

TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD

Number 103, March 2012

Sierra Nevada Barns

TIMBER FRAMING

JOURNAL OF THE TIMBER FRAMERS GUILD
NUMBER 103 MARCH 2012

CONTENTS

LETTERS: Frank Baker, Robert L. (Ben) Brungraber, 2
Thomas A. Vitanza

THE SWING-BEAM BARN IN SOUTHERN
WASHINGTON COUNTY, NEW YORK 4
Molly McDonald and William Krattinger

SIERRA NEVADA BARN EVOLUTION II 10
Paul Oatman

A TANG-STYLE TEMPLE IN DUNHUANG 16
Jan Lewandoski

WOOD PROTECTION BY DESIGN 21
Mack Magee

On the front cover, Big Sky Road barn, Susanville, California. Exceptional bracing and open two-bay construction produce a 28x60-ft. central aisle 42 ft. high. Story page 10. On the back cover, working barn photographed at cloudless sunrise in Standish, California. Steel roof covering has disappeared from hay hood at front. Side-roll sprinkler rests in foreground. Photos Paul Oatman.

Copyright © 2012 Timber Framers Guild
PO Box 295, Alstead, NH 03602
559-834-8453 www.tfguild.org

Editorial Correspondence

PO Box 275, Newbury, VT 05051
802-866-5684 journal@tfguild.org

Editor Kenneth Rower

Contributing Editors

Guild Affairs Will Beemer, Joel C. McCarty
History Jack A. Sobon
Frame Design Ed Levin
Engineering Ben Brungraber

Printed on FSC Productolith, a 10 percent recycled paper. ♻

TIMBER FRAMING (ISSN 1061-9860) is published quarterly by the Timber Framers Guild, 9 Mechanic St., Alstead, NH 03602. Subscription \$35 annually or by membership in the Guild. Periodicals postage paid at Alstead, NH, and additional mailing offices. POSTMASTER: Send address changes to Timber Framers Guild, PO Box 295, Alstead, NH 03602.

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



1985



SIPs, Continued

To the Editor:

Determining the best building enclosure for a high-quality, energy-efficient home involves a number of variables. The ideal building enclosure system should be easy to install, be priced so that builders can participate in a competitive marketplace, and deliver a return on investment for homeowners through long-term energy savings.

Adrian Jones raised a number of issues with structural insulated panels (SIPs) as an energy-efficient building enclosure for timber frames in his article "Are SIPs Necessary?" in TF 99 and in his response [to Chris Schwind's letter] in TF 100. Mr. Jones posed a number of questions regarding thermal performance and payback.

Questions and comments published by Mr. Jones are shown here in italics followed by my answers and comments:

Were the air-sealing properties of R-19 fiberglass batts considered in the Department of Energy Oak Ridge National Laboratory Whole wall R-value studies?

No. Air leakage was not factored into the comparison. If it had been, the differential in performance would have been even more dramatic. Another test was performed at Oak Ridge to compare a typically built 10x10-ft. stick frame room (without drywall) to an identical SIP in order to measure comparative air leakage. In that test the stick frame room leaked at a rate about 15 times that of the SIP room.

SIPA must stop saying "SIPs save energy" without including: "and it will pay back the installation premium in thus and such and such a time frame."

Payback analyses must consider numerous factors such as heating and cooling degree days, fuel type, projected fuel escalation assumptions, interest rates, construction costs, carrying costs, durability, etc. More severe climate conditions, higher fuel costs and higher fuel cost escalation rates obviously make the SIP payback more favorable. Each analysis is site specific and must take into account many variables. Most studies do not take fuel cost escalation into account but this may be the most significant issue in making choices in building options.

The connection [between wall system and timber frame] is irrelevant since the wall systems themselves are sufficient to resist lateral loads.

To ignore the interaction of a stick frame with the timber frame, especially in high wind or seismic zones, runs the risk of seriously overdesigning the structure and adding unnecessary cost and complication.

Stick-framed roof systems over timber frames are even more problematic to engineers since they are not directly equivalent to a

lightweight stick frame roof. Racking resistance is the main issue in a timber frame roof system and typical stick frame engineering does not provide applicable equivalents in a timber frame roof system.

Another commonly overlooked cost in construction is the overhead cost related to longer build times. Since construction loans run for the duration of the build and business overhead costs also continue through the build cycle, the savings by finishing a few weeks early can be significant.

Faster build times translate to overhead and loan cost savings. Is this enough to outweigh the additional costs of SIPs?

Business overhead costs also are relatively fixed, meaning shorter build times translate into potentially more projects with the same overhead, thus reducing overhead burden per project. A much larger factor is that reduced build times enable a builder to complete more homes per year with the same overhead, which translates directly into increased revenue and profit. If you can complete ten projects in a year versus nine, you gain the additional job margin on a complete project. That is a major factor in increasing overall profit or reducing costs to be more competitive.

All costs must be factored into a project. Isolating only one does not tell the whole story.

The cost differences stated in the R. S. Means study show a much higher premium for SIPs.

Most significantly, the R. S. Means study does not account for the cost of making a stick frame/batt building envelope provide equivalent performance to a SIP envelope. The study only focuses on the framing cost, not including the cost of additional insulating materials and air sealing details needed to match performance of a SIP envelope. The 2012 International Energy Conservation Code (IECC) includes insulation upgrades and air leakage standards that are met by most SIP houses today without special detailing or upgrades, but will come at extra cost in stick framing. An article by Steve Lentz in the February 2002 issue of the *Journal of Light Construction*, titled "Building Airtight Houses," stated that "most conventional houses have a natural rate of 4 to 8 air changes per hour. My homes are rated at 0.48 to 1.0 per hour (ACH50). My package of energy-saving details costs . . . about \$1.25 per square foot." SIP houses easily match this air leakage rate without special detailing and easily provide the building envelope performance mandated in the 2012 IECC without changes from the current SIP installation standards.

Many SIP homes are erected without the use of a crane or with a multipurpose lift that would be on site regardless of the type of construction used. Thus the crane cost in the R. S. Means study could be considered a worst-case scenario.

So where's the examination that explicitly studies payback? There have been numerous such studies showing the energy savings of SIP homes versus other types of construction. As previously discussed, the specific payback or return on investment will depend on many site-specific factors:

1. "Side-by-Side Evaluation of a Stressed-Skin Insulated-Core Panel House and a Conventional Stud-Frame House" (Armin Rudd and Subrato Chandra, 1993), funded by the Department of Energy. The report shows a 15–17 percent energy savings of the SIP home that was built for the same construction costs.

2. Identical homes constructed in Ontario, Canada, as part of a side-by-side study conducted by Dr. Tony Shaw of Brock University and supported by the National Research Council of Canada (NRC). Again there was a significant performance advantage in the SIP house.

3. An extensive study performed by Oak Ridge National Laboratory involving a series of side-by-side Habitat for Humanity homes in Loudon County, Tennessee, in 2003. A baseline stick frame house was monitored and compared to four different SIP

houses with slightly different envelope and HVAC systems. Each of the homes provides homeowners with neutral or positive cash flow.

FRANK BAKER (fbaker@pfbcorp.com)

PFB Corporation
Blissfield, Michigan

The Portland Observatory

To the Editor:

As usual, I read every page of the recent issue of the journal (TF 101, September 2011). Unusually, I found I had some previous knowledge of nearly every topic covered. This, I suppose and hope, is the result of working too long in a specialized field.

I was especially thrilled to read Don Perkins's fine article on the entirely noteworthy Portland Observatory. What a great timber structure, and one that so appears to serve its precisely opposite role—to be seen. I was particularly struck, though, by his quoting Julie Larry on why the frame was repaired in situ: for fear that they "might never get it back together again."

In the early 1990s I inspected the observatory and made recommendations on how best to proceed in its repair. Our own Joel McCarty prepared fine 3D drawings to go along with the report. My best advice was to disassemble the tower and spread all the pieces out in a large heated warehouse that the city had set aside for the project. Then, the repair team could triage the various pieces: reusing the fine pieces, replacing the hopeless and repairing the middly bits. I recall trying to sell this on the basis of doing a better job with less butchery, but also with a better chance at hitting an established budget—always tricky in big repair jobs where problems are only revealed as the project moves forward. The available funds could help to guide those repair decisions.

The authorities nixed this proposal, for fear (they said) that "if the observatory ever appeared to be gone, the donations would dry up." I sighed and moved on, glad that the noble structure was to be saved. I have happily climbed it since and never pass by Portland without spotting it on the skyline.

The aspect of all this I found most amusing, though, is that it was only in reading the various theories about how this tall battered octagon was first assembled that I finally recognized my real reason for having so advocated for my more dramatic process. I simply and really wanted to know how this thing went together, and what better way than to take it apart?

ROBERT L. (BEN) BRUNGRABER, PhD, PE (ben@ftet.com)
Fire Tower Engineered Timber
Providence, Rhode Island

Wood Decay

To the Editor:

I am writing to express my enthusiasm for the recent article "Wood Decay and Protection," by Mack Magee (TF 100). Given the nature of the subject, this topic could be quite tedious but I found the article to be the most thorough and well illustrated I have seen in quite a while, an excellent instructional tool. I hope to have the preservation folks here and in various other training programs reference it as a preservation primer. I understand that a protection article is coming—can't wait to see it. Thanks for all the good work. The journal is one of the highest quality publications I use in my work and I heartily recommend it to all who are unaware.

THOMAS A. VITANZA, RA, AIA (Tom_Vitanza@nps.gov)
Senior Historical Architect, Historic Preservation Training Center
Frederick, Maryland

The Swing-Beam Barn in Southern Washington County, New York

Articles of agreement made Between John Mushet and George Laurie Both of Cambridge in Washington County the said George Laurie is to Build a Barn, forty six feet in Length and thirty two feet wide a Stable in one End Eleven feet wide a Granary in one end of the Stable the Remainder Divided into Stands for Horses the floor two inch Plank and above Head the same thickness to Reach the Swing Beam with a Rack and Manger along the Stable the Threshing floor sixteen feet Wide through the Barn laid with two inch plank it is to have what we may Call four Stable Doors and one of the Leaves of the Barn Doors to be in Two there is what is Commonly Called false plates to be in the Roof the posts fourteen feet said Barn is to be Build of Good Sound Timber Boards and Plank all Good the work all done according to the Rule and to be finished Compleet by the last day of June Next from the Date hereof said Barn is to be set up where John Mushet Directs Also the said George Lourie is to provide all the materials for the said barn except such timber as he can find on the said John Mushets farm except the plates and the swing beam which he the said George Lourie is to provide—Likewise the said John Mushet agrees to pay the said George Lourie the sum of two hundred Dollars Provided he the said George Lourie does fulfil the aforesaid agreement according to the tenor of the same— Cambridge January 6th 1814

Witness our hands John Mushet George Lourie

THIS contract documents the construction of a square-rule swing-beam barn in Washington County, New York, and represents the first use of the term *swing beam* known to the authors (Fig. 1). It is one of several surviving building contracts associated with carpenter George Lourie of Cambridge. Lourie was active as a rural builder during an important period of development and change in barn design and timber-framing technology. He was also a farmer, familiar with the peculiar needs of local agriculture and the requirements of area farm buildings.

The threshing barn with swingbeam, many character-defining features of which are described in the Mushet contract, gained popularity and assumed specific characteristics in southern Washington County towns in the early 19th century (see map in Fig. 2). Scholars and timber framers debate the swing beam's primary function, whether to enable animal-assisted threshing or simply to create more space for storage and grain processing.

The broad adoption of this barn type regionally corresponded with a period in which grain cultivation was a principal agricultural endeavor, along with the raising of cattle and sheep. Wheat, rye and corn were staple products of the county's grain economy in this era and necessitated specialized building types to fulfill processing and storage needs. The square-rule, swing-beam barn type identified in this study initially developed to serve the needs of the area's grain farmers, during a period in which wheat farming reached the height of its profitability. It functioned as a threshing and storage building for both unprocessed and processed grain, and accommodated hay storage and shelter for farm animals.

In structural terms it represented the adoption of standardized framing techniques and a simplified method of assembly characteristic of the early 19th century. By this time barns employing tie-at-plate framing solutions derived from the English tying joint

were giving way in the region to those built exclusively with dropped tie beams. This development corresponded with the adoption of square-rule framing techniques and the abandonment of the scribe-rule system. The iconic swing beam constituted the principal character-defining structural element of the early-19th-century English barn in this area, dictating its spatial and functional characteristics (Fig. 3).

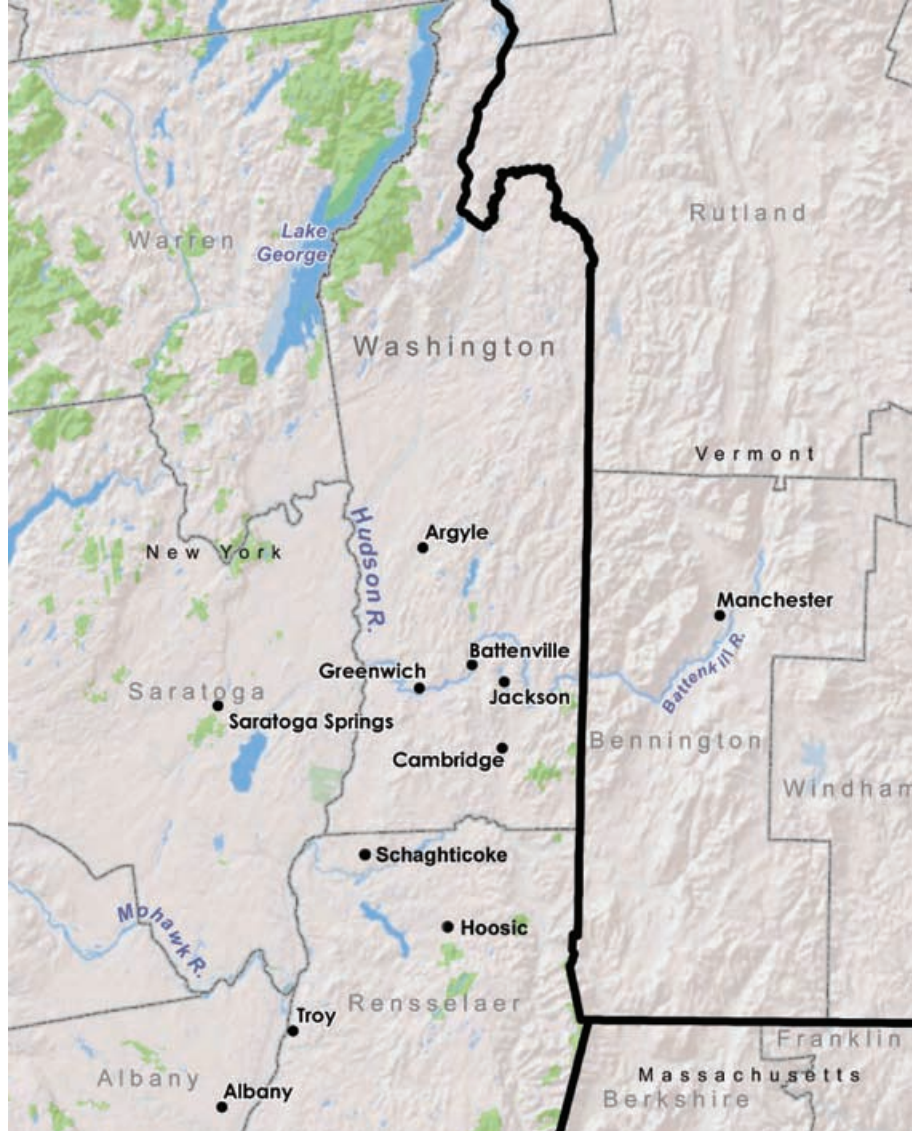
The swing-beam barn was by no means unique to southern Washington County. Swing-beam barns have been observed in Pennsylvania, New Jersey and many portions of New York. Slightly later examples, typically dating to the mid to late 19th century, are found in Ohio and Ontario. Washington County was part of a larger agrarian region that extended along the spine of eastern New York and into adjacent valleys west of the Hudson River. The southernmost reaches of the county were settled first, the early population formed of an intermingling of people of Scottish, Irish, and Scotch-Irish lineage, New Englanders from Connecticut, Massachusetts and Rhode Island, Dutch and Germans from areas to the south and settlers from New Jersey and Pennsylvania. Some, among them the Lourie family, had come into the region by way of the mid-Hudson Valley. The southern part of the county bordered directly on Hoosic and Schaghticoke, settled before the Revolution primarily by Dutch and Germans, representing the northernmost reaches of a New World Dutch cultural zone that extended southward down the Hudson River corridor. Builders of different training and experience were active in the region at an early date and left the imprint of multiple traditions on the county's early architectural development.

