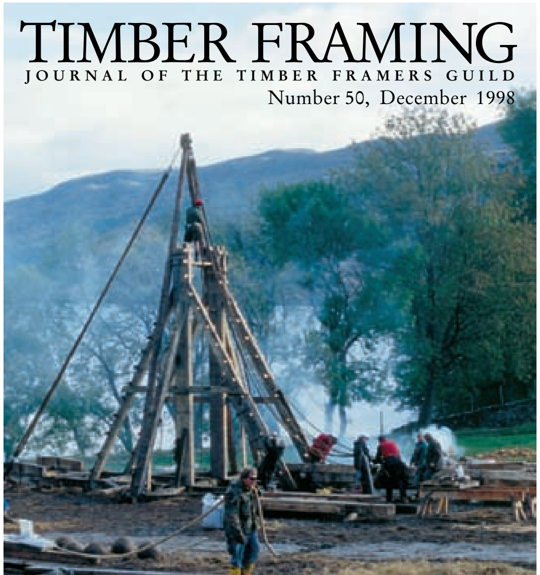
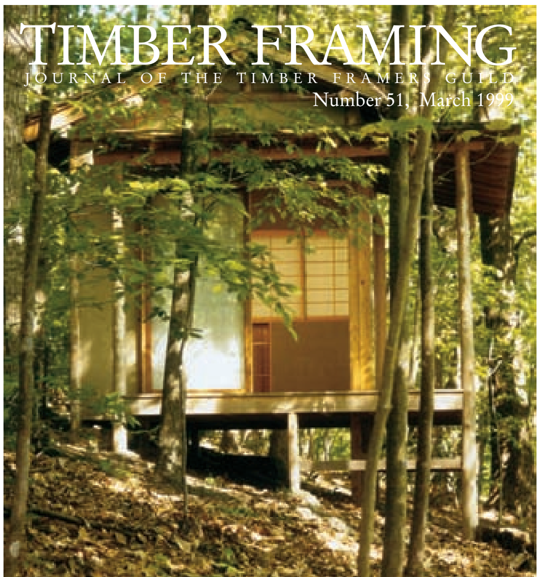
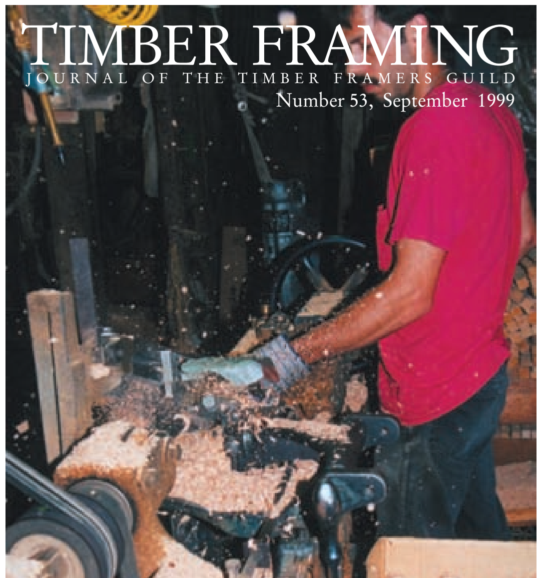
TIMBER FRAMING

