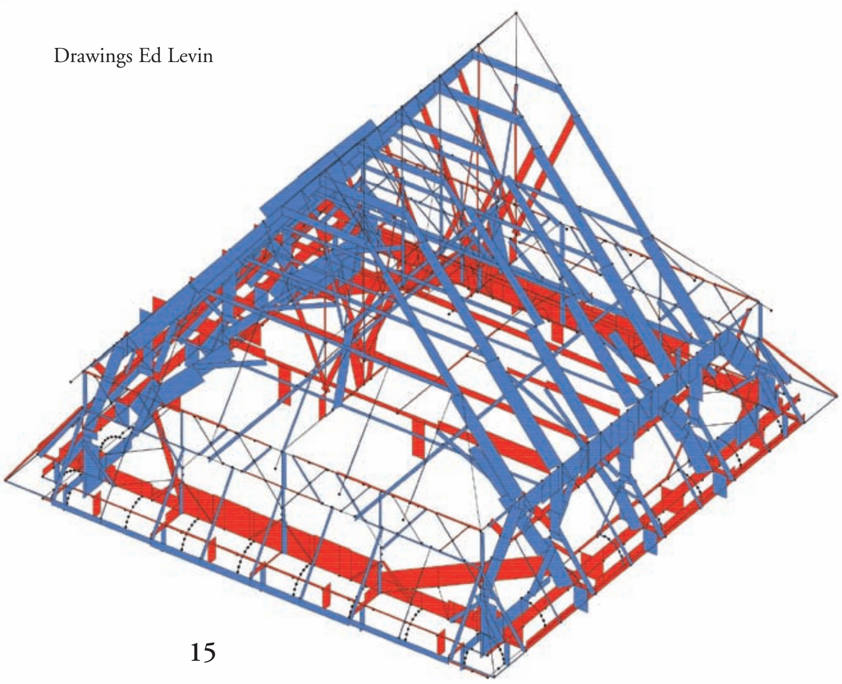

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13 Load displacement drawing shows how core of structure does not sit directly over log walls that ultimately support it. Core elements in red, log walls in blue, connecting and ancillary parts in green. Slender suspension rods (black) lead up to concrete museum ceiling (not shown), from which entire 64,000-lb. timber structure will be hung.

14 At right above, diagram of bending stresses, timber by timber. Width of yellow band is proportional to magnitude of stress. Support rod locations shown by red arrows, reactions in kilograms. Principal bending loads are found in long members crossing ceiling, tasked with supporting cupola over full span of prayer hall.

15 At right, axial loads represented graphically, compression force in blue, tension in red. Major tension loads are found in the box frame sills, octagon braces and the portion of the hammer-beams connecting out to the log walls. Significant compression forces follow main roof load path to stiff log walls.

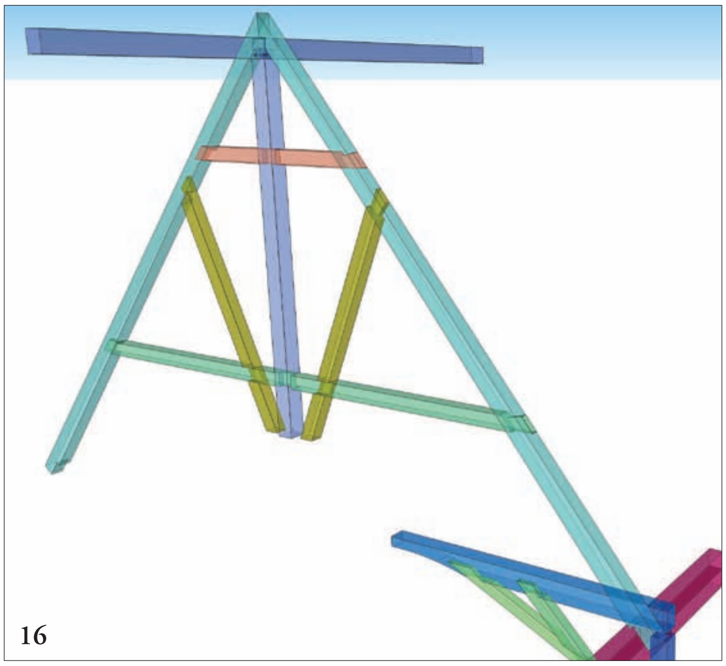
The drawing process for the Gwozdziec frame replica differed in several notable respects from earlier drawings I had made for the model-building at the Handshouse workshops in Massachusetts. For one thing, authentic joinery was now a prime consideration. We weren't building a miniature this time, and it wouldn't go together with hot melt glue and the occasional brad. Along the same lines, there were engineering considerations to be taken into account. As a museum exhibit in a gallery setting, the replicated roof would not have to bear snow or wind load, but it would have to support itself plus the dead load of roofing, cupola and siding, plus the live load of workmen during installation and maintenance, and it would have to comply with modern Polish building codes.