It is clear that people in various parts of the Northeast were familiar with the term swing beam by the first half of the 19th century. A farmer in Cortland County, New York, writing in the 1840s, opined that his swing beam provided "an ample floor . . . without the sacrifice of much room in the barn." A Michigan farmer in the early 1850s noted that when he finished using his horse-powered threshing machine, he "put it away under the swing beam, where it is entirely out of the way." The swing beam's association with the process of threshing grain with animals, which would "tread out" the grain on the barn floor, is indicated in an 1826 advertisement in a Ravenna, Ohio, newspaper. Described for sale was "A new Barn 35 by 45; very convenient; built with a swing beam for thrashing grain with horses."

The early 19th-century Washington County swing-beam barn, similar in overall proportion to the Ohio example, had on average an 18-ft. wide threshing floor between the mow's waist-high partition and the front of the stables and granary. This in turn defined the area in which animals could potentially be guided over unthreshed grain, with approximately 6 to 7 ft. of clearance beneath the swing beam. If this regional variant was not conceived for treading grain with animals, the swing beam was instead adopted for other functional advantages, such as a wider clear-span bay allowing for a larger work surface, and additional storage space in the loft spanning the stables and granary. Threshing would have been achieved manually with a flail until the adoption of threshing machines. As for the area's earlier scribe-rule English barns (as built in New England), such as those thus far identified in Salem and Hebron, they have narrower threshing bays, typically 12 ft. in width, and were built for threshing wheat and other grains with flails.

Articles of agreement made Between
John Mushet and George Laurie both of Cambridge
in Washington County The said George Laurie is to
Build a Barn forty six feet in Length and thirty two
feet wide a Stable in one End Eleven feet wide
a granary in one end of the Stable the Remainder
divided into Stalls for Horses the Floor Two Inch Plank
and above Head the same, ridge to reach the
Swing Beam with a Rack and Manger along the Stable
the ^{Shed} Threshing ^{Room} Sixteen feet wide through the Barn
Laid with Two inch plank it is to have what we
may call four Stable Doors and one of the Leaves of
the Barn Doors to be in Two there is what is commonly
called false plates to be in the Roof the Posts
fourteen feet said Barn is to be built of good sound
Timber Boards and Plank all good the work all
done according to Rule and to be finished Completed
by the Last Day of June next from the Date hereof
said Barn is to be set up where John Mushet Directs
Also the said George Laurie is to provide all the materials
for the said barn except such timber as he can find on the
said John Mushet farm except the plates and swing beam
which he the said George Laurie is to provide. Likewise
the said John Mushet agrees to pay to the said George
Laurie the sum of Two hundred Dollars Provided he
the said George Laurie does fulfil the aforesaid agreement
according to the tenor of the same —
Cambridge January 8th 1814 Witnesses our hands
John Mushet
George Laurie

Cornell University Brockett Collection, used by permission



Jordan Schuler

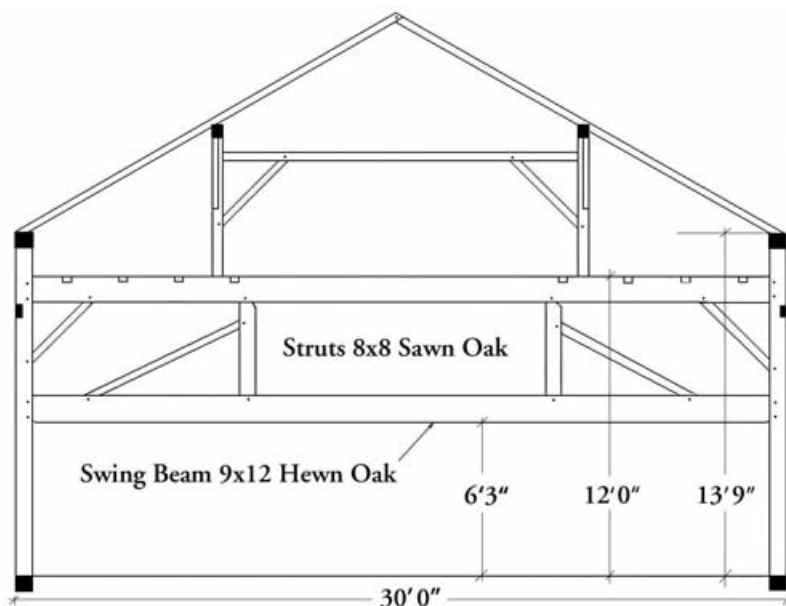
- 1 Above, Mushet-Lourie building contract, Cambridge, N.Y., 1814.
- 2 Above right, map of Washington County, N.Y., and vicinity.
- 3 At right, detail of typical swing-beam bent, A. McLean barn, North Cambridge, N.Y., before 1853.

The 1814 contract between Laurie and Mushet offers an invaluable piece of documentary evidence regarding this building type. Surviving examples in the East Greenwich, North Cambridge, Jackson and Salem areas attest to the general popularity of this type regionally, particularly during the period in which wheat farming reached the height of its profitability in the region, between 1810 and 1820. Among the Jackson-area barns examined is one that bears a carved date of 1812 on its swing beam, offering a particularly close temporal link to the barn described in the contract. This barn type continued to be constructed in Washington County well into the second quarter of the century in spite of a decline in wheat cultivation. Wheat farming's local viability was increasingly challenged during the 1820s by soil exhaustion, disease and increased competition from newly developing agricultural areas. It was all but devastated by the early 1830s arrival of the wheat midge, after which time it continued at a much-reduced scale. While the swing-beam barn was given distinctive form during the most profitable era of wheat cultivation in Washington County, it persisted for a time while the area's agriculture evolved in response to localized and more wide-ranging conditions.

George Laurie was but one of many carpenters operating in the region and his story provides a window into the cultural, ethnic, and economic background of one Washington County builder in this era. Many examples of the type of barn described in the 1814 contract between Laurie and Mushet survive in the area, with related structural and spatial characteristics representing a well-defined



Photos and drawings Molly McDonald and William Krattinger



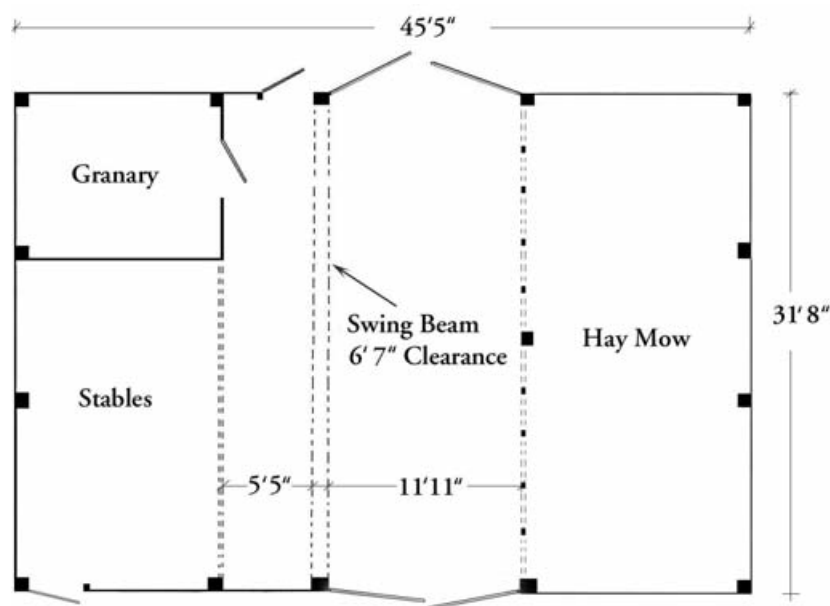
4 Swing-beam bent section of 30x48-ft. barn surveyed by the authors on Scotts Lake Road north of Salem, N.Y. Struts between tie beam and swing beam are braced, unusual for the area.

building type. All are five-bent structures employing dropped tie beams, swing beams and purlin roof frames with common rafters. They were built using square-rule framing and appear to date to the first quarter of the 19th century. A number of post-1825 representations indicate a persisting form, and two scribe-rule examples that appear to predate the five-bent swingbeam type (one may well be a retrofit of an earlier barn) are notable as potential points of departure for the subsequent development of the type in Washington County.

George Lourie George Lourie's father, Alexander, was born in Dunbar, East Lothian, Scotland, in 1749. He emigrated to New York state in 1770, settling first in the New Windsor area of what was at that time Ulster County. A carpenter by trade, Alexander Lourie enlisted in the Continental Army during the Revolution, and served under General George Washington in "The Line," Third Regiment. In 1783 Lourie married Scotland native Elizabeth McDonal in the New Windsor Presbyterian Church; the couple lived in the Little Britain area of New Windsor, where they had three children including George, born in January 1786.

The Louries moved to Cambridge, Washington County, in 1792, when George was six years old. Cambridge then encompassed the present towns of Cambridge, Jackson and White Creek. Tracts in the town were conveyed to Dutch and English-descendant families in the 17th and early 18th century, but only a small number of these actually established settlements in the area. The first substantial settlement in Cambridge had been made in the 1760s, mainly comprised of families who had lived for a time in the Connecticut River Valley in Massachusetts. They included Quakers, Baptists, Congregationalists and Presbyterians largely of English and Scotch-Irish descent. While the area of Cambridge in which the Louries lived was by no means homogeneous, Scots and Scotch-Irish were the prevailing ethnic groups at the turn of the 19th century.

George Lourie grew to maturity on his father's acreage in the portion of Cambridge that later became Jackson and was there educated in the rudiments of carpentry and agriculture. Alexander and George Lourie were two of at least four carpenters of Scottish descent who were members of the small congregation of the Associate Presbyterian Church of Cambridge, in the hamlet of Coila. In December 1809, George Lourie married Mary Whiteside Irvine, the daughter of James Irvine, who had also emigrated from Scotland in 1770. The couple was married by the newly installed



5 Plan view of 32x45-ft. barn at Hillview Farm near North Cambridge, N.Y. Hewn pine swing beam is 18 in. deep (see Fig. 11 for detail view of swing beam).

pastor of the Associate church, Reverend Alexander Bullions, and had their first child a year later.

Lourie's accounts indicate he was supplementing his efforts as a farmer with carpentry work by this time. In 1810 he was active with a number of projects, including the construction of a corn house for his neighbor, John Mushet, and repairs or other work on a schoolhouse for William Stevenson and on barns for George Millar and Alexander Bullions. The following year he erected a house for John Irvine and a shed for his father, in addition to a barn, shed, and kitchen for George Small. He contracted to build a house for John Welch of Cambridge in 1812 and a house for Samuel McDoual the following year.

Throughout this period and in the years to come, Lourie was engaged with carpentry and construction. In addition to framing barns and houses, he tended masons and plasterers, painted, harvested and processed timber, sawed planks, built architectural finish work and joined and hung doors. He also built sleighs, cradles for harvesting wheat, and chairs and tables. This did not preclude his taking on agricultural work, including grain-cradling and other farm labors characteristic of the period. Lourie worked with several assistants, notably Henry McAuley and Thomas Gallaway, teenage relatives of his wife, who were of Scottish and Scotch-Irish descent.

George Lourie left Washington County for a brief period during the War of 1812, and was present for the British defeat at the Battle of Plattsburgh in the autumn of 1814. In 1816 his mother and younger brother died, at which time Lourie and his growing family moved into his father's house. In that year his father Alexander deeded his farm to him, on the condition he maintain him "with good and sufficient meat, drink, clothing, lodging, attendance, and all other necessities and conveniences."

In 1819 Lourie contracted to take a boy from Saratoga County as an apprentice, that he might learn "the art, trade, and mystery of Farming." In 1837 he made an application for fire insurance, which offers details of his own Jackson farm and his diverse agricultural activities. Each building is described and evaluated, along with a sketch of the layout. Lourie's property at this date included the one-and-one-half-story house likely built by his father, a barn and shed containing grain and hay, a wood house, a wagon house, a corn house, a corn crib, a hog pen and a boiling house "over a chaldron kettle and arch," which he was constructing at the time. The farm also included a tenant house with an associated barn and shed. George Lourie died in 1868 at the age of 82, and is interred at Woodland Cemetery in Cambridge.



6 Swing beam in barn at Sharts Family dairy farm, North Road, near Greenwich, N.Y., formed of two swing-beam barns placed end to end. Studded wall, once boarded, partitioned off animals and grain room. Note sturdy chamfered strut to upper beam supporting braced purlin posts (one dimly seen at upper right). Scaffold poles (now removed) ran over threshing floor for drying crop to be threshed.

The swing-beam barn Lourie built for John Mushet in 1814 articulates many features observed in remaining examples in southern Washington County. As we have seen, it was by specification 46x32 ft. in plan, with a 16-ft.-wide threshing floor and a bay containing a granary and stable for four horses, built “according to the Rule,” confirming it was of square-rule construction. The use of the term Swing Beam suggests the latter was a familiar barn component and descriptor by this date, known to both the carpenter and the client. Finding a timber of appropriate characteristics for a swing beam was here left to the builder, and Lourie may have harvested the requisite timber from his own woodlot. A related contract reveals that Lourie subcontracted the “inclosing” of Mushet’s barn—sheathing it and hanging the doors—to Joel Carby, who was to do the following:

To sheet and shingle put on ridge boards and a fan over both Doors on Each Side of the barn. . . . Also to board it all round . . . to make and hang two Large Doors on the West side with a Stud between them and Latch to hold them too, to make and hang three large Doors on the East side with a Stud between them and Latches to hold them too to make and hange one Stable Door, and a Small Door beside the large ones leading on the Barn floor also to joint and Lay the floor and partition between the bay and floor.