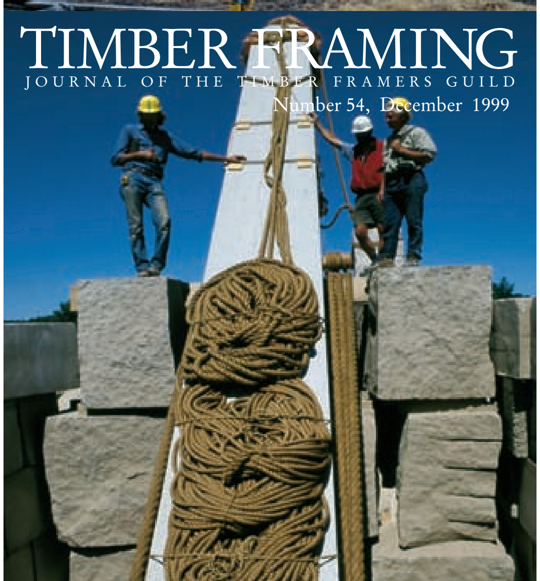
JOURNAL OF THE TIMBER FRAMERS GUILD

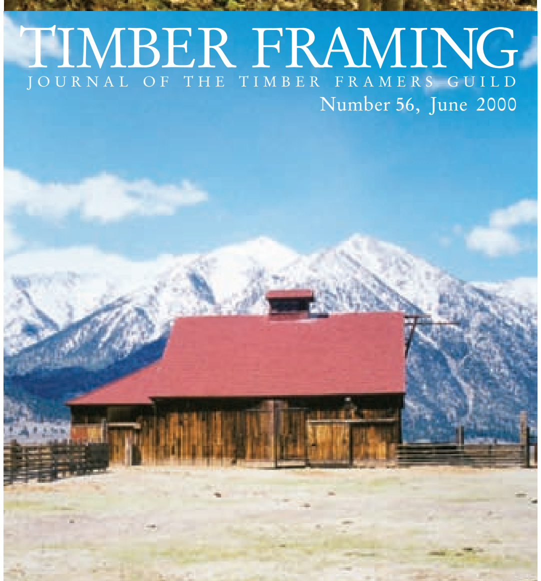
Number 100, June 2011

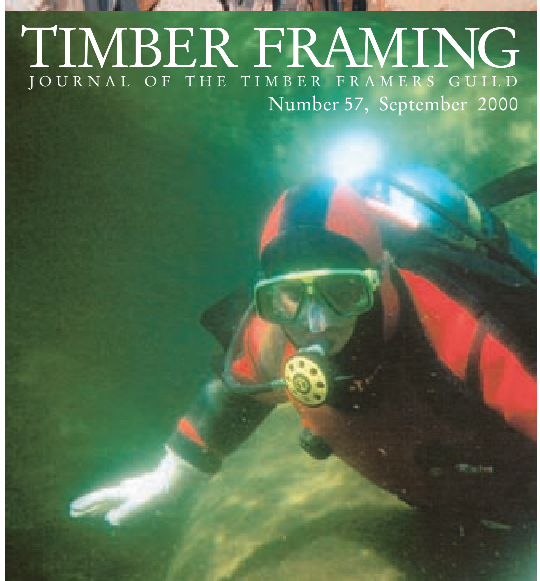


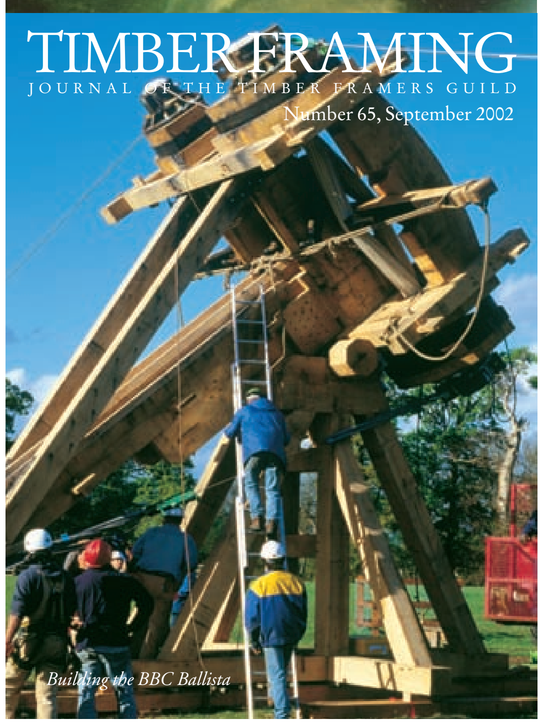












TIMBER FRAMING

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NUMBER 100 JUNE 2011

CONTENTS

On the covers of this issue, selected color covers from the archive, to celebrate reaching the milestone of 100 issues. The first issue appeared in October 1985, titled Timber Framers News. *In 1990 the title changed to* Timber Framing *(but without restarting the numbering). Color arrived in 1998.*

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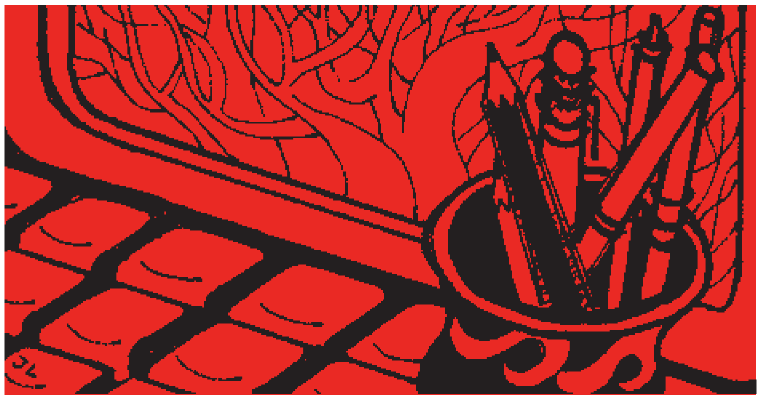
Printed on FSC Productolith, a 10 percent recycled paper. ♻

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



LETTERS

Bending Scarfed Beams

To the Editor:
Our friend Higgs Murphy did not miss any boat (Letters, TF 99). It's a good question ["Who would ever subject a scarf joint to such a bending load?"]. Scarf joints are not primarily intended to sustain bending loads, but as he mentions, they often are called to assist the structure in this way. A rolling rafter plate is in bending.

If we idealize a scarf joint as a pinned connection—a hinge which does not transfer moment—the deflected shape of the beam under load will not be smooth. A discontinuity occurs at the idealized scarf. In other words, the curvature of the timber would change abruptly at the joint when loaded. Practically, we would expect the scarf joint to open just as a hinge would. This is not what we want. We use undersquinting to keep the joint tight—an acknowledgment that we expect the scarf to transfer moment.

Our generalization of a beam as a gravity load–carrying member is a convenience. Nature has a way of confounding these simplifying idealizations. For good reasons, engineers are required to analyze a structure for unbalanced loads—loads that occur occasionally on only one side of the beam (or post) but not simultaneously on both sides. For example, when pallets of roofing are staged, they load some rafters and not others; or snowdrifts can collect on one side of a dormer; or floors can be loaded unevenly (let's say from hay). When the engineer performs the analysis, a continuous scarf-jointed beam over a post supporting such unbalanced loads will have considerable moment to transfer at the unloaded side quarter point.

For these reasons, among others, having a feel for the moment capacities of a variety of scarf joints aids us in making our design decisions. Education, useful learning, is indeed our purpose. We hope that folks learned what we did while having fun busting sample joints. Thank you for this opportunity to explain.

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Structural Insulated Panels, An Exchange

To the Editor:
Adrian Jones's article "Are SIPs Necessary?" (TF 99) offers one builder's perspective on the drawbacks of using structural insulated panels (SIPs) to enclose timber frame structures. Although Jones makes many good points, much of the data he provides is grossly inaccurate. In an effort to help timber framers accurately determine the best enclosure system for their projects, the SIP industry would

like to present the following data on the energy savings, labor savings and resource efficiency of SIP construction.

Energy Savings. Much of Jones's argument against SIPs is based on his own calculations that show energy savings of only 1.6 percent by using SIPs instead of 2x6 framing at 24 in. o.c. with open-cell spray foam insulation. Without seeing the exact calculations, it is impossible to determine how he arrived at that number, but other research conducted by the Department of Energy suggests Jones's claims are off by a factor of 10.