By modern standards, the original structure was notoriously lightly framed and its roof structure had been significantly compromised by the major early-18th-century cupola remodel. As seen in photographs, it is apparent that the roof frame was less than robust and that gravity had taken a toll.

Issues engendered by units and scale led to additional bends in the path from source material to construction documents. With historic joinery taken into account, working at 85 percent of the original to meet the museum's size requirements was not a simple matter of pressing a 15 percent reduction button. Given the Eastern European standard of side-lap joinery, and the fact that lap joints were not typically framed with the members set flush with one another (save for the sheathed surfaces of floors and walls), changing member sizes affected relative member positions. Thus minor size adjustments could ripple through and have significant effects on the overall configuration of the frame.

Before engineering review of the frame, I ran the timber lists by the leadership of the Guild building crew. Looking at sections of 5x7 and 5x5 equivalents (and sometimes smaller) in 32-ft. to 36-ft. lengths, the professional framers nixed any reduction in timber section. So it was back to the drawing board. In the final frame drawings, lengths were scaled down 15 percent. Where the outside footprint of the log wall base had measured 37 ft., for instance, it now scaled at 31 ft. 6 in. But all timber sections and thus most joint dimensions remained unreduced.

Engineering As specified under the design and engineering agreement for the Gwozdziec frame replica, framing plans would be prepared in the US and analyzed here for compliance with Polish building codes. The plans and structural analysis would then be submitted for review and approval by the Museum's project engineer. The American structural engineer was Ben Brungraber of Fire Tower Engineered Timber (Providence, Rhode Island), the Polish engineer Arkadiusz Łozinski of ARBO Projekt in Warsaw.