These details inform our understanding of this barn type as originally built, as many extant examples were later altered or enlarged.

The Washington County swing-beam barn The early-19th-century Washington County swing-beam barn was a modification of the traditional English barn built in New England, New York and elsewhere in earlier periods. It retained the characteristic three-bay interior division of space, its central threshing floor accessed from the side elevations, a hay mow on one side of the threshing floor and a space set aside for stables and storing processed grain on the other. Five bents defined the form and plan of the building: two end bents, two interior bents (one of which contained the swing beam) and, spaced closely to the swing-beam bent, an additional bent that received framing for the stable and granary. The clear span of the swing beam allowed for the extension of an otherwise 12 to 14-ft. wide threshing floor by about 5 ft., to the stable and granary wall (Figs. 4–6).

The transverse beam of the bent corresponding with those



7 Barn at Kenyon Hill Road, Jackson, N.Y., signed J.D. and dated 1812 on its swing beam. In form and framing, barn follows New England-style four-bent, eaves-entry English barns, with added bent.

enclosures together with the swing beam supported a tier of storage space above, additional to that provided for by the loft. The posts that carried the purlin plates were footed on the tie beams of the two end and two interior bents. Two sets of horizontal wall girts between sill and plate level, mortised into the uprights and clad in vertical board sheathing, were standard features.

Also ubiquitous was an integral loft ladder on the interior bent opposite the swing beam, framed into the girt of the waist-high partition and central upright. Paired doors accessed the threshing floor, while doors for humans were often incorporated into the narrow bay adjacent to the swing beam, such as described in the Mushet barn contract. Identified examples are typically larger in plan than the standard English barn, and the standard proportion of 3:4 between gable end wall and eaves side wall is no longer observed. The side elevations now are more often 45 ft. to nearly 50 ft. in length. Oak and pine are the species most employed in surveyed examples, with oak used exclusively for forming the uprights; swing beams are fashioned from both.

Though further survey may identify others, only one example (not shown) was found of a five-bent barn of this layout built *without* a swing beam, on the farm developed by the Coulter family in Jackson in the early 19th century. The square-rule frame, fashioned largely from oak, nonetheless featured all the other spatial and construction characteristics of the swing-beam barns discussed.

The agricultural complex at the intersection of Kenyon Hill Road and the former Northern Turnpike in Jackson includes at its core an important representation of the Washington County swing-beam barn (Fig. 7). A presumed date of erection, 1812, is prominently carved into the threshing bay side of the hewn pine swingbeam, along with the initials J.D. It offers an excellent point of comparison with the 1814 barn contracted for Mushet by Lourie, embodying many discernible features expressed in that contract. The carved initials may well be those of Jonathan Dunham, who came with his family in 1793 from Piscataqua, New Jersey, settling on a 400-acre parcel on the adjacent hillside.

Unlike other examples considered below, this barn adheres more closely to standard English barn dimensions (as built in New England), measuring roughly 30x40 ft. It nevertheless exhibits the basic characteristics of the five-bent swing-beam type in its overall structure and its definition of the interior space. It retains partitioning for the stables and granary, a loft ladder and framing for the mow’s waist-high partition. Perhaps the only deviation from the other surveyed examples is the omission of a strut mortised into the

swing beam and upper tie beam of that bent, a pervasive feature of examples thus far surveyed.

Determining when the swing beam was first used as a feature of Washington County barns requires continued research. Two scribe-rule examples (not shown), have been identified, one located on a farm developed by the Maxwell family in Jackson. In that example, however, the swingbeam appears to be a retrofit added when a barn of earlier characteristics was modified. This suggests older barns were being modified in response to the five-bent model. The original Maxwell barn, before multiple expansions, displayed characteristics observed in earlier scribe-rule English barns in the county, particularly in its asymmetrical plan with offset threshing bay and combination of tie-at-plate and dropped tie bent framing.

A more compelling example of a scribe-rule swing-beam barn stands in the Beadle Hill area of Easton on land associated by the early 19th century with the Fort family. This barn in its original form is a 40x60-ft. structure with six equally spaced bents defining five bays, English tying joints for the two end bents and dropped tie beams for the four interior bents. Purlin plates supported by posts footed on all six bents carry 19 pairs of common rafters. This barn retains its 28-ft.-wide threshing floor comprised of two layers of 2-in. plank secured to the framing below with oak pins. Partially empty mortises, scribe marks and other evidence clearly indicate the former presence of a 23-in.-deep swing beam framed to the upper tie beam by two struts and secured in its post mortises with four pins. This timber, at some point cut from its mortises, spanned the threshing floor at midpoint at a height of about 6 ft. Built at a scale suggesting a level of grain processing well above that of the typical yeoman, the Fort barn is by all indications the oldest known swing-beam barn in Washington County.

A third early swing-beam barn (likewise not shown), the barn on the Livingston farm near East Greenwich was likely erected for Alexander Livingston, son of Argyle Patent (1764) Scottish settler Archibald Livingston. The Livingstons were among the early Argyle settlers, another component of the region's larger Scottish settlement. A five-bent type, it measures roughly 35x48 ft. in plan, rising nearly 13 ft. from sill to plate. There are 6 ft. 6 in. of headroom between the floor surface and the underside of the swing beam, which is slightly over 14 in. deep and hewn from pine. A distance of 3 ft. 2 in. separates the swing beam and upper tie beam, joined by a central strut. Both the swing beam and upper tie beam of that bent are secured in their mortises with three pins. The barn's threshing bay measures 17 ft. 5 in. wide, 5 ft. of which constitutes the area added by the swing-beam bent.

This barn is likely a close contemporary of the Livingston dwelling, a one-and-one-half-story building of rectangular plan erected sometime around Livingston's 1806 marriage. The barn was augmented at an early date with the addition of a smaller section on the east side and a longer one forming an L-shape plan, a development observed in other examples. It now sits above a banked foundation. The Livingston barn contains an additional set of braced posts between the threshing floor and end bents on the mow side of the plan as a feature of its sidewall assembly.

This is the case with most of the early examples—the Kenyon Hill barn discussed earlier (Fig. 7); the A. McClean barn in North Cambridge, roughly 30x46 ft. in plan (Figs. 3, 8, 9); and, not far from the Lourie family farm, a 30x44-ft. example in the Coila area. End wall assemblies in the early examples include two median posts between the corner posts. A 30x48-ft. barn surveyed on Scotts Lake Road north of Salem is built in this manner, though it employs only one braced post for the end wall assembly. Its swing beam features double struts with bracing, among the more complex treatments encountered in the framing of the swing beam in the area (cross-section Fig. 4).

More notable in its deviation from surveyed examples is a barn

on King Road near Cambridge (Fig. 10). This barn is unique among examples encountered thus far in its use of a ridgepole and associated sway bracing. The swing beam has a crown, one of three examples observed in the region to date, and was rabbeted on the inside corner of its upper face to receive planking for the loft above stables and granary. The central strut joining the swing beam and upper tie beam is also distinctive, having been fashioned from a tapered section of 2-in. plank.

The largest swing beam we encountered was in a 32x45-ft. barn at Hillview Farm near North Cambridge (plan view Fig. 5 and detail Fig. 11). The swingbeam, hewn from pine, is 18 in. deep at its deepest point and crosses the barn slightly more than 3 ft. below the bent's tie beam. Secured with three pins at each end, it is a massive timber more reminiscent in scale of New World Dutch than English building traditions.

The McLean barn in Battenville is yet another example of the local swing-beam barn type (detail Fig. 12). Members of the McLean family came to Washington County in the post-Revolution period from New Jersey, among them Thomas McLean, who owned this farm for a time. The earliest section of the McLean barn, now in imminent danger of collapse, presumably postdates ca. 1815, when a sawmill was put in service on the Battenkill by the McLeans. The main uprights of its frame were fashioned from reciprocating-sawn white oak, unlike the other examples discussed, which feature hewn posts. Smaller framing components, such as the oak braces and girts, and pine rafters, were also sawn. The main tie beams and the swing beam were hewn from white oak, while the plates were hewn from pine. The barn measured 30x44 ft. before lateral extension with a 13-ft. addition. The 13-in.-deep swing beam is on the east side of the bay, connected to the upper tie beam by a central sawn strut with chamfered corners. The end wall assembly includes a single, rather than double, braced upright between the corner posts, like the Scotts Lake Road barn.

Examples of this type continued to be built well into the second quarter of the century in Washington County. The Henry R. McLean barn in Jackson, which measures a substantial 35x56 ft., is prominent among these. Built perhaps as late as ca. 1850, it nevertheless exhibits the characteristic arrangement of structural bents. The swing-beam bent is spaced 4 ft. 6 in. from the adjacent bent to form a narrow fourth bay and an unobstructed 18-ft.-wide central floor, and spans 7 ft. above floor level. The building measures 16 ft. from sill to plate and roughly 34 ft. to the ridge, and was built with integral studding for narrow horizontal board sheathing and a purlin roof frame with 16 pole rafters. Distinctive is the manner in which the purlin posts were aligned with the double struts connecting the swing beam and upper tie beam. Both its scale and construction details reveal it as a later example.

Conclusion The square-rule, five-bent, swing-beam barn was a pervasive type in southern Washington County during the first half of the 19th century. The geographic focus of this study was too localized to yield significant conclusions to debates among scholars and timber framers over the swing beam's ethnic and cultural affiliations or its primary function in the barn. Nevertheless, southern Washington County represents an identifiable area in which the swing-beam barn gained popularity concurrent with the profitability of wheat farming in the early 19th century. The story of George Lourie, a farmer and carpenter of Scottish descent, informs this inquiry by portraying the activities of a builder who was familiar with this barn type both as carpenter and yeoman. Lourie's 1814 contract with Mushet, among other evidence, suggests the term swing beam was in common use by that date.

The pattern of emergence of the swing-beam barn in Washington County may be better contextualized as other regional



8, 9 A. McLean barn, 30x46 ft., North Cambridge, N.Y. Transverse beam once was installed in post at far right of Fig. 9, supported by regularly spaced studs that partitioned off animals and grain room.

10 English barn with somewhat elongated eaves walls, on King Road, Cambridge. Distinctive interior features include a crowned swing beam and a wind-braced ridgepole.

11 Detail of 18-in.-deep pine swing beam and triple-pinned connection in barn at Hillview Farm, North Cambridge.

12 T. McLean barn in Battenville, N.Y. Much of its frame is reciprocating-sawn white oak, reflecting family ownership of a water-powered mill in service by 1815. As in Fig. 9, a transverse partition beam supported by studs once filled empty housed mortise at left.

studies of the barn type are undertaken in Pennsylvania, New Jersey, Ohio, Ontario, and other parts of New York state. Patterns are likely to emerge from comparisons of detailed regional studies, which may yield conclusions on whether ethnic, cultural, agricultural or technological factors were instrumental in the adoption of the swingbeam barn type.

—MOLLY McDONALD AND WILLIAM KRATTINGER
Molly McDonald (mmcdonald@akrf.com) is an architectural historian and archaeologist at AKRF in New York City. William Krattinger (William.Krattinger@parks.ny.gov) is a Historic Preservation Program Analyst in the New York State Historic Preservation Office.





All photos Paul Oatman

Sierra Nevada Barn Evolution II

THE arrival of the hay trolley system changed barn framing in the valleys of the Sierra Nevada Mountains (see “Sierra Nevada Barn Evolution,” TF 102). Barns were now framed to allow storage of loose hay in the main aisle. The new design eliminated a wagon entry—the trolley was hauling the load. A main door coupled with the overhead trolley entry in the main aisle, with animal doors to the side aisles, became the norm on the front gable wall. Braces in the main aisle could now run from cross sills to posts allowing for bracing in three directions. The new design also added more square footage to the barn and saved on the labor and materials to build a driveway in the interior, as well as the ramping and dirt work on the exterior of the driveway.

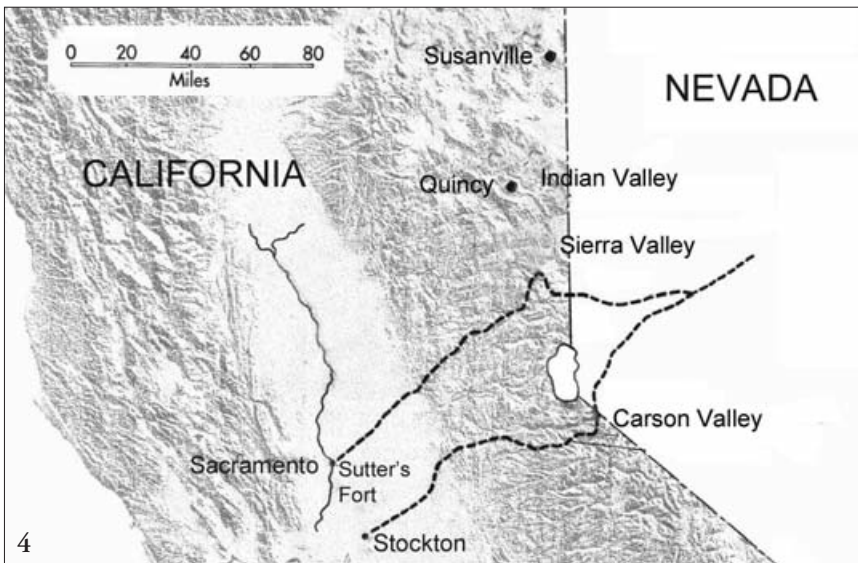
Traveling north from the Carson Valley to the Sierra Valley, the largest alpine valley in the Sierras, one steps back in time. The only recent marks on the landscape are the paved and graveled roads, a few gas stations, and a general store here and there. Many ranches in the valley have multiple barns in their fields (Fig. 1).

The forceful winds in the Sierra Nevada valleys mandated both head and foot braces in all barns. Builders some miles north of the Carson Valley employed sill-to-plate braces in lieu of knee braces. This Continental bracing style, while using more board footage in timber, had obvious structural advantages and in some configurations considerably reduced the numbers of joints. One might attribute this practice to German influence, yet in the heavily ethnic-German Carson Valley not one barn (of about 200) displays this type of framing. (So many Germans lived here that Federal authorities surveilled the population during the Second World War.) The different ethnic groups who settled in these valleys and their willingness to embrace new inventions gave birth to innovative design. The possibilities of bolting with heavy threaded fasteners, now mass produced, also opened the doors of imagination for these pioneers, who built with considerable ingenuity.

In all but one of the three-aisle barns shown here, the transverse tie beam runs over the top of the aisle post, tenoned or bridled to it, while the longitudinal purlin plate passes over the tie beam, possibly pinned or bolted down to it. I was only able to verify without a doubt the presence of a bolt in one of the examples, and in a second with some reservation. A mine building in Plymouth, California, that I surveyed a number of years ago had timber trusses with this connection and I was able to feel the head of the bolt in the top of the plate. It's possible that this connection was a standard one from about 1890 on.