In the 1990s, the Department of Energy's Oak Ridge National Laboratory began developing the concept of whole-wall R-value by constructing and testing entire wall sections for thermal performance. When they tested 2x6 walls with studs 24 in. o.c., fiberglass insulation rated at R-19 actually performed at R-13.7. That is a 28 percent drop due to thermal bridging. Of all the 4-in. and 6-in. SIP wall assemblies tested, the maximum decrease was around 6 percent.[1]

Open-cell spray foam fared better than fiberglass insulation but still experienced an 18 percent drop in R-value in a 2x4 cavity with studs at 16 in. o.c. Oak Ridge has compiled this information into a free, online calculator that builders can use to make evidence-based decisions regarding wall system performance.

A second study by Building Science Corporation for the Department of Energy's Building America program examined the performance of 14 high-R-value wall assemblies.[2] Unlike the Oak Ridge data based on physical testing, this analysis was done using Therm 5.2, a software program developed by Lawrence Berkeley National Laboratory to examine heat transfer through building components.[3] Although Jones claims that thermal bridging "is not the demon that SIP manufacturers would have you believe," the report found that the assembly Jones is recommending (2x6 wall with studs at 24 in. o.c. and 0.5 pcf open-cell spray foam insulation) experienced a drop in R-value of 21 percent due to thermal bridging, arriving at a whole-wall R-value of 16.5. Their examination of a 4-in. SIP wall showed a drop of only 6 percent, consistent with the Oak Ridge findings.

Equally disturbing is the lack of discussion regarding air infiltration. It is not clear whether Jones omitted this information because he felt air infiltration is not a factor in determining energy savings or because he assumed that his wall system and the SIP wall system were equal in terms of air leakage. In either case he is incorrect.

Ongoing research by Building Science Corporation estimates that air leakage accounts for 30 to 50 percent of energy loss in a home[4]. For this reason, blower-door tests have become a crucial part of Energy Star, Passive House, and even the 2012 IECC.

Spray foam insulation can do an excellent job of air sealing if it is installed correctly. However, cavity wall assemblies have difficulty reaching the performance levels of continuous insulation systems like SIPs and insulated concrete forms (ICFs).

This was demonstrated by the Zero Energy Building Research Alliance, a residential building research coalition that includes the Tennessee Valley Authority, the Department of Energy and Oak Ridge National Laboratory. Working with a local builder, the alliance constructed two identical homes: same floor plan, same design, same windows. One home was constructed with 6-in. SIPs with an expanded polystyrene (EPS) core. The second home used 2x6 framing at 24 in. o.c., with the flash-and-batt method of applying ½ in. of spray foam for air sealing and R-19 fiberglass batts for insulation.

When a blower door test was conducted, the SIP home tested at 0.74 ACH50, 40 percent better than the flash-and-batt home.[5] The SIP home required 20 percent less energy to heat, despite having an R-35 SIP roof compared to R-50 roof insulation in the flash and batt home.

Structural testing of SIPs over timber frames by Rob Erikson and Dick Schmidt ("Sheathed Frame Behavior," TF 64) notes that SIPs add stiffness and lateral load resistance to timber frame structures, offering the potential to reduce cost by eliminating the required amount of knee braces and other structural members.

Similar lateral resistance testing for wood-frame walls attached to timber frames has yet to be done, so engineers are at a significant disadvantage when attempting to properly engineer such structures.

Time and labor savings. A 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.

In 2007, the chemical company BASF commissioned R. S. Means to conduct a time and motion study on the speed of SIP construction. R. S. Means is a division of Reed Construction Data, the leading supplier of construction cost information in North America. Engineers from R. S. Means observed the construction of a two-story, 2300-sq.-ft. home by an experienced SIP framing crew. Their results showed 55 percent labor savings over conventional framing.[6]

The study also found that the electrical subcontractor completed the rough wiring 11 percent faster on the SIP home than a conventionally framed home. In many cases, the SIP installer can reduce electrical costs by meeting with the electrician prior to installing the panels to make sure they understand how to wire SIP homes. Installers can also assist by ensuring the correct chases are marked and maintained between panels. With the proper planning, electrical work on a SIP home is less time consuming than a conventionally framed structure.

Waste. Factory waste is dealt with differently by each SIP manufacturer, but most manufacturers are making efforts to minimize the amount of waste generated and recycle as much as possible. It is in the manufacturer's best interest to maximize yield, and this is made possible by producing a variety of panel sizes and using design optimization to reduce fabrication waste. Large pieces of scrap are kept for use as dormer cheeks or small panels underneath windows on later projects.

With unusable EPS panel scraps, it has become standard practice for SIP manufacturers to separate the foam core from the oriented strand board (OSB). The foam is then ground up and either recycled into lower-grade EPS products or used as bulk fill insulation.

Manufacturers are exploring ways to deal with scrap OSB, including grinding it up for livestock bedding. Another option emerging is using ground SIP scraps as a component of lightweight growing medium for vegetated roofs. Some manufacturers offer their scraps to the public.

Saying that scrap lumber can be used as firewood ignores the immense environmental impact created by harvesting, processing and transporting that lumber to the jobsite. Two recent studies have examined the environmental impact of SIPs over the

[1] http://www.ornl.gov/sci/roofs+walls/AWT/Ref/TechHome.htm.
[2] Straube, John, and Jonathan Smegal. *Building America Special Research Project: High-R Walls Case Study Analysis.* March 2009. http://www.buildingscience.com/documents/reports/rr-0903-building-america-special-research-project-high-r-walls.
[3] http://windows.lbl.gov/software/therm/therm.html.
[4] http://www.buildingscience.com/documents/digests/bsd-014-air-flow-control-in-buildings.
[5] https://www.sipsonline.org/elements/uploads/files/fileManagerSIPSvsOVFChicago_rev.pdf.
[6] BASF Corporation Time & Motion Study. Reed Business Information, April 2007. See http://construction.basf.us/files/resources/RSMeansSIPSCostStudyReportJan2007.pdf.

product's life cycle, one conducted by BASF and a second life-cycle analysis on SIP walls conducted by Franklin Associates, a well-known life-cycle analysis consulting firm. Both studies show that SIPs have a net positive impact on the environment by preventing greenhouse gas emissions through reduced heating and cooling costs. And both studies show that SIPs outperform wood framing and fiberglass insulation when these environmental factors are considered.