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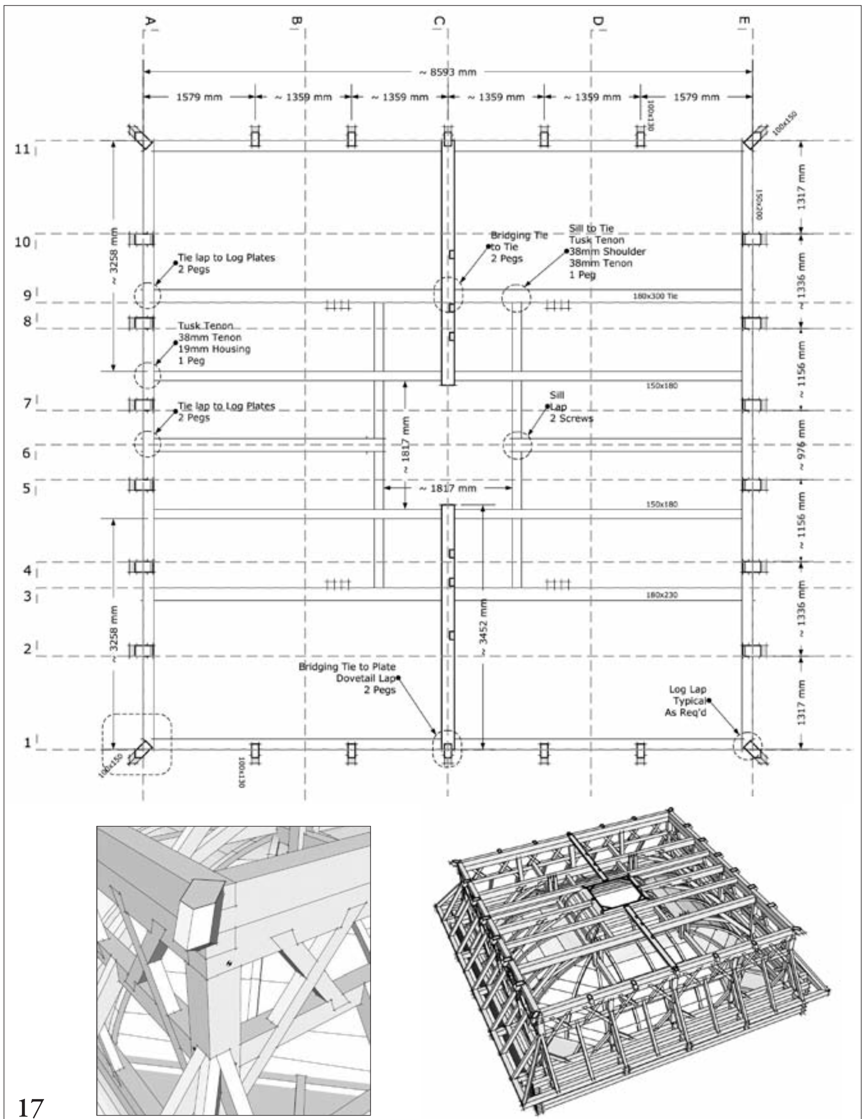
16 Rendering showing roof truss joinery in Gwozdziec framework, mostly half-dovetail laps at ends and halvings at crossing joints, with an occasional mortise-and-tenon joint and notched joints at rafter ends. Wall log corner joints not shown.

17 At left, typical shop drawing (elements rearranged for publication) by Mike Beganyi, who brought the AutoCad frame model into SketchUp and, using LayOut, created a handsome set of shop drawings keying each dimensioned bent and wall section to cutaway 3D frame models, with connections highlighted in bubbles. Area inside dotted line at lower left corner of plan view is rendered in shaded perspective, entire assembly in line drawing.



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Mike Beganyi

The timber frame CAD model (Fig. 13) was ported over to a finite element analysis (FEA) engine for review of resultant deflections, stresses and connection loads. No surprise, the Gwozdziec frame presented some unusual modeling challenges. A particular engineering concern regarding the frame was the horizontal displacement of major loads from major support mechanisms. Specifically, the weight of the main roof and the timber frame superstructure was channeled down along the perimeter of the box frame, which sits 2 ft. inside of the log walls. Thus the entire weight of the roof and box frame sits well inside its principal means of support.

Four load paths present themselves as possible channels to get this load to ground:

1. Some or all of the load can follow the box frame sills outward to the log walls. However the eight beams that comprise the double sills cross one another at the corners of the box frame where they are substantially weakened by half-lap joints.

2. A portion of the load can flow out along the hammer-beams that span between box frame sills and flying plates, with the log walls as a fulcrum between.