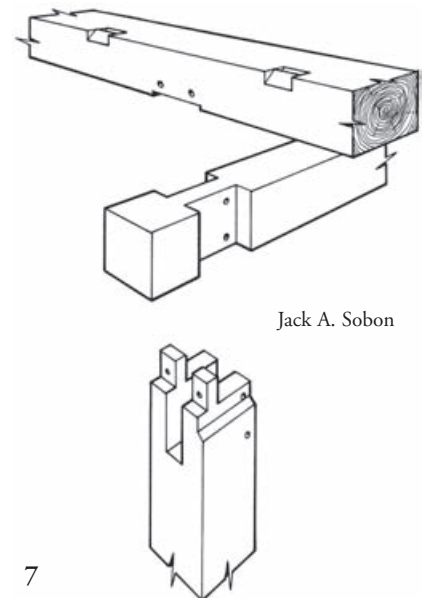
The Hannon barn, in the Indian Valley about a hundred miles north of the Carson Valley (see Fig. 4) is 60 ft. long with a 24-ft. central aisle and side aisles 12 and 15 ft. wide. The barn has round cedar posts, round sills and square purlin plates, and round cedar saplings for rafters. Longitudinal bracing runs aisle sill to purlin plate in a V pattern. Visible connections are mortised and wire-nailed, the latter dating this barn to 1890 or later. I could not determine the tie beam-plate connection. In theory, a tenon could rise from the top of the post up through the tie beam and into the purlin plate, or a rod or heavy lag screw could be bored down from the upper face of the plate through the tie beam into the post (Figs. 2 and 3).

In the Susanville area, 80 miles northeast of Reno, Nevada, long-brace framing occurs on a larger scale, with both round and square material and a lot of experimentation. The three-aisle form remains the same, but the bracing now appears to take on some of the load-bearing work on the posts. The Cabodi barn in Susanville, 56x60 ft., may date from after 1870 as it has no wagon entries, but looks earlier, framed entirely of hewn 10x10s with all pinned joints. The main aisle is 24 ft. wide with side aisles at 16 ft.; there are five equal bays. Gable-end V-bracing, rising from the center of the cross sill into the tie beam, survives in the rear gable wall. This barn also harbors the rare necked tying joint (Figs. 5–7).



- 1 Barn cluster in Sierra Valley seen near Vinton, California.
- 2 Hannon barn, Indian Valley, 51x60 ft., after 1890.
- 3 Hannon barn interior, mostly round timbers.
- 4 Map of area discussed. Broken lines are Gold Rush trails.
- 5 Cabodi barn, Susanville, possibly 1870s, all hewn square.
- 6 Cabodi barn, detail of necked tying joint at purlin plate.
- 7 Exploded view of typical necked tying joint.

Adapted from Greg MacGregor's *Overland: The California Emigrant Trail of 1841-1870*



Jack A. Sobon



8



9



10

East of Susanville on US 395 toward Standish stands another substantial barn with sill-to-plate bracing (Fig. 8). Today it's owned by Five Dot Cattle Co., meatpackers. This late 62x60-ft. barn is built with sawn 8x8 timbers and nailed connections, in six equal bays. Long 2x8s nailed to the undersides of the rafters stiffen the skip-sheathed roof membrane (Fig. 9). The main aisle is 30 ft. wide, the side aisles 16 ft. The first and last 10-ft. bays use inverted V-bracing that clasps the tie beam while the other bays have standard head and foot braces. Aisle purlins are supported by brackets (some incomplete) from the purlin posts (Figs. 9 and 10). Front and rear gable walls have modified A-braces (they don't meet at the peak) along with standard head braces. Originally the Five Dot barn also had long braces running from the cross sills into the posts, which will be illustrated in the next example.

Farther down the road in Standish is the Eagle Ranch barn, built almost exclusively with round timbers (there are only two squared pieces, a brace of braces). The sills are 16-in. dia., the posts 12-in. dia. and the interties (the proper name for any substantial lengthwise tying member) and purlin plates 8-in. dia. Braces from sill to intertie level, then to the purlin plate, mimic a German Wild Man pattern, and combine with bracing from the cross sills intersecting on the posts at the intertie level (Figs. 11–13). Like its cousin back up the road, this barn measures 62x60 ft. with the main aisle again 30 ft. and side aisles 16 ft., but this time it has three 20-ft. bays. The barn is absent of scarf joints, as all logs are full length! Connections are nailed or pinned and date the barn after 1890. A metal tie rod, probably original, runs unobtrusively close above each of the interior tie beams, restraining the plates (Fig. 14).



8 Facing page, Five Dot meatpacking barn at Standish, California.

9 Five Dot central aisle. Note under-slung nailed roof bracing and brackets to purlin in aisle roof.

10 Inverted V-brace to purlin plate.

11 Above, Eagle Ranch barn with round timbers and nailed joints, also at Standish.

12 Eagle Ranch barn, detail at purlin post. Junction of upbraces to purlin plate, downbraces to aisle sill and cross sill, and interties between posts. Joints hewn flat for nailing.

13 View of barn central aisle. Note transverse bracing and braces out to purlin in aisle roof.

14 Tie beam-purlin post connection secured by tie rod passing through purlin plates.





15

15 Big Sky Road barn, Susanville, California, one of two 28x30-ft. bays showing heavy pyramidal roof bracing rising from purlin plates. Paired aisle braces descending from purlin plate stand in plumb plane.

16 Detail at tie beam of central bent. Roof braces seat in scarfed purlin plate, which passes over tie beam tenoned to purlin post.

Our last example, just outside Susanville and accessible to anyone, is a work of art (Fig. 18). The spectacular Big Sky Road barn, 60x76 ft., has a square, three-aisle layout with a 16-ft. outshot in the rear. All the cow stanchions in the outshot are intact as well as the horse troughs and granary bin in the left aisle. (That aisle has a ladder that opens to a small area with a couch. Kids have spray-painted a couple of rafters and dope fiends have left their works on the floor, but all in all the barn stays unmolested.) The central aisle is 28 ft. wide with side aisles at 16 ft., and in length there are but two bays at 30 ft., plus a 16-ft. outshot. All timbers are circular sawn. The sills are 12x12, the posts and plates and long braces 10x10 and the tie beams 10x12. Given the combination of all-wood joinery, sawn timbers and hay track, we might date this barn after 1870 but before 1890.

Bracing the 30-ft. bays lengthwise is accomplished by four giant A-braces, one in each bay along each side of the central aisle (cover photo and Figs. 19 and 20). The end bents use transverse V-bracing to the sills. I was perplexed to see empty mortises on the underside of the central tie beam but none on the posts—had the builder recycled a timber?—until from the middle of the central aisle I noticed empty mortises in the cross sill for the feet of the missing braces. Yet the most amazing framing is in the roof. Pyramidal 8x8 roof beams notched into the purlin plates and rising along the underside of the common rafters form an apex in each bay (Fig. 15). The feet of these wind braces are 28 ft. above the sills and notched about 4 in. into the plates. Though I reached one of these connections via a succession of (risky) ladders at an end bent, I could not confidently determine the configuration of the purlin plate connection to the tie beam.

Outward thrust of the pyramidal braces against the plates might mandate a joined connection, perhaps the post tenon passing right

17 Detail at tie beam of end bent. Joinery indeterminate.

18 Exterior view. Drive-through side aisle is 16 ft. wide.

19 Interior view of same aisle from central aisle.

20 View from central aisle toward front of barn.

through the tie beam and then (suitably reduced in section) up into the plate. Supporting this possibility, at the end bents the 10x12 ties have 6 in. of relish beyond the crossing of the plate, and the plates present a similar amount of relish beyond the crossing of the tie—they can be seen coming through the siding in the front of the barn (though they are concealed in the rear outshot). At the central bent, the plate has a 2-ft. lapped scarf with pins from the upper face angled to pass right through the scarf into the side of the tie beam (Figs. 16, 17). The feet of the pyramidal braces appear to be unsecured at the purlin plates in all locations—no pins, no nails.

A rough calculation of the board footage for this elegant arrangement, compared with a standard Sierra Nevada barn frame, shows about 2385 bd. ft. for the 28x30-ft. area under the standard arrangement and 3100 bd. ft. for this arrangement, considerably more. But by number of joints, the comparison goes sharply the other way. A standard frame of this size would require 74 mortise and tenon joints to cover the given area; this framing method required but 36.

Hundreds of timber-framed barns still stand in the valleys of the Sierra Nevada mountains in Northern California and Western Nevada. The actual number is unknown but certainly diminishing in this changing landscape as residential development throughout the Sierras—with the exception of the Sierra Valley—absorbs ranches and their barns.

—PAUL OATMAN
Paul Oatman (pauloatman.com) is a contractor and timber framer in Pioneer, California, who researches timber framing in the Far West. This is the second of two articles. His previous articles on barns appeared in TF 56 and 81. With William Hurley of Dos Osos Timber Works (Los Osos, California), he has launched the website cnbarn.org for news and information on California and Nevada barns.





Zhou Qing Kun

A Tang-Style Temple in Dunhuang

THREE hours by air to the west of Beijing lies Dunhuang, a 2000-year-old oasis (now a small city) in a barren desert at the western extremity of China's Gansu Province. Dunhuang was the point where the southern and western branches of the ancient Silk Road came together to enter China and as a result has a culturally and genetically mixed population. Along with my wife and one of her sisters, both natives of Beijing, I was there last July to visit the Mogao Grottoes, some 812 caves dug out between 366 and the 1300s, and now a UNESCO World Heritage site. Fully painted inside with figurative, spiritual and architectural imagery, the Buddhist devotional caves have survived for so long because it almost never rains in Dunhuang.

Quite by accident, while visiting the small Lei Yin Temple (rebuilt in 1772) at the treeless edge of town, I looked over a fence to encounter one of the largest fields of logs, timber and framing I had ever seen, not to mention large new timber frames already standing (Fig. 1).

Dunhuang being a casual and friendly locale, we walked around the fence and began to look and inquire of the six framers of the Shanxi Ancient House Company, who, we learned, were three years into an expected six years of colossal framing. I don't use "colossal" as hyperbole. Many of the columns were as much as 47 ft. tall and went all the way from ground to purlins as single sticks.

I begin all commentary on China with a disclaimer: China is a very big country and it is unwise to generalize about it. After five years of Chinese conservation and restoration carpentry with Chinese craftsmen on the Yin Yu Tang project (an 18th-century merchant's house removed from Anhui Province in eastern China and reerected in 2002 at the Peabody-Essex Museum in Salem, Massachusetts), and after having visited China many times, I might know more about Chinese carpentry than most Westerners. But when confronted with the vast quantity of historic fabric standing all over the Chinese countryside and the regional and

dynastic differences, I don't know much. I will describe what I saw at the Lei Yin–Da Soong Temple Complex in Dunhuang because it was so ambitious and different from the carpentry I was acquainted with 1500 miles to the east in Anhui Province. In addition, it's a long way to Dunhuang. Few Western framers will ever see this work.

Entering the framing yard, a forecourt of about four acres in front of the partly completed temple, I was struck by the familiar appearance of the very large logs: they looked like larch. The construction foreman, A Bu Deng, informed us they were "the falling leaf pine" from Russia, likely *Larix sibirica*. All the heavy framing timber appeared to be this species. Meanwhile, a white, clear Chinese cedar called *Bai Shu* ("white tree") was in use for door and window jambs and panel frames, where stability is needed (Fig. 2).

Material for the small common rafters was probably the local poplar, and used as found, round and irregular. The last seemed normal practice around modern and ancient Dunhuang, while elsewhere in China I had always marveled at the tendency to apply labor to hew and plane even the smallest members into a more regular form. The average larch log was 30 to 50 ft. long and, often enough, 18 to 24 in. dia. at the butt. With the notorious tendency of larch to move, particularly in these conditions of extreme dryness (Dunhuang averages 3200 hours of sunshine per year), and its hardness, heaviness and spiral grain, these must have been formidable objects to frame (Fig. 3).

The typical tie beam or girt was sawn to 14x14, but many of the higher and larger horizontal ties were sawn or hewn on two sides only and left tapering and irregular on the other faces (Fig. 4). This was a characteristic, I was assured by the foreman, of late Sui–early Tang (618–907) framing, abandoned in favor of more extensive conversion of all timber during following dynasties. The same distinction apparently applies to the decorative carving of architectural elements such as brackets: minimal in Tang structures, extremely elaborate 1000 years later (Fig. 5).



2



3



4



5

Photos Jan Lewandowski except where noted

HOW traditional were the framing techniques being employed at Da Soong, and how skilled was the workmanship? Pretty good on both counts, I would say. In the Yin Yu Tang project, we had a mandate to do almost everything by hand, and we had Chinese framers, joiners, and stone, brick and plaster craftsmen from the building's original neighborhood to show us how. The house was mostly extant, just in need of repair or copying of parts, and from the late 18th century, a relatively recent period. The timbers were small and of moderately soft woods. By comparison, at Da Soong

1 Facing page, Da Soong Temple, Dunhuang, Gansu Province, China. At far right, A Bu Deng, foreman of Shanxi Ancient House Company. Back to camera, Zhou Mo, wife of author, interpreting.

2 At top left, *Bai Shu* door jambs on larch sill, limestone column bases, limestone blocks in the form of bricks, and drifting desert sands.

3 At top right, larch boneyard. Note very long through tenons and crossing-bridles joint. Poplar forest in background.

4 Above left, tie beams left close to their natural form, with purlin post top yet to tenon or bridle. Post bottom bridles around stiffening bolster ("camel's hump"), then enters tie beam with double tenons. Foreground, a long timber partially scored for hewing.

5 Above right, roof bracket sets without decorative carving.



6



7

6 Chopping out the bulk of a mortise with the *beng* after starting cheeks with chainsaw.

7 Above center, trimming the mortise with hatchet and chisel. Electric drill with Forstner-type bit for starting mortise center removal.

8 Above right, author and joiner pose with tools of the trade. Note bent blade on square to mark on rounded surfaces.

9, 10 Frame saws, probably site-made except for the blades, for cutting tenon shoulders, and the all-important *beng*. Note cant hook behind.

a huge amount of large-dimension, hard, dry wood was being worked to produce a monumental structure from scratch in a style from a very remote time period. A bandmill was on site, some portable power tools such as a 3½-in. power plane and a chainsaw were in use for limited purposes, and materials could be handled by forklift and crane, but the bulk of the work was done by hand.

A typical mortise, face measure about 2½ x 14 in., was worked as follows right through a 16-in.-dia. round column. The carpenter having struck ink centerlines on diametrically opposite sides of the column (four center lines are routinely struck on any round or square column as references for all joinery), he then laid out and scored the outline of the mortise at both extremities with a chisel driven by the hammer end of a small handaxe. (So much ink was required for this vast project that it was acquired in caseloads of half-liter bottles rather than by crushing small dry ink blocks, as is traditional.) Next, the carpenter plunge-cut the mortise cheeks some distance in from each side with an electric chainsaw. The interior of the mortise was then wasted with a large, swung, long-handled edge tool called a *beng*, and finally a man sitting right on the timber finished the mortise from both sides with a chisel (Figs. 6–8).

Tenon shoulders, meanwhile, were cut with frame saws (Fig. 9).