Conclusion. The SIP industry recognizes that SIPs are by no means "necessary" or the only option when it comes to enclosing timber frame structures. In some situations, SIPs will not be the best option because of cost constraints, site accessibility, product availability or a number of other reasons. But an honest examination of enclosure systems needs to look at the research that has been conducted on SIPs and other enclosure systems so that conclusions can be drawn from verifiable data.

Contrary to Jones's belief that the nation's building scientists are still struggling to figure out Microsoft Excel, the examination into the most cost-effective methods of energy-efficient construction is more active than ever. There are a number of free tools and software programs available online from the Department of Energy that allow builders to conduct their own energy analysis. And millions of dollars worth of research on energy-efficient construction (such as the studies cited in this article) is part of the public domain and easily accessed online.

With these tools in hand, we encourage timber framers to work with a certified Home Energy Rating System (HERS) rater or energy consultant and find the right enclosure system for their clients and their business model.

Chris Schwind (cschwind@gmail.com)
for the Structural Insulated Panel Association (SIPA)
Frank Baker, PFB Corporation; Paul Malko, Foard Panel;
Al Cobb, PanelWrights; Terry Dieken, Extreme Panel
Technologies; Bill Wachtler, SIPA Executive Director

Adrian Jones replies: I'm glad the SIP industry has responded to my article. The conversation should help observers and readers to take a closer look at how they're enclosing buildings and begin to assimilate their local variables until they arrive at their best conclusion. The SIPA rebuttal may be summed up, I believe, in one sentence. "SIPs save energy and site labor and we can prove it with third-party studies." It does omit several components of the overall consideration, among them initial cost, durability and serviceability. We seem to agree that since local costs, subcontractors and clients all vary, only when all of them are considered can we make an educated decision about enclosure systems.

Now where's that spreadsheet where I can enter my variables and see how long it takes to pay back the additional cost of SIPs?

Some specifics of the SIPA rebuttal:

When they [the Department of Energy] tested 2x6 walls with studs 24 in. o.c., fiberglass insulation rated at R-19 actually performed at R-13.7. That is a 28 percent drop due to thermal bridging. Were the air-sealing properties of R-19 fiberglass batts considered in this experiment? They're quite poor.

When a blower door test was conducted, the SIP home tested at 0.74 ACH50, 40 percent better than the flash and batt home.The SIP required 20 percent less energy to heat, despite having an R-35 SIP roof compared to R-50 roof insulation in the flash-and-batt home. SIPA must stop saying "SIPS save energy" without including: "And it will pay back the installation premium in thus and such a timeframe, given thus and such factors." Living without a house at all is remarkably more energy efficient than using SIPs, as is living in a doghouse in a sleeping bag or in a cave heated by fire, with wolves. All ridiculous situations, of course, but the claim about energy savings without payback data approaches being equally ridiculous.

Similar lateral resistance testing for wood-frame walls attached to timber frames has yet to be done, so engineers are at a significant disadvantage when attempting to properly engineer such structures. There's significant data about the performance of sheathed framed walls and millions of them have been engineered in the last century. Their connection to the timber frame is irrelevant since the wall systems themselves are sufficient to resist lateral loads. How do the authors expect that conventionally framed houses resist lateral loads?

A 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. Assuming a $500,000 construction loan at 8 percent, the interest cost per week is $769. Is this enough to outweigh the additional costs of the installed system of SIPs? SIPA must include some math with the claims, to change this from a subjective argument to a scientific one. Even if SIPs could save two weeks in a project, the interest cost on the construction loan could be replaced in the budget by the cost of the boom truck required for SIP installation but not required for stick framing installations.

The study also found that the electrical subcontractor completed the rough wiring 11 percent faster on the SIP home than a conventionally framed home. What is 11 percent faster wiring rough-in worth, and how does it apply to payback scenarios? Oh yes, $109, according to the R. S. Means study cited. And now let me quote Section 3.5 of the same study:

> Cost Analysis. Erecting prefabricated structural insulated panels is much faster than building a comparable house using conventional framing. SIPs installation requires the use of a crane, which adds to construction costs and partially offsets the savings from reduced labor. In this example, the cost of erecting the SIPs house was $35,622, including the cost of the crane, while the conventionally framed house would cost an average of $21,197. Field erection demonstrated that using SIPs is faster, yet the total cost is approximately 68% greater.

The cost differences stated here are much higher even than the numbers my article suggested. If it costs 68 percent more, please explain to me how it's a good value for my customers. They're not stupid, and they will ask me to explain why my enclosure package costs so much more than alternatives. I need to be able to demonstrate a return on investment for it to have any value at all.