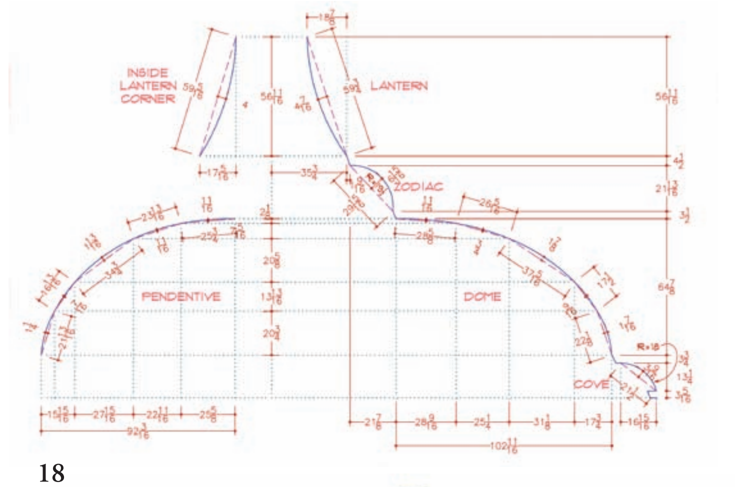
3. Load coming down the box frame posts can divert outward via the frequent 4x5 struts down to the log walls.

4. Finally, it's conceivable that some of the load finds its way down into the log walls via the ribs and boarding that form the cove, the lowest stage of the cupola.

Reviewing the axial forces in the roof struts and cove ribs, and the shear forces in the hammer-beams and box frame sills, the gravity load of the core of the building— the box frame, roof above and almost all the cupola load—is indeed shared between the available mechanisms, with about half the force taken by the roof struts, a quarter by the hammer-beams, a fifth via the box frame sills and about a twentieth by the cove ribs (sheathing effect ignored). Collectively, these four load paths carry close to 40,000 pounds, approximately two-thirds of the total combined load of the entire structure. The results of the analysis were a bit of an anticlimax, which is to say they were what we were hoping for. Deflections were well within acceptable ranges, as were resultant axial, shear and bending stresses in the frame members, even under our unrealistic maximum load (Figs. 14 and 15).

The balance of the structural assessment was to review connection capacities under predicted loads. Joints (Fig. 16) were secured with wooden pegs, allowing 400 lbs. capacity per peg in single shear (lap joints) and 800 lbs. in double shear (mortise-and-tenon joints). Where pegging was not practical, timber screws were substituted with a working capacity of 300 lbs. per screw in single shear and 600 lbs. in double shear. Shop drawings were now in order (Fig. 17).

Suspension Since we would not carry the synagogue's log walls down to the ground, the structure must be designed to hang from the ceiling of the museum building. Our ultimate solution was to suspend the frame with a total of 16 vertical 24mm-dia. steel rods (four per side) on 8-ft. centers (visible in Fig. 13). The rods would run down through the centers of the log walls to washers and nuts at the bottoms of the walls. This system was adopted by the Polish engineers with the addition of X-rod sway bracing in the center panels. Given the small rod size, the suspension system was unobtrusive, and it could be used also to install the completed frame and cupola by rigging grip hoists to half the suspension points, allowing the timber structure to be winched up into place and the balance of the rods installed. By the same means the whole rig could be lowered at later times as needed, for maintenance of the frame or clearance to work on mechanicals in the museum ceiling.



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Alois Breier, Max Eisler and Max Grunwald
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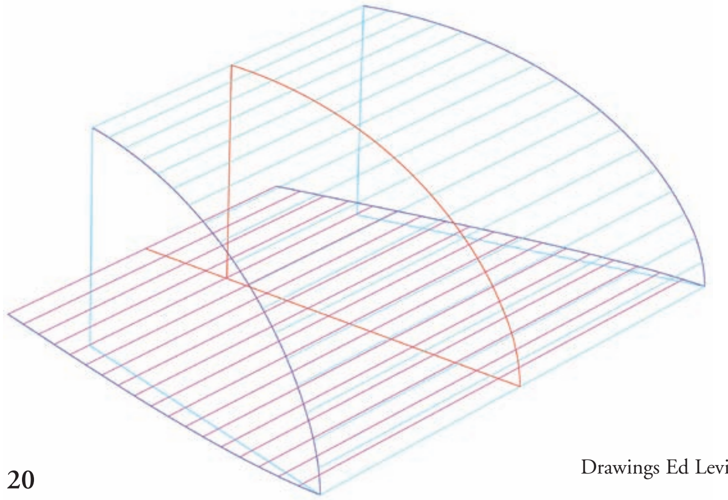

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18 At top, dimensioned drawing shows profile of various ribs that carry cupola sheathing and was used to make full-size patterns for those ribs.