An electric drill (Fig. 7) was used, I was told, only to begin the wedge mortises on the anchor tenons, not for wasting larger joinery. The carpenters laid out the wedge mortises using the same technique as I had seen the Yin Yu Tang carpenters use for the hundreds of through holes they cut for their Anhui Province-style pinned joinery: the small square hole was outlined centered on or tangential to an ink centerline, and then the hole, sometimes as much as 9 in. deep from one side, laboriously chopped through the timber before any other joinery was cut, even though that joinery (for example a set of four mortises arriving at the same position, or the reduction of a fat timber to a slim anchor tenon) might have

removed 75 percent of the pinhole they had just chopped. The carpenters from Anhui guaranteed you would never get it right unless you did it that way, and they didn't drill any of it.

Many of the joints in the standing frame at Da Soong showed slightly open shoulders or mortises taller than their tenons. I don't think this was unexact work, rather the result of extreme shrinkage of very large green timber in a desert environment. A larch column originally 24 in. might ultimately shrink an inch in diameter and take two years to do so.

The framers of eastern China use a medium-sized axe for everything from felling and hewing timber to paring remarkably small elements close to their finished state, and even to drive chisels and nails. Illustrations of all of these operations appear in the famous 15th-century carpenters' manual *Lu Ban Jing* ("Lu Ban's manuscript"). Here in Duhuang in western China the framers used the powerful *beng* for most of the same functions.

The *beng* has a straight wooden handle about 3 ft. long carrying a socketed heavy chisel at one end of its wooden head. The opposite end of the wooden head is round and bound by an iron ferrule, suggesting its use to drive wedges and to drive joinery together. The *beng* is swung in front of the body like an adze or mortise axe to debark logs, hew between scorings, waste deep mortises (Fig. 6) and trenches, round protruding ends of beams and do perhaps a thousand other tasks. In function it is related to the English twybil or French *bisaigue* except that it has only the one blade, about 2 in. wide in the examples I saw (Fig. 10).

No one in the *Lu Ban Jing* is seen using a *beng*, but rusty ancient examples show up in museums in western China. Since the *beng* carries out most of the functions of the axe, the carpenters building Da Soong used the small handaxe only to drive chisels and nails and to pare. I saw evidence of juggling or scoring for hewing, but didn't see how it was done (Fig. 4, far end of long timber).



8

Zhou Mo



9



10



11 *Zhu jia-zi* posed at author's US workshop.



12 Reduced shoulders and tie beam end for bridle joint roughed out by the *beng*.



13 Limestone column base. Larch column has been sized and scraped, first of many painting steps.

Neatly joining square timber to round columns always presents a problem, but the Anhui carpenters working on Yin Yu Tang had it solved by a tool of which I can say that nothing like it exists elsewhere. The *zhu jia-zi* ("column holder thing") is a sort of clamp that springs onto the center lines of a round column while straddling a mortise and allows one to transfer the curvature of the column to a coping on the shoulders of the horizontal beam entering the mortise. In use, its bamboo stick is kept plumb and readings are taken about every half inch (Fig. 11). A separate set of readings may be taken for the bottom shoulders in the case of very deep beams, where conditions on the post may differ.

At Da Soong, however, the large squarish timbers had tapered reductions near the ends, resulting in relatively small shoulders around a tenon. Given the large size and thus the small degree of surface curvature of the columns, the shoulders required little or no coping, and I saw no *zhu jia-zi* in use.*

Eighteenth-century, late-Qing dynasty structures from eastern China like Yin Yu Tang display in their framing and interior woodwork what I have heard called a "love affair with the mortise and tenon joint." The frames in Anhui, of the renowned Huizhou style, are connected by mostly cross-pinned mortise and tenon joints, and with some anchor tenons, while here at Da Soong I saw no cross-pinning but only anchor tenons, bridle joints and slotted dovetail connections between beams and columns (Figs. 3, 4, 12).

WHENEVER visiting the reconstruction of a lost historic structure, whether in Europe, America, Japan or China, I wonder how confident I can be that I'm seeing "the real thing." There are few examples of Tang dynasty structures standing in China (or wooden buildings of that age anywhere in the world). Two good ones are about 1200 miles away in Shanxi Province at the large and remote Buddhist complex at Wutai Mountain: the East Hall (dated 857) at Foguang Monastery (see TF 98) and the Main Hall (782) at Nan-ch'an Monastery. Both are smaller than the new temple at Da Soong and lack its two roof levels, or veranda. However their framing style, joinery, conversion and level of decoration are consistent. While the supervisor for the Shanxi Ancient House Company told me the temple was modeled on Foguang, in elevation and plan it resembled the Tang Imperial Halls in Chang'an (today's Xi'an) I have seen in partly hypothetical drawings based on excavated floor plans, rubbings from stone stelae and Tang dynasty fresco paintings.** In any case, what we saw at Dunhuang was a very large temple 137 ft. across the front and 92 ft. deep, nine bays by six bays not including the wraparound veranda. This structure is attached by covered walkways to two small remote dependencies.

Rammed-earth platforms and stone column bases were being laid out for two slightly smaller timber-framed structures flanking the courtyard in front of the newly built temple—in fact, the timber for them was being worked by the framers when we visited. Long-span trusses are one of the few timber constructions not developed historically in China, so the interior of the Da Soong Temple is a relatively closely spaced grid of tall and massive

columns, carrying tie beams, purlin assemblies and eventually the roof above. The columns don't stand on a sill (perhaps never used in traditional Chinese carpentry), but rather on individual carved stone pedestals (Fig. 13).

The pedestals here are grey-green limestone from Hubei Province, and the beautiful lotus-petal carvings are based on Tang-contemporary evidence (Fig. 13). Close inspection shows them to have been fabricated mostly with power saws and chisels. The raised platform that the temple sits upon and the steps leading up to it are paved with large slabs of remarkable blue-and-red granite. The exterior infill walls between the columns appear to be of gray brick, as in many Chinese frames, but in reality these bricks are sawn and polished limestone blocks (Fig. 2). The roof is glazed tile laid in mortar on top of a fiber mat, on solid though small and variously dimensioned boarding, over the small rafters earlier described.

The large temple frame in these photos was erected, we were told, piece by piece with a crane and scaffolding. The glazed tile roof and the masonry-infilled exterior frame presented a monumental appearance, but a vast amount of work remained to be done. The interior will be divided into partially enclosed spaces with platforms and altars carrying Buddhist statuary. Every square inch of the timber and woodwork will likely be painted, except perhaps the rafters.

We asked who had the money to spend in such an out-of-the-way location on such a massive project that will be of interest mostly to Buddhists and some domestic tourists. The answer given was Chinese Buddhist associations, and the deep pockets of today's Chinese government, which seems to be spending money on heritage everywhere in this large and ancient country. Most Chinese are infatuated with their own history, the more ancient the better, and domestic tourists vastly outnumber those from abroad. Timber framers would enjoy seeing this traditional, largely hand-crafted framing carried out on a gigantic scale, but that sort of tourist is few and far between in Central Asia. Dunhuang, an extremely quiet and pleasant place to stay, and not as hot as you might fear, is nowadays visited mostly by scholars and cultural tourists interested in earthen architecture, frescoes painted on cave surfaces and the history of Buddhism.

—JAN LEWANDOSKI
Jan Lewandoski (janlrt@sover.net) operates *Restoration and Traditional Building in Greensboro Bend, Vermont*.

*While the Anhui carpenters on the Yin Yu Tang house assured me in 2002 that the *zhu jia-zi* was invented by Lu Ban, it isn't seen in his manuscript, nor did the skilled Hebei carpenters I met re-creating the Jianfu Garden structures at the Imperial Palace in Beijing in 2005 know of it, nor did those of the Shanxi Ancient House Company here in Dunhuang, nor does it appear in a comprehensive 1997 work (not yet published in English) by the renowned Ma Bing Jian on techniques of ancient Chinese timber framing and carpentry.

**See Fu Xinian et al., *Chinese Architecture* (Yale 2002).

Wood Protection by Design

OUR first article (“Wood Decay and Protection,” TF 100) explicated biodeterioration agents and the processes they employ to return wood—the manufactured, dead organic material—back to nature. This article discusses what constitutes good design and skilled construction to avoid wood decay and degradation. Together these two practices make possible effective maintenance, the means of wood protection over time.

Archaeology and history record many examples of rudimentary wood protection such as single-stone pedestals and caps to reduce water entry into the end grain of wood columns, or broad eaves on thatched roofs to direct water away from the wall. The use of durable species for water exposure such as the cedars of Lebanon, or ancient concoctions such as cedar oil and pitch for preservation, provide other examples (Graham 1973).

Today’s designers and builders increasingly turn to renewable, organic materials, which they want to last, if not forever, then for many decades or if possible centuries. All materials degrade over the long term, but wood’s organic character determines its longevity and ensures its susceptibility to nature’s genius for waste removal. Though not mutually exclusive, these two goals for the materials, that they be at once organic and long-lived, naturally conflict.

Yet ancient timber structures are scattered across Europe and parts of Asia. Their longevity demonstrates the achievability of these simultaneous goals and results from five key requirements: good design, skilled construction, consistent maintenance, the ability of the wood to dry quickly after wetting and, finally, a relatively termite-free environment. Additional tactics for durability today include chemical preservatives or modification as well as the designer’s choice of a wider range of durable wood species.

Achieving these requirements, moisture control the most important, over the extended life of a building challenges the builder more today than it did historically. The consequences are sometimes apparent in spectacular failures such as extensive EIFS (exterior insulation finishing system*) leakage in the Southeast in the 1990s. Owners and users of buildings demand more from shelter today than in the past, and builders and designers struggle to meet these increasing demands. Moisture, the biggest threat to wood durability, has proved to be difficult to control. Today it is the source of one of the most litigated construction failures in the US (Easley 2010).

For centuries, builders in cold climates sought to limit the flow into buildings of air in the form of drafts and moisture in the form of liquid water. Interior moisture generated by inhabitants or their activities found its way to the outside atmosphere or was dried inside wall cavities by conducted heat or heated air that consistently flowed through these assemblies. With today’s ever-rising interest in energy efficiency, control of the *outflow* of air has gained importance and has significantly contributed to moisture issues.

For improved energy efficiency, fitting insulation between studs and rafters of light-framed buildings gained acceptance as fiberglass insulation became widely available in the US ca. 1960. Insulation requirements became common in North America with the focus on energy efficiency and tight building construction during and after the Carter-era global cooling scare and the OPEC-induced oil shortage in the late 1970s. The Canadians led the way with their R2000 program to reduce energy consumption, in which they

*EIFS is described by professional building inspector Dan Schilling as “a vulnerable surface coating as thin as a soda cracker applied over the top of foam insulation board that has the structural density of a Styrofoam cup” (residentialinspections.com). See also dspinspections.com.

strived to limit the flow of air and moisture by installing polyethylene vapor barriers under wallboard and over 2x6 studs and 6 in. of insulation. Though successful in many colder areas of Canada, its application in different climates proved problematic. Limiting the flows of heat, air and moisture caused an increase in moisture issues. Without the necessary heat and circulating air, wall and roof assemblies no longer dried as quickly.

The building community is a subculture that exhibits strong traditions and practices passed on mostly through hands-on experience and word of mouth (not through vocational education), at least in the US. In particular for house-builders, this allows even uneducated laborers to work with less-detailed information in prints or specifications, relying instead on tried-and-true practices.

As a necessary consequence, change usually works its way slowly through the construction industry and is often resisted, often with good reason. Unlike evolved building materials embraced by builders such as plastic piping or Romex wiring, heat, moisture and vapor flows are complex and climatically diverse phenomena best understood by those with backgrounds in mechanical engineering or thermodynamics. And, unlike commercial work for which documentation runs into hundreds or even thousands of pages of drawings and specifications, domestic construction generally has not warranted or received the attention of mechanical engineers in the design process. The building industry is still working to integrate ratcheting performance demands and the products and processes to satisfy them. Like builders, many architects, engineers and designers do not understand the mechanics of moisture movement. Yet they must now devise systems that provide excellent primary barriers to energy, air and vapor flow and back-up systems for when they fail, and must work with builders and the labor force to guide their proper installation.

How moisture infiltrates—the physics Moisture movement requires a driver. Gravity drives liquid or bulk water. Capillary action or wicking, another driver, acts counter to gravity. Wicking arises from the surface tension of water at its boundaries. Water rising inside a straw against gravity to a higher level than the surrounding water provides a familiar example. The smaller the pore, the more dramatic the rise. In specific circumstances, wicking contributes significantly to moisture movement. Additionally, two gradients (local differences) act as moisture drivers: temperature and pressure. Under most conditions, heat is transferred from warmer to colder areas, and differences in pressures equalize.

Heat is energy but in the vernacular even most physicists speak of heat as a substance. As a measure of the excitation of the molecules of a body, heat always moves from the hotter body to the colder body. Colder air, however, can move toward hotter air if the pressure difference drives toward the hotter zone—consider drafts. The heat in the air will then equilibrate across the hotter and colder air. In a wall cavity heat is transferred by convection from the inside wall to the outside wall. Air moves up the inner surface of the wall as it warms, transfers the heat after crossing over at the top of the cavity and flows down the outer wall as it cools. Heat also radiates from a house as black-body radiation even without air movement.

Air and vapor produce the pressure differences necessary for moisture movement. They often act in concert. Air pressure gradients occur under several circumstances. Wind as it hits and flows around buildings causes higher pressure on the exterior face of the windward wall than normally exists on the interior face of that wall. Simultaneously, air flowing around a building induces a partial vacuum on the leeward exterior face of a building relative to the

pressure at the interior face of that wall. Wind also induces lower pressures as it flows around corners or over roofs just as it does when it travels over an airfoil such as an airplane wing. Other key sources of air pressure gradients include the stack effect—warmer air rises because of its lower density (think of a hot-air balloon)—and the pressure differences generated by heating and cooling structures with forced air. Forced-air heating and ventilating systems pressurize or depressurize buildings or specific rooms. For example, forced air will pressurize a bedroom that has no return air ducts. The curious sucking sound that sometimes accompanies the opening of a door indicates a depressurized space. Air pressure gradients move moisture if air moves from higher to lower zones. Arrest the air movement and the moisture movement stops, too (Fig. 1).

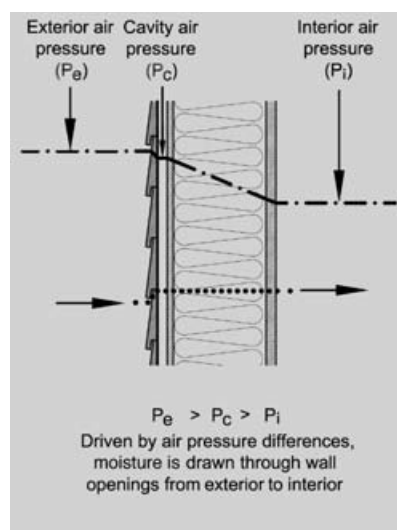
A less familiar phenomenon, vapor diffusion, is caused by vapor pressure differences (Fig. 2, from Lstiburek 2006). Vapor diffusion is the movement of moisture into and through building materials even without air movement. Vapor pressure is the weight of the water in the air—the more water in the air, the higher the vapor pressure. Vapor will diffuse through a permeable substance, even substances with limited permeability like wood or stone, to equilibrate the unbalanced vapor pressures on either side of the material barrier. In many circumstances, vapor diffusion moves moisture too slowly to contribute significantly to wood degradation.