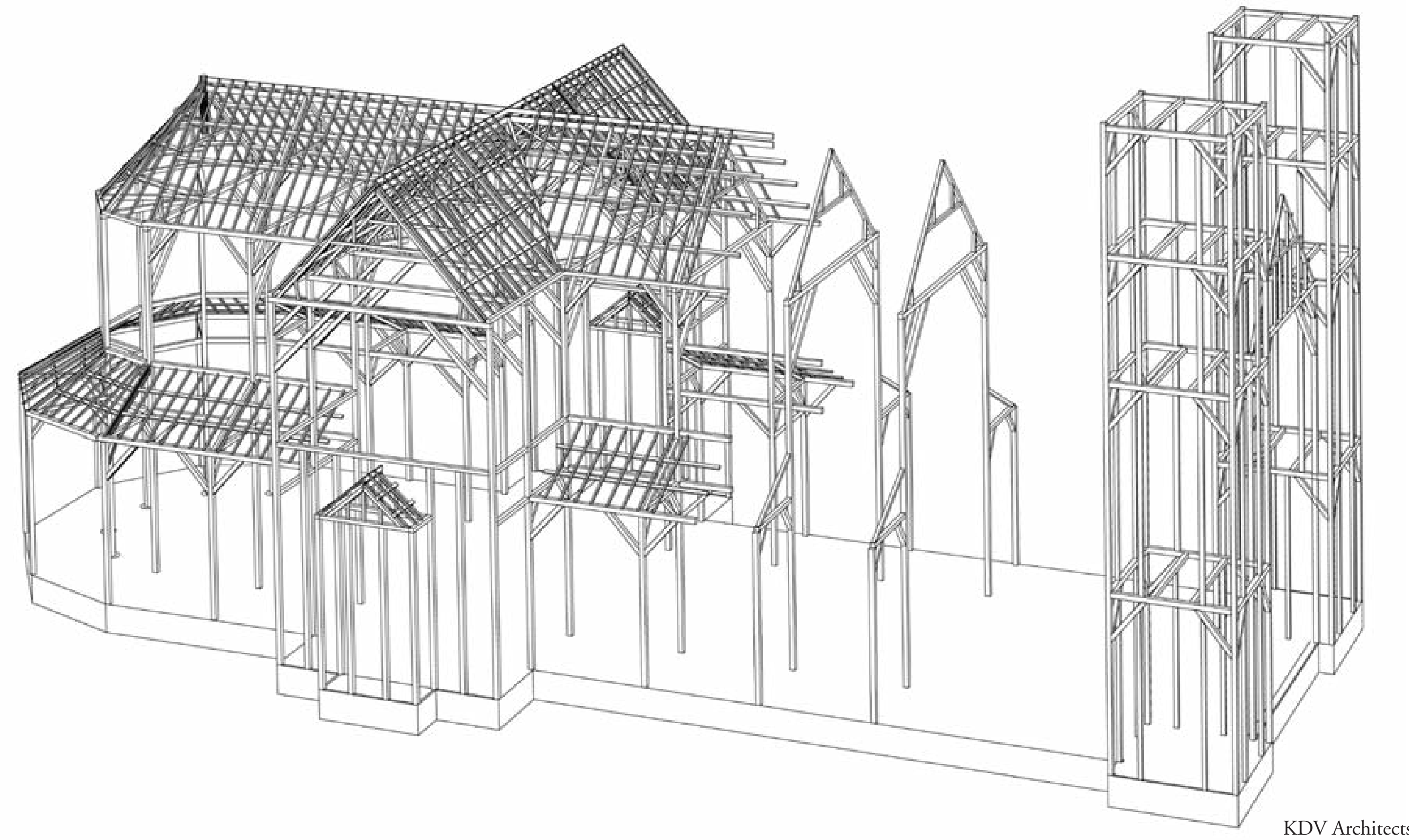
Contrary to Jones's belief that the nation's building scientists are still struggling to figure out Microsoft Excel, the examination into the most cost-effective methods of energy-efficient construction is more active than ever. So where's the examination that explicitly studies payback?

We encourage timber framers to work with a certified Home Energy Rating Systems (HERS) rater or energy consultant and find the right enclosure system for their clients and their business model. On this we agree. Study your local conditions, material and labor supplies, and figure out which enclosure system is best. The authors have done a good job of explaining why SIPA believes their products are superior but hasn't addressed the overall cost issue. Even if we accept all of the benefits at a particular local level, are they worth the cost of the system? The authors have made not one reference to cost. And do they care to address durability and serviceability?

Erratum

In TF 99, the Guild's 2010 Southeastern regional meeting was said to have been held in North Carolina. In fact, it was held in Mountain Rest, South Carolina, The editor regrets the error.

Restoring Saints Peter and Paul Cathedral in Paramaribo



KDV Architects

Fig. 1 Wood framing of Saints Peter and Paul Cathedral, 1885, Paramaribo, Suriname. The building is clad in wood inside and out.

THE all-wood Saints Peter and Paul Cathedral (Fig. 1), in Paramaribo, Suriname, was erected 1883–1885 around and over an existing church (Figs. 2–3), itself an old theater converted into a church in 1824. The cathedral is the largest wooden building in South America, some 213 ft. long, 82 ft. wide and with a tower frame height of nearly 79 ft. The full basilica is built in neo-Romanesque style on a cruciform plan, except for tower spires added in 1901 in neo-Gothic style. By the beginning of the 21st century, the building had suffered much deterioration of its decorated wooden surfaces and displayed serious structural deformation, which proved to result from the significant undersizing of original timbers as well as hidden decay and insect damage. A five-year restoration effort was completed in 2010.

The international architectural consulting firm A.R.S. Progetti in Rome was originally commissioned by the Republic of Suriname to design and oversee a complete restoration, which began in survey phase in 2005. In 2009, after about two years of structural work directed by A. R. S. Progetti, KDV Architects and Carel van Hest Architecten in Paramaribo took on management and supervision of the project. By that time, the towers were almost completely restored and work on the remaining components of the cathedral had, except for minor maintenance items, yet to begin.