19 Above right, photo of cupola lantern is sole photograph we have of Gwozdziec Synagogue framing.

20 Above, sheathed surface of dome section with individual boards indicated by cyan lines. At base of 3D figure, surface is developed or laid flat, with edge joints shown in magenta.

21 At right, this surface shown with boards numbered and dimensioned theoretically on left (taken off the frame and cupola drawings) and on right by actual measurements off completed structure.

Cupola In addition to the frame drawings, a second set of drawings documented the plans and profiles of the various cupola surfaces. The master CAD model included the cupola ribs and sheathing (Fig. 18). A set of beams expressly installed for the purpose (presumably in the 18th century) defined each cupola stage.

The cupola sill at the base of the cove was cleated to the inside of the log wall. The beam at the next stage—top of the cove, base of the dome—was attached to the underside of the box frame sills. Above that level, a gridwork of new timbers had been threaded through into the frame to carry the upper cupola stages: four long beams crossing tic-tac-toe fashion at the dome peak–zodiac base, with their ends framed in to the box frame girts; similar arrangements at the zodiac peak–lantern base (joined into the box frame plates and main tie beams of the original frame); and finally a quadrant of cupola top plates at the lantern peak, hung from truncated braces and kingposts in the roof frame.

A series of hewn curved ribs stepped upward and inward between these five levels of cupola foundation timbers: three dozen 2-ft. cove ribs, two dozen 11-ft. dome and pendentive ribs (each sistered together in two parts), sixteen 3-ft. zodiac ribs, and finally eight 6-ft. lantern ribs. By the evidence of the one surviving photo of the roof frame (Fig. 19), these sticks were hewn out of natural curves straight from the tree, and cupola team captain Kricker largely followed this precedent, save for the dome ribs, which, in deference to our limited time schedule, were taken out of machine-sawn stock (Figs. 22, 23). Likewise the cupola sheathing, which would be silver fir boards, milled, kiln-dried, planed to 1 in. and finish-planed by hand. The critical interface was the curve that defined the inside of the ribs and the outside of the boards. The cupola drawings needed to supply the cupola framing team with the plan layout of ribs and boards and the curved inner profile for each of the ribs. Simple dimensioned 2D rib and board profile sections met most of the framers' needs. These could be taken directly from the CAD model. The painters, on the other hand, would need to know the numbers of boards per ceiling section, and their widths and lengths. Painting would be done section by section with the boards laid on horses (painting two or three boards at a time, limited by the reach of the painters).

To generate this data, the curved surfaces of each ceiling section needed to be developed (laid out flat), a plan drawing made

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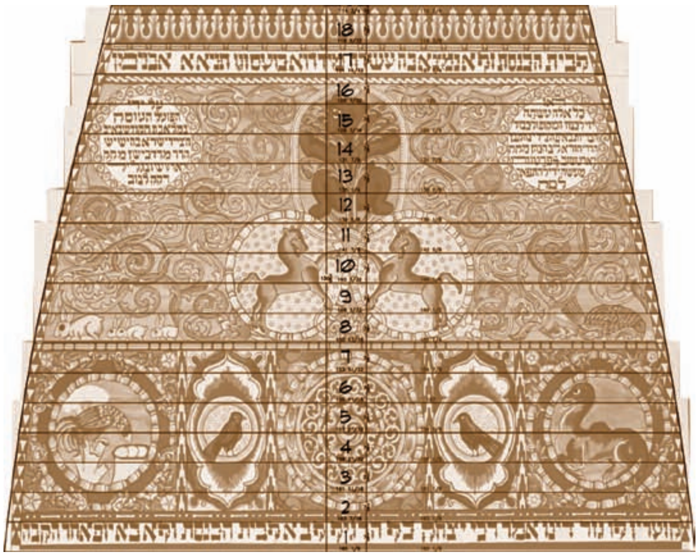
Photos Ed Levin