How moisture infiltrates—the ways All three phases of water—vapor, liquid and solid (ice and snow)—act on structures and should be considered in design. Rain, snow, ice, sprinklers, respiration, heating, washing and cooking provide the water that affects structures and their subassemblies.

Water might enter a wall or roof assembly in four general ways: liquid flow, capillary action, carried on moving air as vapor, and water vapor diffusion (Lstiburek and Carmody 1994). But, in the case of a wood-framed wall, research has shown it might enter in more than a dozen specific ways (Tsongas 2007). Nine conditions, according to Tsongas, cause serious damage:

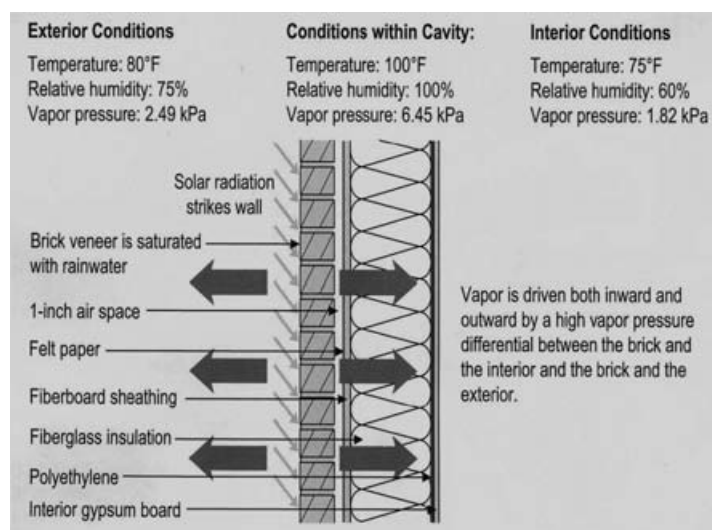
1. Liquid water wicking up between the laps of cedar siding (this specific species only).
2. Liquid water leaking behind or around siding and trim (e.g., window trim, or corner boards) including through water-resistant barriers.
3. Liquid water wicking into gypsum sheathing behind siding (gypsum sheathing outside the studs—not frequently used by timber framers or SIPs builders).
4. Siding in contact with wet concrete or too close to soil and landscaping.
5. Liquid water wicking into poorly- or un-painted siding edges.
6. Water vapor migrating into wall cavities from inside house.
7. Solar-driven moisture transfer from siding into sheathing.
8. Indoor moisture entry from or through wet (moisture-laden) concrete slab-on-grade floors (or from foundations).
9. Moisture entry into walls from wet lumber.

Rain and gravity drive water more readily into and behind non-wood siding materials such as stone, stucco and brick, depending upon their porosity and coatings. Capillary action and vapor pressure also move significantly more water into and behind these



After Lstiburek and Carmody

1 Air pressure differences alone can move moisture.



J. Lstiburek ©Building Science Corporation, reprinted with permission

2 Solar radiation, vapor pressure and resulting movement of water through wall cavity. 1 kPa (kilopascal) = 20.89 psf.

materials and potentially into the sheathing and the wall cavity. Sunlight, by heating wet siding material, creates a vapor pressure differential, which can be as high as 80 lbs. per sq. ft. (Fig. 2). Moisture driven through wood members that pierce the building envelope should be added to this list. Moisture can be driven by all means described, around or through the wood, though condensed liquid water does the most damage. Checks and separations in the seals around the wood result from drying and moisture cycling (shrinking and swelling) even in engineered wood such as glulams, laminated veneer lumber (LVL) and parallel strand lumber (PSL), allowing both liquid and vapor to bypass the building envelope.

Besides being driven in by gravity or rain, liquid water occurs on or within building assemblies when it condenses from vapor (items 6 and 8 in Tsongas's list). This happens in heating climates when warm, moisture-laden air travels from inside the building through the wall assembly. At some point, the building material surfaces are cool enough that the water vapor in the air hits its dew point and condenses out. Alternately, in cooling climates, when warm, humid air travels from outdoors inside the building envelope, it too will eventually hit a surface that is cool enough to condense the vapor to water, usually on the backside of gypsum wallboard. If the flow of humid air in either direction continues for a protracted period of time, and the temperature is conducive to the growth of fungi (greater than 1 degree C or 35 degrees F), decay fungi will attack the wood. If the moisture is being carried on air, stopping the air flow will stop the moisture flow.

Mildews and molds Though they affect human health rather than cause decay, mildews and molds remain on the surface of materials and act to increase the susceptibility of wood to decay. They raise the moisture content of wood and soften the fiber cell structure. (See the previous article.) Molds and mildews form on building materials when the surface relative humidity (RH) rises above 70 percent.

Surface RH should not be confused with ambient RH. Within a conditioned room or insulated wall cavity, the ambient RH may be considerably lower than 70 percent, but at a cold surface such as an outside wall in winter or on the backside of the interior gypsum wallboard of an air-conditioned room, a thin layer of air at the surface of the wall will be above 70 percent or higher. A familiar example of this phenomenon occurs at cold window surfaces that fog or frost within heated spaces.

Weathering and decay Like mildews and molds, ultraviolet (UV) radiation and weathering contribute to wood degradation by making it more susceptible to decay. Although UV and erosion generally result in wood fiber loss of no more than ¼ in. per century, weath-

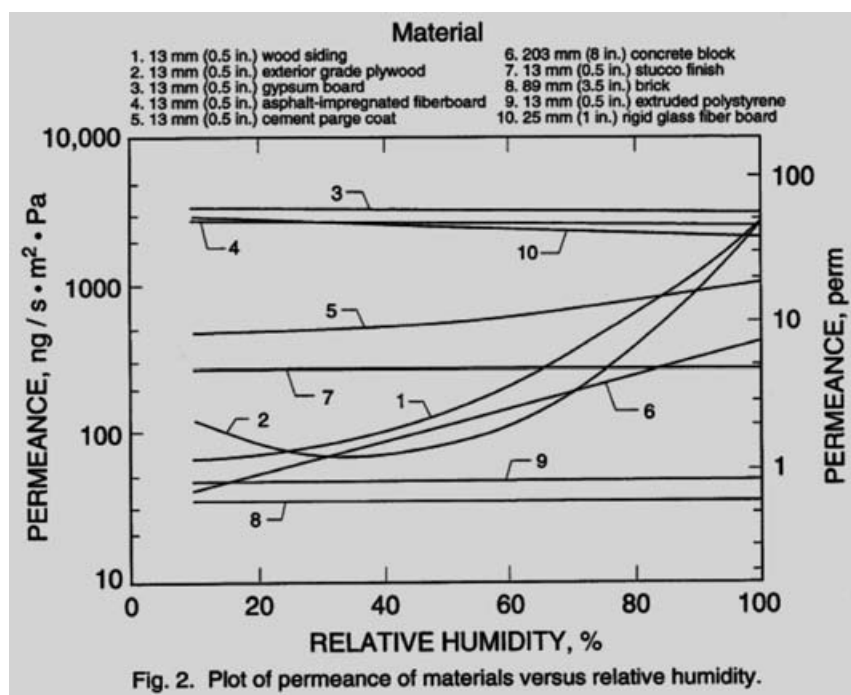
Expected Strength Loss at an Early Stage of Decay (5–10% Weight Loss) In Brown-Rotted Softwoods

PROPERTY	Strength Loss (% of original property)
Toughness	80+
Impact bending	80
Static bending (MOR and MOE)	70
Compression perpendicular to grain	60
Tension parallel to grain	60
Compression parallel to grain	45
Shear	20
Hardness	20

After W. W. Wilcox

3 Above, strength property loss as a result of decay.

4 At right, generally direct relationship between relative humidity and permeance. Each line represents a particular material numbered in key at top.



US Department of Energy

ering processes cause finish wood and timbers to warp and crack. Photodegradation strips away hemicellulose and lignin and increases surface area and the absorption of water (Williams 2010). These processes create more opportunity for decay fungi.

Of the nonbioagents of wood degradation, water often aids the processes of weathering and erosion. (Fire destroys wood more effectively and rapidly than any other agent, but lies outside our scope.) Water in its several forms plays the leading role in this drama with UV radiation and weathering processes playing minor parts. Limiting exposure to water limits wood's susceptibility to all of the agents and extends its longevity for decades and maybe centuries. (If exposure to water cannot be limited, then other means such as chemical treatment or modification of the fiber can be used to poison the food for bioagents or to increase the physical resistance of the fiber to weathering.)

Health and safety too motivate an interest in wood protection. Wood infected by mildew and decay fungi affects indoor air quality and invites other bioagents such as mites, termites and beetles, which themselves affect human and pet health.

Additionally, insect-ridden wood suffers loss of strength as the wood fiber disappears. Significant loss of strength and stiffness results from even microscopically detectable decay. This fact is poorly understood by builders and engineers (Wilcox 1978, and see Fig. 3).

Timber framers whose designs may depend upon the structural properties of foam-core panels should be mindful that the panels themselves typically rely upon slender, oriented-strand board (OSB) skins $\frac{7}{16}$ in. thick to carry the building's vertical and lateral loads. Even low levels of decay of these wood-and-glue skins, often unseen within a wall or roof assembly, impair the panels' ability to carry design loads and thus the building's performance.

Moisture that drains or collects on OSB from poor construction such as improper flashing or improperly installed water barriers most often causes decay and structural degradation. Even very small holes allow a significant amount of water to drain, and unless the wall can dry in a reasonable time frame, decay and strength loss will occur. Decay ultimately turns OSB to an oatmeal consistency.

As is the case with all vapor and air flow-control technologies—and panels should be considered one such technology—panels must be properly installed to avoid moisture issues. The OSB skin provides excellent barriers to air flow, and thus to moisture borne on air. Vapor permeability** of OSB ranges from 1 to 10 perms, increasing with increasing relative humidity—changing vapor categories from semi-impermeable to semipermeable. Most foams,

however, are categorized as impermeable to semi-impermeable, only allowing vapor to diffuse very slowly (Fig. 4).

While unbreached panels do not themselves experience moisture problems, the connections at their perimeters or holes cut in them, if not properly configured and sealed, permit moisture-laden air flow. Panels are connected in a variety of ways, some inherently difficult to configure properly. Where OSB splines are used in panel-to-panel connections, sealing the two foam faces with expanding foams generally performs very well. When solid lumber or engineered wood splines are used, however, sealing is more difficult and more likely to fail. First, there are now two foam-wood faces to be sealed—one on either side of the wood. Second, wood is susceptible to checking that may provide direct avenues for air and moisture flows through the wall system. And third, since it is hygroscopic, wood absorbs and desorbs moisture reacting to the relative humidity of the surrounding air. Shrink-and-swell cycles may lead to failure at the interface of wood and sealant, providing moisture flow paths.

When panels are installed against green timbers, significant timber movement as it dries can also cause failures at a sealant-wood interface. This is much more likely with relatively high-shrinkage species such as oak than with lower shrinkage species such as Eastern white pine. Timbers in timber frames, unless they pierce the wall or roof and are exposed directly to moisture, generally do not suffer significant decay before the problem is noticed. But the timber frame and panel structural system can be compromised, particularly when panels are engineered to be the lateral resisting system for the timber frame, or in hybrid systems where panels also support horizontal timbers on the exterior walls.

Durable building The key to durable framed buildings is to keep moisture out of the wood. Though measures may be taken that minimize or eliminate wetting exposures, it is not always possible to keep moisture out of wood; it will find ways into the walls and roof assemblies. Designers and builders are wise to expect this eventuality and to construct buildings that dry quickly when water intrudes. They must recognize that wood takes much longer to dry than to wet. Like clothes that get wet in an instant and take hours

**Vapor permeance measured in perms is defined as the rate of transfer of vapor through a material. Brick veneer is permeable at 40 perms (category *vapor permeable*) whereas 6 mil polyethylene is permeable at 0.03 perms (category *vapor impermeable*). One US perm = 1.0 grain/sq. ft./hour/inch of mercury (7006 grains = 1 lb).

to dry absent significant applied air flow or heat, wood can be wetted in minutes and take weeks or months to dry, particularly in enclosed, dead air spaces like wall cavities (Easley 2010).

Fortunately, wood decay does not start immediately upon wetting. It does not occur below 20 percent moisture content (MC) and for most fungi must be above the fiber saturation point (FSP), usually considered to be near 30 percent MC. (A devastating exception to this rule is *Meruliporia incrassata*, the “house-eating” decay fungus that brings its own groundwater to the wood it consumes.) Little documentation exists on decay occurring between 20 and 30 percent MC levels.

Recent testing, however, demonstrated that even at MC levels as high as 26 percent, OSB and hemlock did not show visible decay and did not lose strength or stiffness even after three and a half years (Clark, Symons and Morris 2007). This research suggests that moisture in liquid form might need to be present for incipient decay in wood building materials. (At normal temperatures and 100 percent relative humidity, the equilibrium moisture content is less than the FSP.) Even at 40 percent MC, OSB and hemlock did not exhibit any loss of strength until after 21 weeks, suggesting that at least some woods must be exposed to liquid moisture for an extended period of time for decay to initiate.

Barriers to water in its several forms must deflect or drain water to eliminate opportunity for wood decay. And, accepting the inevitable failure of wall and roof water barriers, good design allows wetted wood to dry out rapidly enough to limit decay potential.

Keeping moisture out: good design and construction Good design protects wood by minimizing its exposure to the physical and biological agents that would return it to its constituent elements. Others have noted that well-designed structures—structures that serve their inhabitants well—are loved and, being loved, are well treated and maintained. Certainly, vernacular architecture constitutes an excellent source of ideas for protecting wood and achieving longevity. Research into the morphology of vernacular wood-protecting building techniques suggests that climate rather than geography drives their use (Aho 2007).

Durable buildings, whether of wood or other materials, are protected from water. Design starts with quickly draining away the water to which a building is exposed. “The fundamental principle of water management,” according to Lstiburek’s *Water Management Guide*, “is to shed water by layering materials in such a way that water is directed downwards and outwards out of the building or away from the building. The key to this fundamental principle is drainage. . . . Drain the site, drain the ground, drain the building, drain the assembly (e.g., the wall or roof), drain the opening, drain the component (e.g., door or window), and drain the material.” Simplifying this fundamental if perhaps self-evident principle, we might intone, “Drain, baby, drain.”

Steve Easley, in *Moisture Control in Commercial Wood Buildings* (2010), proposes another comprehensive strategy that he calls the Four Ds of moisture management: Deflection, Drainage, Drying, and Durable components.

Easley uses the word “deflection” rather than Lstiburek’s “drain” for the redirection of water that strikes the building directly, and “drainage” to describe removing water or moisture that succeeds in getting into building assemblies. Both authors accept that water cannot always be prevented from entering a structure and recommend draining the water that bypasses the defenses, as well as providing means to dry wetted components.