We started with an intense inspection of the architectural state of the basilica. The cathedral at the beginning of structural work in 2007 was still completely covered on the inside with beautiful cedar cladding, such that the degradation of the main supporting

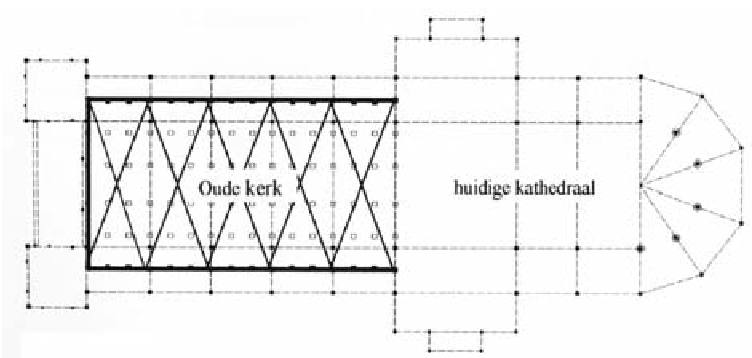


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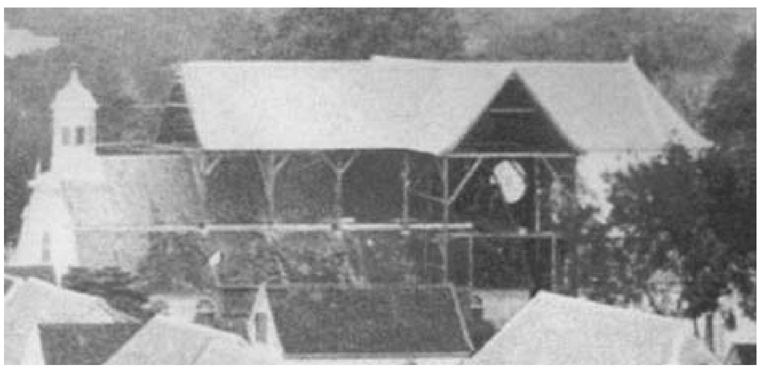
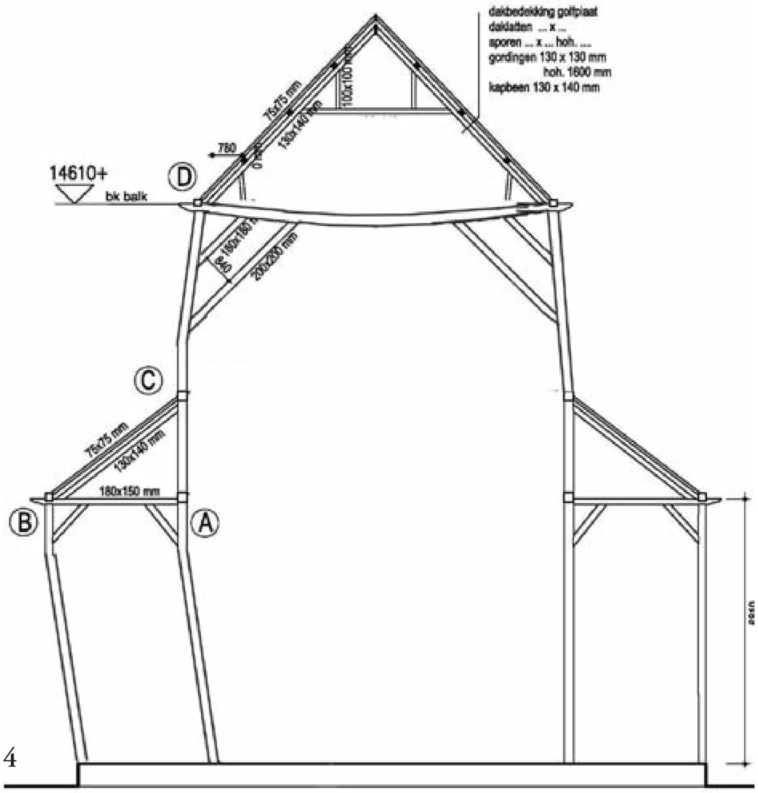
Fig. 2 Relationship of 1824 church to surrounding 1885 cathedral.



Royal Tropical Institute

Fig. 3 Cathedral construction photo, ca. 1884.



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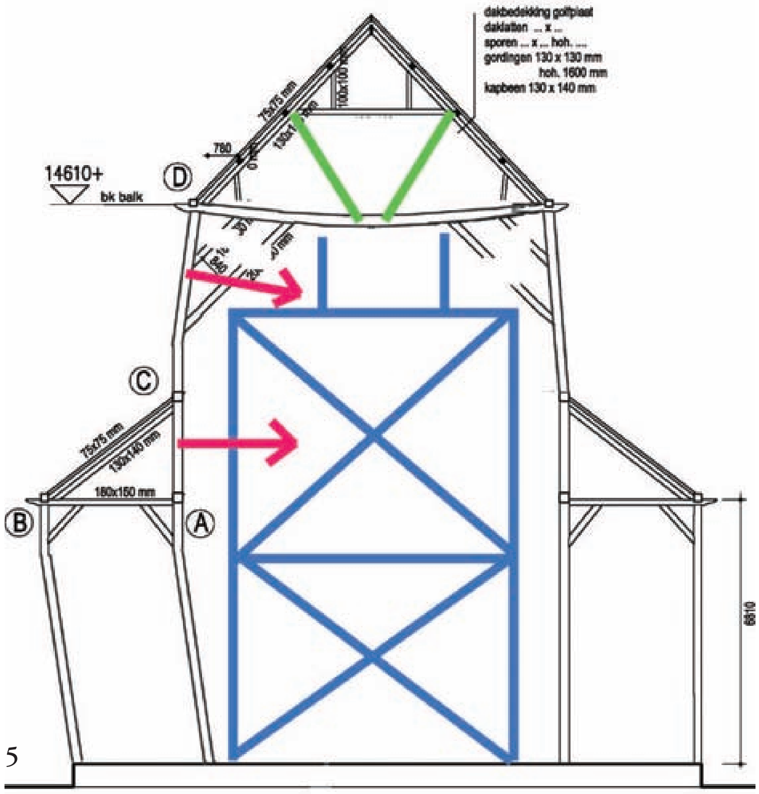

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structure remained hidden behind it. To make the damage fully visible, the covering on all the critical positions of the primary and vital connections was removed. Considerable original lining material was inevitably lost in the process, and a number of issues came to light, such as significantly more decay in the framing than had been estimated.