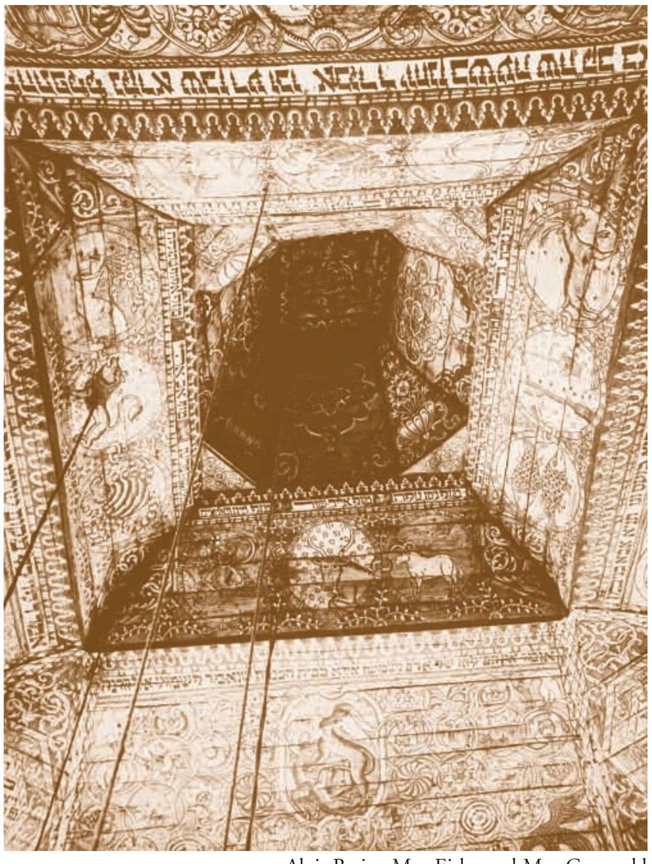
24

Ed Levin and Handshouse

22, 23 At top, framer Mark Surnoskie shaves a fair curve on lower surface of dome rib, and dome ribs spring from box frame sills.

24 Above, ceiling painting applied over as-built board layout. To fit painting to wood, MassArt student Cailigh MacDonald, member of framing and painting workshops alike, carefully reshaped painted image in Photoshop without distorting internal geometry.

25 At right, detail of historic monochrome photograph used by Handshouse as basis for replication of Gwozdziec ceiling.



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Alois Breier, Max Eisler and Max Grunwald
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and the numbers, widths and lengths of the boards established (Figs. 20, 21). As far as possible, the numbers of boards per section should duplicate the original building's, a count that could be determined by close examination of photographs of the ceiling taken before the destruction of the building (Fig. 25).

These developed drawings were used to rough-in the sheathing. But since actual frame dimensions differed at least slightly from the framing plans, nor were actual board widths identical to those in the drawings, members of the painting crew went back and took as-built dimensions and the board plans were redrawn (Fig. 21). Finally the image of the painting was overlaid on the as-built board plan and tweaked carefully (so as not to distort images and geometry) until aligned (Fig. 24).

—Ed Levin

For more on the Poland project, visit mcnorlander.wordpress.com (the framing blog) and gwozdziecpainting.blogspot.com (the painting blog). For the history and philosophy of the project and much more (including a 120-page pamphlet for download), go to handshouse.org. For information on the Museum of the History of Polish Jews, go to jewishmuseum.org.pl/en/cms/home-page. To explore the skansen *in Sanok, Poland, go to skansen.mblsanok.pl/a/stronaa.php?id=stronaa.*

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