The roof of any structure constitutes the first defense. A Chinese symbol for *building* consist of two characters, one that represents *shield* and another *roof* (Aho 2007). Arguably, this describes the minimum requirements for a human shelter: shelters without walls are common (pavilions), but few roofless structures feel like shel-

ters. As their primary purpose, roofs provide protection from precipitation and UV radiation. Besides shielding UV radiation, roofs redirect rain (or hold it for later draining if in the form of snow or ice), deflecting it away from inhabitants, their possessions and the building itself, particularly the roof’s support structure.

Aho’s studies of vernacular architecture and its literature demonstrate that culturally and geographically separated builders used very similar roof designs in similar climates, and that climate more than culture drove the development of building styles.

For drainage, the three variables of roof design are roof pitch, roof style and length of eaves. Researchers noted that roof pitch increases with increasing local precipitation whether in the form of rain or snow. In regions closer to the equator in such widely disparate places as the Mediterranean, Latin America and China, roof slopes tend to be low. In their more northern counterparts, roof slopes increase, signaling the local need to shed more rain or snow. Aho suggests that the increasing popularity of the gambrel roof beginning in the mid 17th century in New England, New York, New Jersey and Pennsylvania can be explained by its greater tendency to shed rain and snow from the steep lower pitch.

In coastal areas, however, even in northern latitudes with heavy precipitation, low roof slopes predominate to limit wind loading, minimal when bearing on 20 to 25 degrees of pitch.

Designers cannot always orient a building ideally because of zoning requirements or other site considerations, but when possible should limit the exposure of the building to the weather and the summer sun and maximize exposure to the winter sun. When designing the roof or the rooms below the roof, designers should consider reducing roof complications on the sides most exposed to weather and summer sun.

Though not currently fashionable, simple building shapes such as local archetypes with their roofs of little complication deflect water and weather most effectively. Breaks in planar surfaces such as valleys in roofs and corners in walls not only cost more time and money to build, such discontinuities also create greater opportunity for envelope failures, allowing energy and moisture to move more freely into and out of the structure. In particular, closely spaced dormers facing away from the sun in wet and cold climates challenge the building envelope with water, snow and ice, and with little drying potential.

Eaves protect buildings in two ways: they deflect rain that would otherwise strike the walls and they divert water some distance away from the foundation. P. Roy Wilson writes that the overhangs of the Québécois pavilion roof grew from 9 in. in the mid 17th century to 36 in. by 1720 (Wilson 1975). And Les Walker reports that Tidewater cottages first built in the southeast US around 1680 had little eaves projection, but that early in the 18th century the projections developed into south-facing porches that protected the building from wind-driven rain as well as solar gain (Walker 1981).

Eaves drain water off the roof and away from walls, but this falling water may splash the wall or drain back toward the building’s foundation unless collected and diverted. (Drain the site.) Of course, properly sized and sloped gutters at the eaves provide the means to collect this water and redirect it down and away from the building, using downspouts, splash blocks and foundation drains. (But flora growing from the gutter is not a good sign.)

Shed roofs are easiest to build but, with one wall mostly unsheltered, do not protect a building as well as gable roofs. Hip roofs protect walls better than gable roofs, as well as spreading roof load on much more wall length. Hip roofs and hipped gables reduce or eliminate otherwise tall gable walls, making buildings less susceptible to wind-driven rains (Aho 2006). Certainly, the thatched, hipped-gables of Eastern Europe better protect gable-end walls by putting water-deflecting eaves over them.

In Louisiana plantation houses of the 18th and 19th centuries, the porch wrapped all the way around the house, shielding the walls from most wind-driven rains. Adding a belvedere to the roofs of these structures also promoted their cooling and drying. The induced stack-effect of air drawn into the building via the porches and then upward through the belvedere conferred comfort as well as adding drying potential and thus durability.

Vernacular architecture such as Tidewater cottages demonstrates an important means of protecting wood from the rising damp: raise buildings off the ground. Wood floor framing, if close to wet or moist soils, suffers from decay and from insect damage. Raising the structure allows ventilation of the floor framing, reducing the potential for both, particularly in the South.

Even for buildings in less humid climates, good design dictates a first-floor height well above the landscaping level, to ensure that groundwater splashing from rain or sprinklers does not strike the wall siding or that bushes and other plantings do not deflect or hold moisture against it. Water upwardly directed from these sources may well find an easier path into the wall assembly. The designer should also consider the potential for snow accumulation around a structure or a structural element such as a post. Water from snow readily wicks into wood end grain or siding edges, or into timber and lumber checks or cracks, thoroughly soaking the wood during the day and possibly freezing during the night. Significant damage from freeze-thaw cycling, not to mention moisture cycling, can lead to water infiltration, damage, decay and premature wood failure.

When structural elements are intentionally exposed to the elements as in overhangs, walkways, trellises, galleries and porches, designers should make every effort to hold structural wood back from the eaves edge, allowing the roof surface to extend beyond the structural wood in both horizontal directions (Billups 2010). Where possible, wood should not be exposed to direct UV rays when the sun is high in the sky. A projection of a given member's exposure to direct overhead sunlight through the year will indicate how it can be protected by an extension of roof eaves or by an angled end cut. (It is seldom structurally necessary for a joist, purlin or rafter to extend fully to the edge of the eaves.)

The tactics, then, are to hold the member back from the edge, taper the main carrying member toward its end and consider cutting the end on an angle that reduces its exposure to rain and keeps it in shadow for a large part of the time when the sun is high. As does limiting wood's southern exposure, limiting its exposure to only the long UV rays in early morning or late afternoon reduces the potential for UV damage and reduces the likelihood of it being struck by wind-driven rain.

Designers and builders should make every effort to cover end grain and ensure water is not shed on exposed wood members such as rafters, joists, braces and struts. Besides metal end caps, sacrificial wood end caps may be added to flat or pitched members to limit the decay. Caps, unless glued on, can be easily removed and replaced when they degrade. Some glulam manufacturers glue side-grain caps on the ends of exposed members. Though effective in forestalling degradation, glued end caps may make maintenance more difficult, undermining their purpose.

A special challenge to the designer is the shed or butterfly roof with exposed, downward sloping, wall-piercing timber rafters. Usually supporting large protective overhangs, sloping rafters, whether solid sawn or engineered wood, can drain water into and beyond the wall through separations between the rafter and the wall or directly through the rafters internally via checks and cracks. Cracks and checks can open long after construction, created by drying of the timber or moisture cycling. A surprising amount of water, gallons per minute, can drain through very small holes (Easley 2010). Though large overhangs and lower pitched rafters

diminish water drive, there is no perfect design solution to this problem. Exposure should dictate use or avoidance of the design.

Connections Care should be taken with exposed pitched wood members that terminate at a vertical surface, such as a rafter terminating at a post, an outrigger brace abutting its vertical strut or a kingpost truss with angled struts. Water will run down and accumulate at the connection on the upper surface of the inclined member and wick into its end grain. If the connection is by mortise and tenon, water will drain into the mortise of the vertical member, creating conditions for decay in both members. If the pitched member is painted or well sealed, the required drying time may be long for any water that intrudes into a crack or the end grain.

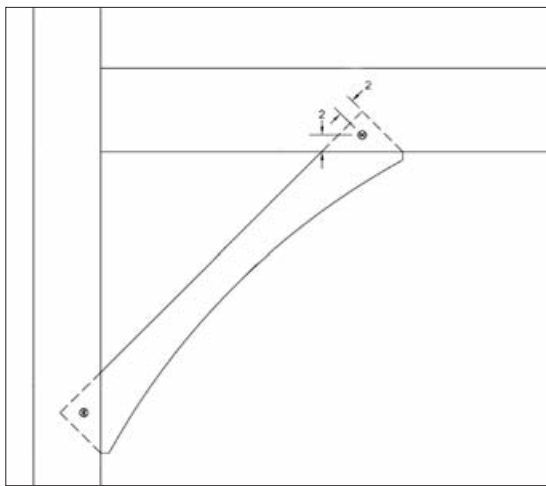
Water can be caught or can wick between tightly spaced or in-contact members exposed to bulk water. When possible space members to allow water to drain between them. Horizontal or pitched members sitting on top of posts should be significantly wider than their supporting posts so that the lower corners of the horizontal member form a natural drip edge allowing water to separate from the timber. If a timber post or strut supporting an open-air pavilion must pierce the roof, the designer should consider stopping the roof well short of the piercing member and flashing the opening. The opening at the timber will allow more water to drain directly down the timber through the pavilion, but water will be less likely to intrude into the roof assembly or the timber itself if the opening is properly constructed (Billups 2010).

Fastened connections present another challenge for the designer. Bolts and other metal connectors catch and hold water, often right against the wood. Exposed saddle connectors for horizontal members should be avoided. Even if equipped with weep holes, dirt and debris can clog the holes and turn the saddle into a bucket. Flat steel plates on the surfaces of timbers hold water against wood, too, whether from rain or condensation. Bolted connections (with or without steel plates) can wick water into the wood or can expose the wood interior to wind-blown rain when green timber shrinks and the steel plates, washers, nuts and bolt heads are no longer tight. (Bolt-hole drill sizing should always meet *National Design Specification for Wood Construction* requirements, but making sure the holes are not oversized for an outdoor structure is particularly important for wood protection.) Undermining even the best efforts, checks often occur at or near bolts and other connectors, providing deep ingress for bulk water.

Using dry material—seasoned solid-sawn timber, glulam, parallel strand lumber or laminated veneer lumber—reduces but does not eliminate the potential for water intrusion. Use of malleable washers on bolts in dry timber will go a long way to eliminate ingress, however. Countersinking and plugging holes to cover bolt heads and nuts, another tactic, reduces the capacity of a connection because effective widths of side members are reduced, possibly forcing the designer to use a larger timber, so the practice is not often specified commercially.

Slotted-in knife plates can be an excellent connection choice, particularly if the plate enters the wooden member from underneath. Because bearing on the perimeter edge of the plate is not typically a consideration, the slots can be configured to drain. The slots also should be large enough to accommodate timber movement and avoid water surface tension. If the knife plate includes an additional bearing plate welded on at right angles, the designer should ensure that the steel bearing surface is narrower if below the timber or wider if above it, and sloped to drain water that otherwise might intrude.

Hidden connectors such as mild steel shear plates and split rings should generally be used only in covered structures and have upper surface protection from water intrusion. Structural screw connections, especially if stainless steel, provide a good option for exposed



Mack Magee

5 Draining brace mortises for exterior use.

timber connections. As long as screws are not countersunk to any extent (unless plugged), there is little opportunity for intrusion.

Epoxy connections should be avoided unless it is known that moisture cycling will not be significant. Over time, shrinking and swelling of timber fibers around an epoxy-fiber interface will degrade connection capacity.

Pegged mortise and tenon connections, particularly if in a durable species, typically fare better in wet environments than ferrous connections. The dry pegs are squeezed by the seasoning shrinkage of surrounding wood at the connection. Vertical mortise lower ends, however, typically flat or inwardly sloped surfaces, become exposed and accessible when girts or plates shrink up toward their peghole centers. Water then drains or is blown into the lower end of the mortise, whence it cannot drain. Braces and struts drain a significant amount of water into their mortises, exposing the post and brace to decay. Sloping the bottom of brace mortises to be perpendicular to the brace axis, though in some cases more difficult to cut, allows the mortise to drain but does not diminish the capacity of the connection (Fig. 5).

For horizontal members, creating large-enough shoulders at the top and bottom of the tenon (how much is species dependent) reduces though does not eliminate the exposure of the mortise. A drying, shrinking post pulls away from the horizontal member exposing end grain and the mortise perimeter to bulk water intrusion. Sloping the bottom of the mortise is not recommended unless using a wedged through-tenon, in which case the sloped mortise bottom can drain. Open-air structures, more readily than enclosed structures, can be designed with orthogonal members meeting posts at different elevations, allowing opposing wedged through-tenons with caps on the exposed tenon ends. Dovetail and other blind tenons, particularly in green timber, will not fare well in wet conditions. After the timber shrinks, water drains into the gaps and soaks the end and side grain of both members.

Post bottoms The usual objective applies: to drain water down and away. And the tactics remain the same: keep the bottom of a post as far as practicable from exposure to snow, puddling and splash, and drain water off wood surfaces as quickly as possible. Set posts on pedestals significantly above rain splash and snow lines. Keep a post, like a rafter end, as far from the edge of the eaves as practicable. A post, unless pressure treated, should not sit on concrete. Setting the post on stainless, galvanized or otherwise properly coated steel minimizes the potential for degradation and decay.

At times, setting a post on a pedestal of a famously durable species (greenheart for example) or preservative-treated wood will work if the water that reaches the pedestal is also drained away quickly so that it and the post end can dry quickly. This arrangement should not be used in wet exposures unless little water is expected to strike the pedestal.

Keep the bearing surface at the bottom of a post smaller than the post section and slope the bearing surface when it makes engi-

neering sense. Mortise any steel bearing surface (such as a knife connection, with or without a bearing plate) into the post bottom to keep the surface from exposure. Leave sharp edges at the post bottom cut—do not chamfer the cut lest water crawl around to the end grain of the post—and gap the bottoms of doubled members so that water will drain between them.

A post connection to a foundation is subject to the same moisture hazards as all other connections. Design connectors in a single row with the grain and, when this is not possible, minimize the spread of the bolts. Because of their greater exposure, post bottoms cycle moisture more frequently and to a greater degree than other members in open structures. This can cause post bottoms to split if bolts unduly restrain their swelling or shrinking. Assume the timber will shrink and swell with varying humidity and UV exposure and ensure that any mortise or slot for steel is large enough to accommodate the resulting movement.

Primary defenses: caps and flashings Good design makes extensive use of caps and flashings, which can form a primary line of defense against water intrusion. They deflect water away from wood members, siding and wall and roof assemblies, and they have sharp edges that readily shed water. Caps embody the important if obvious principle that a sloping surface sheds water away and down.

When capping is deemed unacceptable, such as on flat or pitched rafters in a trellis or open pergola, the designer can specify 15-degree flat slopes or hip backings for top surfaces. Sloping surfaces offer a simple approach to extend wood longevity. The wall plates of open-air structures should be sloped as well to shed water and ideally include sloped birdsmouth seats (this fabrication challenge will be worth the effort). Convention dictates that top surfaces of all thresholds and sills be sloped 15 degrees to shed water away and down and that all window and door head casings be protected by projecting drip caps pitched at 15 degrees (and back-flashed). Builders should avoid nailing into the top surfaces of caps where dimples or dents lead to water intrusion.

For exposed posts, the designer should use caps to protect wood from direct water intrusion. Wood end grain should not be exposed to direct wetting. Water that soaks into end grain can accumulate and keep a timber wet for an extended period of time. The moisture cycling works to prematurely weather the wood and creates checks and cracks for decay. Top caps should be noticeably larger than the post section and fabricated with sharp vertical edges to allow water to separate cleanly and drip off without running back toward the post surfaces.