Our main problem was the instability of the cathedral. Designed by Brother Francis Joseph Leonard Harmes (1835–1894) with slim members, and actually built with somewhat slimmer ones, the cathedral's framing assemblies appear fragile if set against the scale of the building (Fig. 1).

The resources with which Harmes had to work likely had something to do with the problem, and his limited experience with large wooden structures may have played tricks on him. Harmes had much experience in setting up small churches and schools throughout the colony, for example in the Coronie district, but the cathedral was his first really big structure.

The result was a very beautiful building, but also one with structural problems. From the beginning there was very little margin of safety against deformation. Over time, deformation became increasingly visible, even unsafe, especially in the sharply bent west front (Figs. 4–5).

The wooden cathedral presents itself in all respects like a stone building: the architectural image, the organization of construction principles and all the details. One thinks of a comparison (if in reverse) with Greek temples, originally built in wood, but which over time petrified. It is natural that Saints Peter and Paul was built in wood, the readily available building material in Suriname, where there were plenty of craftsmen who, entirely in the tradition of the country, worked with no other material. The building looks familiar and obvious, related to the specific character of the place.

Restoration expertise in design and implementation prolongs the life cycle of a building. (Nothing is forever, everything man does or makes is temporary.) Prolongation, that is the task, nothing more, nothing less. But how does it work? The best restorations remain true to the properties and character of the original building. Authenticity, however, is related not only to the preservation of historical fabric, but also to the character, the architecture, the identity, the historical sensation, the experience, the wonder, the traditional production process of the object itself and its transformation over time. Thus, while preserving as much authentic material as possible, the preservation of the authenticity of the building as an architectural object is not guaranteed.

Beautiful, but in an extremely poor state of maintenance: restoration was necessary. And structural improvements had to be made—but how? A much-used approach in restoration is the method of so-called *honesty.* A historical construction is unable to deliver the necessary performance (or deliver it any longer), so elements must be added. Honest additions are intentionally of another architectural appearance and contrast with the historic environment. It is argued that disturbance from additional, so-called *fair* (structural) improvements does not affect the monument.

The choice of our new design team for making structural improvements in the cathedral was, however, to carry out invisible repairs. "Invisible" need not be taken literally; it can mean also adding something that is safely hidden.

Correction of the Tilt First, we made a careful measurement of the tilt to analyze the structural problem and to calculate the necessary correction forces. Some columns showed divergences of approximately 10 in. (Fig. 4).

Based on these data, the systematic correction of the cathedral began. A huge structural scaffold was erected in the cathedral, from which the columns were straightened frame by frame, two opposite columns at a time (Figs. 5–7).

Very carefully, of course, a few centimeters at a time. This straightening could only be done after the framing was slackened as much as possible to offer no resistance at the connections. To this end, the pegs from the relevant joints were driven out. This was permissible because the cathedral in that phase of work was entirely supported by the structural scaffolding.

Work began in November 2009, and in January the cathedral walls were reasonably straight. Not entirely straight, because that result appeared to be impossible, given the composite action of the main supporting structure and the double boarding on the aisle and upper nave walls.