When using metal caps to protect the top surface of horizontal or vertical wood members, designers should consider the tendency of water to condense on the metal surface in contact with the wood. In temperate, wet climates, narrow pressure-treated spacers or furring can be added between the metal and the timber to admit air flow and reduce condensation leading to decay. Copper and lead caps and flashings, unlike aluminum, also discourage decay because of the toxicity of their leachate, though the latter may stain nearby wood.

Flashing of openings plays a critical role in limiting water intrusion into walls, roofs and foundations, and draining water down and away from building surface components such as windows and doors. Tracing how water flows defines how to layer flashing and how it should direct water. Proper flashing includes the layering of water-resistant membranes, each layer successively moving water farther away from the building and down. Building papers, the last line of defense before the wall and roof assemblies and typically up against the sheathing, should generally be draped over the all-important flashing which then directs water away from the building. The final layer of flashing should direct the water at a downward angle away from the building and include a sharp drip edge.

Flashing basics may be simply summarized, but are no simple matter. For wall and roof openings alone, ASTM International offers the excellent *Standard Practice for Installation of Exterior Windows, Doors and Skylights* (2007), an 89-page document with no fewer than 147 defined terms to guide a builder. Of course, there are any number of circumstances in building construction. (See the posted version of this article at tfguild.org/woodprotection.)

Poor flashing leads to many construction failures, some of which result in serious building damage and lead to structural collapse and injury. (Improperly flashed and maintained ledgers on an elevated deck represent one scenario where decay can lead to serious structural damage.) Flashing failures often seem obvious after the fact—"tucking your raincoat into your underwear"—yet they occur with surprising frequency (Easley 2010). The reader is encouraged to review at least the building construction guides included in the bibliography.

Secondary defenses: skilled construction Easley's admonitions to drain and dry once water intrudes past primary defenses such as flashings, or once vapor infiltrates, fall to construction practice. Given that moisture will get into wall and roof assemblies, the builder had best provide the means to drain it out of the assemblies and components or to allow enough air flow to dry the wood and the other building materials when wetted.

The best means for draining and drying wall and roof assemblies is the construction of screen assemblies to provide a second layer of moisture management. Historically, masonry walls are the best example of screen construction. The siding material of brick or stone is separated from the load-bearing components, whether wood frame or more masonry, creating an air gap. This gap not only provides a separate, internal drainage plane but also provides a capillary break and a drying channel.

Screen construction for wood wall assemblies has proved effective in improving building durability. Furring strips are often used to set siding off sheathing; for the gap to function, it need be only a minimum of $\frac{3}{8}$ in. Brick and stone gaps are usually an inch. Bulk liquid driven through or around the siding will drain down this plane and out the bottom of the gap, redirected down and away from the building by flashing installed at the bottom of the wall. The gap's relatively large size short-circuits capillary action. Additionally, if air is allowed to enter this cavity from below and to vent at the eaves height, the stack effect-induced air flow dries the materials.

The gap also reduces vapor diffusion. Recall that vapor pressure, vapor diffusion's driver, is the amount of the water or vapor in the air. In the case of a wall sheathed and sided in wood, solar radiation drives moisture absorbed by the siding behind it, significantly increasing vapor pressure. Vapor can diffuse into the sheathing layer and then into load-bearing components of the wall. But drier air flowing into and up through the gap flushes the vapor, reducing the vapor pressure and diffusion.

Roof screens function similarly, though they require a second layer of sheathing as a nailing surface for shingles, shakes or tiles. Herringbone or diagonal furring, or other batten systems with openings to the eaves, have been used instead of solid sheathing to create drainage planes under metal standing-seam roofing.

A critical component of any screen is the building paper installed over the wood sheathing. Historically, a tar paper or asphalted felt membrane functioned as a water barrier under siding or roofing to drain water that managed to get under the finish. Over the last 30 years, these papers have gone through several generations, with mixed results. Sold variously as air, moisture and vapor barriers and retarders, at times their use has proved problematic, ironically in part because of their effectiveness. Water, in liquid or vapor form, may flow into a wall or roof from inside or

outside. An effective barrier against these inflows, if breached in one spot, can limit outflow elsewhere. In such a circumstance, water accumulates and, if in sufficient amounts, leads to degradation and decay, often unseen.

If a vapor barrier on the inside surface of gypsum wallboard is installed imperfectly, airborne moisture flows into wall cavities around tears or breaches, condensing and creating potential for decay. Reversal of the expected vapor flows, such as during summer cooling, also traps water inside cavities on the backsides of barriers. Likewise, vapor barrier wraps installed on the exterior walls capture moisture driven through breaches or from interior moisture-laden air flows, and hold the water against the sheathing, promoting decay. Effective barriers to vapor flow do not allow the underlying components to dry.

Some manufacturers produce and sell vapor *retarders*, as opposed to vapor barriers, recognizing the need to allow vapor to pass albeit slowly. However, in cold climates and in some wall assemblies, there may not be enough solar gain to evaporate the moisture under the retarder or drive it through, particularly on elevations of buildings facing away from the sun. Standard building papers like No. 30 (formerly 30#) felt possess higher permeability, which actually increases the wetter they get, raising their drying potential above that of more-recent products. Used in two layers, the wrinkling of the paper after moisture cycling can actually create drainage planes on its own.

—MACK MAGEE
Mack Magee (m@ftet.com) is a principal at Fire Tower Engineered Timber in Providence, Rhode Island. This is the second of two articles. It appears in original, unedited form, with many additional illustrations, at www.tfguild.org/woodprotection.html.

Bibliography

- Aho, Arnold J. "Umbrellas, Storm-Flaps and Boots: Designing for Durability." In *Wood Protection 2006 Proceedings*. Madison, Wisc., 2007.
- ASTM International. *Standard E2112, Standard Practice for Installation of Exterior Windows, Doors and Skylights*. West Conshohocken, Pa., 2007.
- Billups, Bill. "Durability by Design: The Dos and Don'ts of Exterior Wood Detailing." WoodWorks Presentation, 2010.
- Burch, D. M. and C. A. Saunders. *A Computer Analysis of Wall Constructions in the Moisture Control Handbook*. Gaithersburg, Md., 1995.
- Clark, J. E., P. Symons, and P. I. Morris. "Resistance of Wood Sheathing to Decay." *Wood Protection 2006 Proceedings*. Madison, Wisc., 2007.
- Easley, Steve. "Moisture Control in Commercial Wood Buildings." WoodWorks Presentation, 2010.
- Graham, R. D. "History of Wood Preservation." In *Wood Deterioration and Its Prevention by Preservative Treatment*, Vol. 1, Darrel D. Nicholas, ed. Syracuse, N.Y., 1973.
- Lstiburek, J. *Water Management Guide*. Westford, Mass., 2006.
- Lstiburek, J. and J. Carmody. *Moisture Control Handbook: Principles and Practices for Residential and Small Commercial Buildings*. New York, 1994.
- Tsongas, George. "Water Movement in Wood-Frame Walls." *Wood Protection 2006 Proceedings*. Madison, Wisc., 2007.
- US Dept. of Energy. *Guide to Insulating Sheathing*. Washington, D.C., 2007.
- Walker, Les. *American Shelter*. Woodstock, N.Y., 1981.
- Wikipedia. "Vapor Barriers" and "Framing Construction." 2012.
- Wilcox, W. W. "Review of literature on the effects of early stages of decay on wood strength." *Wood and Fiber* 9(4): 252–257, 1978.
- Williams, R. Sam. "Finishing of Wood." In *Wood Handbook*, Ch. 16. Madison, Wisc., 2010.
- Wilson, P. Roy. *The Beautiful Old Houses of Québec*. Toronto, 1975.



Yes, It's Possible

Innovative Glulam and Timber Solutions

Timber Products

Green & Dry Timbers
Standard CSA & APA Glulams
APA GrainMatched™ Glulams
Pressure-Washed Logs

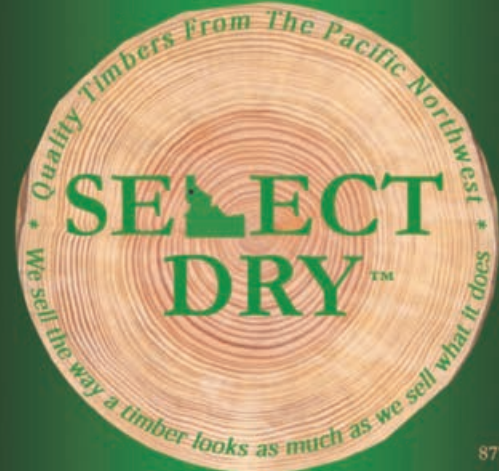
Timber Services

Drying
CNC Fabrication
3D Modeling
Steel Fabrication



Contact us today.
(401) 489-4567
www.fraserwoodindustries.com

Whiteman Lumber Co.
Est. 1928



877-682-4602

www.whitemanlumber.com

Foard Panels • Now Available 8 Foot Wide

when size matters



Foard
PANEL

Serving
Timber Framers
for 20 Years

Chesterfield, NH
foardpanel.com
800-644-8885

ELEVATING THE DESIGN & ENGINEERING OF TIMBER STRUCTURES



Weston Historical Society Museum by Maine
Post & Beam and Fletcher

Bringing a Modern Perspective
to an ancient craft, Fire Tower
specializes in timber structures
and related systems.

Ben Brungraber, Ph.D., P.E.

Mack Magee, M.S.

Duncan McElroy, P.E.

Joe Miller, Ph.D., P.E., P. Eng.

**Talk to us about your next
project, large or small.**



FIRE TOWER
ENGINEERED TIMBER

27 SIMS AVENUE, UNIT 2R
PROVIDENCE, RI 02909
401.654.4600 • WWW.FTET.COM



Port Orford cedar, Curry County, Oregon

*Trees selectively harvested.
Timbers sawn to your specifications.*

EAST FORK LUMBER CO., INC.
P.O. Box 275 • Myrtle Point, Oregon 97458
Tel. 541-572-5732 • Fax 541-572-2727 • eflc@uci.net

Techno PF CNC Joinery for Timberwork



If you can design it in wood,
Essetre PF can cut it!

Timbers to 16x32

essetre

timbertools.com • 1-800-350-8176

SwissPro KSP 16/20 Chain Mortiser

The state-of-the-art mortiser Germans wish they made



*Inch scales throughout
Reference scribe plate
Easy Glide
Mortises like a dream*

1-800-350-8176
timbertools.com

www.hullforest.com 800 353 3331

Pine, Spruce & Hardwood

Timbers precision milled
to your dimensions

Sawmill-direct pricing

Surfaced or rough-sawn

Also milling wide plank
flooring, paneling, siding
and custom stair parts



**HULL
FOREST
PRODUCTS**



SCS-COC-002641
©1996 Forest Stewardship Council A.C.

A family business for over 45 years

PREMIUM WEST COAST TIMBER

ANY SIZE ANY GRADE
ANY SPECIFICATION
S4S KILN DRYING
DELIVERED PRICES

DOUGLAS FIR
RED CEDAR
YELLOW CEDAR



**West Forest
Timber Inc.**

www.WestForestTimber.com

Alf and Pam Butterfield
9060 Clarkson Ave., Black Creek, BC,
V9J 1B3 Canada
Tel: 250-337-5357
Fax: 250-337-5358
Email: Pam@WestForestTimber.com

Making Energy Smart Building Decisions Easier Since 1982

Structural Insulated Panels For a Greener Tomorrow



Foam Laminates

of Vermont
A Division of Energy Smart Building Inc.

**COMING
SOON!**
8 by 24 ft
Panels

1 800 545 6290

mark@foamlaminates.com
www.foamlaminates.com



Timberline PANEL COMPANY, LLC.

8'x24' JUMBO SIPs!



Phone: 518 665-8128

Fax: 518 665-8129

Cambridge, NY & Bennington, VT

www.timberlinepanels.com

*Seeking tranquility?
Place your ad here and relax.*



mafell

ZH 320 Ec Carpenter's Beam Planer



BST Drilling station



ZSX Ec Carpenter's Saw

The widest range of specialized machines for timber framing

The only yardstick for professional woodworking is quality from start to finish. For decades this has been MAFELL's guiding principle, reflected in its comprehensive range of high-quality woodworking machines. Any craftsman geared to efficiency these days knows the importance of the right tools. For joiners and carpenters alike, there is only one choice - the experience and quality offered by MAFELL. The right choice for all professionals: the benefits of reliability, flexibility, precision and durability.

Please call us!
We can provide leaflets with detailed information and all technical data.

MAFELL North America Inc.
435 Lawrence Bell Dr., Suite 3 • Williamsville, N.Y. 14221
Phone (716) 626-9303 • FAX (716) 626-9304
E-mail: mafell@msn.com • www.mafell.com

www.mafell.com

Specializing in timber framing
and related topics

Summer Beam Books

2299 Route 488
Clifton Springs, NY 14432
877-272-1987 toll free
315-462-3444
www.summerbeambooks.com

Charlotte Cooper, Owner

David R. Hourdequin, PE
Timber Engineering and
Related Structural Design
Tel: 828-389-1717

Enjoy the gallery and
see license list at
www.dremy.com

Over 500 timber structures.
In practice since 1976.
Member TFG, TFEC, TFBC.



EVERGREEN SPECIALTIES LTD.

Supplier Timber & Lumber
Doug Fir, Red Cedar, Hemlock, Yellow Cedar

**FORTUNATELY,
WE'VE NEVER BEEN TOLERANT.**

This ensures you that every timber you order
is sawn to your precise specifications.

Our attention to detail is something that has
become second nature to us.

As natural, in fact, as the materials you use.

brucelindsay@shaw.ca

877 988 8574

Land ArkTM

Natural Wood Finish

You can now order ONLINE with

Land Ark Northwest

www.landarknw.com

☛ All natural penetrating oil finishes for easy use on all
types of woodwork and earthen floors.

☛ Fast, reliable service. Orders ship out in 1-2 business
days. And now you can use our safe, online ordering!

Call us at (541) 844-8748 for free samples!

Made in Corvallis, Oregon



Our job is to make your job look good

- Kiln Dry, RF-KD, Dead Standing, Re-claimed
- Environmental Forestry Certified
- FOHC, Surfaced, Rough, Hand-hewn, or Circle Sawn Tex



SPECIALTY BUILDING PRODUCTS

"Reliance: someone you can trust or rely on"

www.reliancesbp.com (800) 697-4705

Custom Timber Packages

Quick Quote Turn-Around • Short Lead Times
High Quality Timbers • Top-notch Personal Service

Our Signature Line:

FOREST SALVAGED STANDING DEAD

Sometimes Being Dead is a Good Thing

LARGE & LONG LENGTHS (UP TO 40' LONG) AVAILABLE

We will saw to any custom size, including Odd Inches (e.g. 9" x 13")

erin@clarksforktimber.com

866-898-1655

Timber Frame Quality:

GREEN EASTERN WHITE PINE

Simply the Best EWP on the Market

FULL SIZE S4S IS STANDARD

Ordinary or Odd - Give us a chance to Find what You are Looking for!

Clark's Fork Timber

www.clarksforktimber.com

PUBLISHED BY
THE TIMBER FRAMERS GUILD
PO BOX 295, ALSTEAD, NH 03602