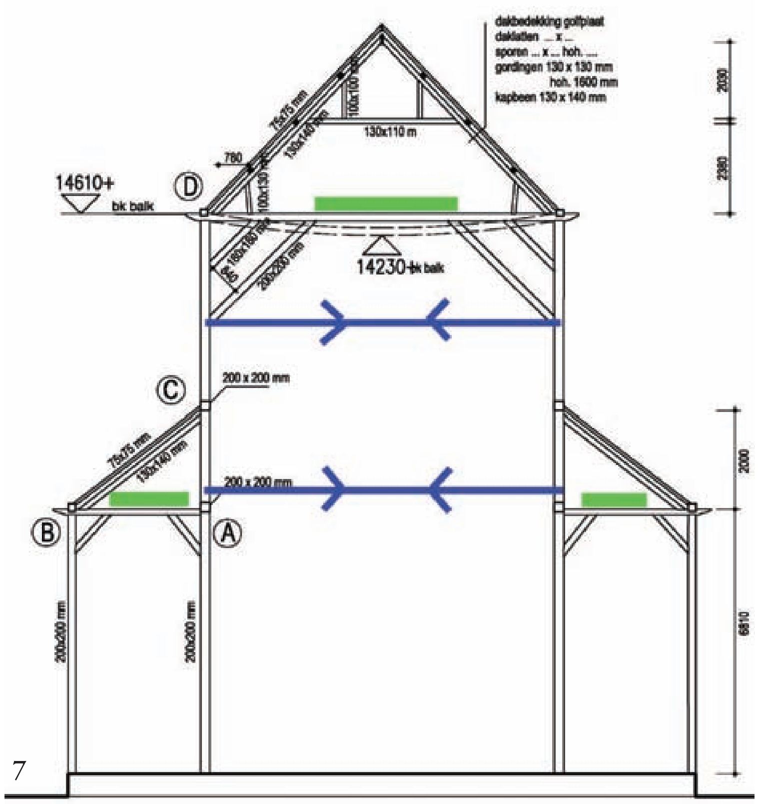


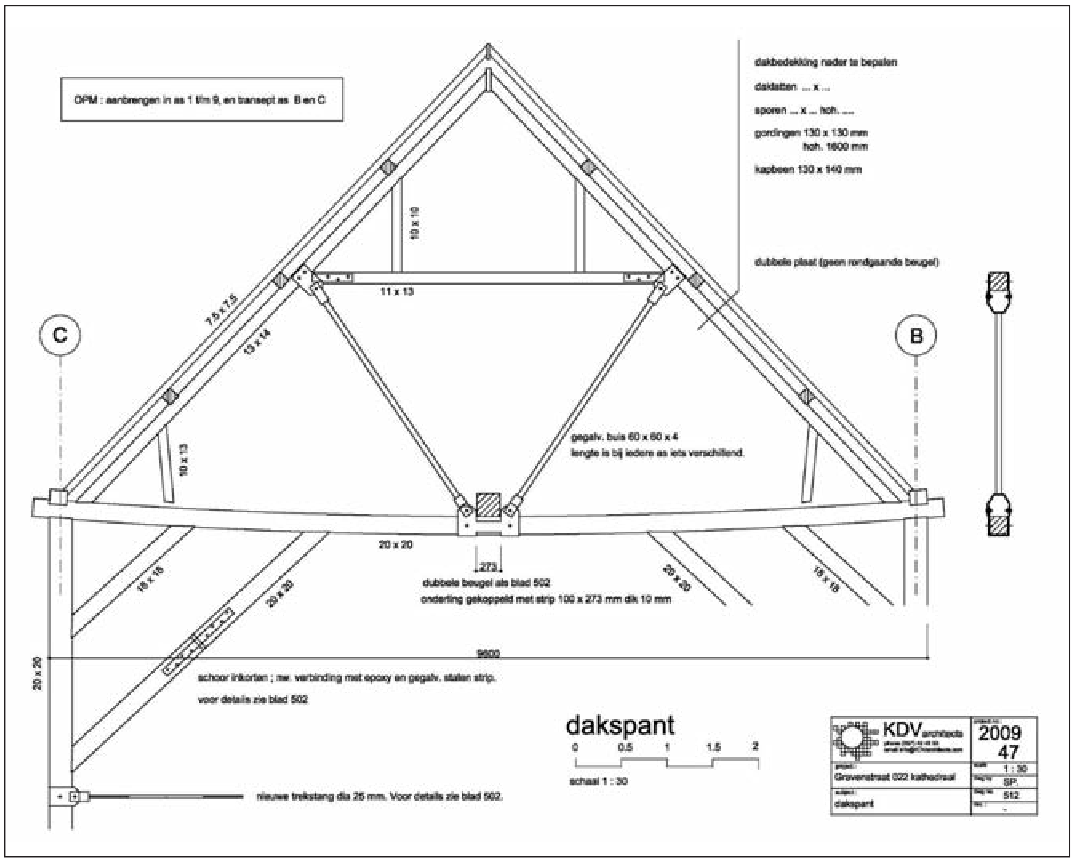
Fig. 4 Facing page at left, west front framing elevation showing perilous distortion resulting from inadequate engineering design, decay and insect damage. Tie beam in particular was overloaded by elaborate hung wooden ceiling.

Fig. 5 Facing page at right, scheme to straighten walls using copiously braced structural scaffolding. Braces were cut to allow straightening of walls without straightening tie beams. Green bars indicate tension members installed in roof framing to stabilize tie.

Fig. 6 Above, elaborate structural scaffolding erected inside nave of cathedral to anchor straightening devices.

Fig. 7 Above right, walls straightened with double array of tension rods (dark blue) installed across nave. Heavy green bars indicate concealed steel stiffening structures to be installed over nave and aisles. Tie beam is in fact not straight.

Fig. 8 At lower right, nave roof section showing tension rods to tie beam and shortened, fishplated long braces to walls.



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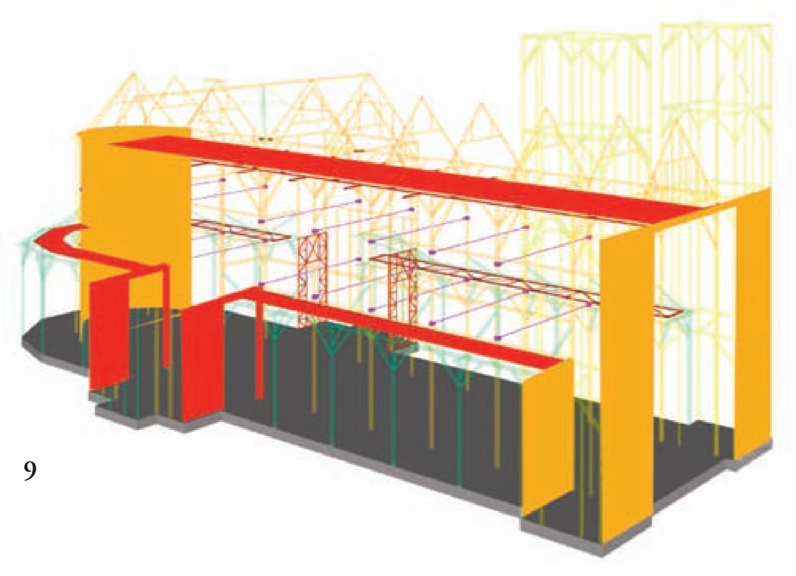
Deflection of Roof Timbers Two of the reasons for outward buckling of the columns in the upper part of the nave side walls (over 46 ft. high) were the deflection and especially the creep-deformation of the tie beams from which the cathedral's barrel vaults hang. The deflection of the tie beams and the consequent buckling of columns from descending brace thrust were surveyed in some areas at 8 in. The steadily progressive buckling of the columns (the second-order effect) was a threat to the safety of the structure and thus of the cathedral as a whole.

The A. R. S. plan and the agreement with the contractor had stipulated that the tie beams should be jacked simultaneously, followed by the application of steel tie cables. The new team questioned the viability and sustainability of the proposal and chose instead to cut and shorten the long braces (now fishplated) and truss the sagged tie beams, just as they were, to the rafters (Fig. 8), taking advantage of the strutted collar beam already in place. This relatively simple procedure had already been proposed by the engineer from the Netherlands, Wim Polman.



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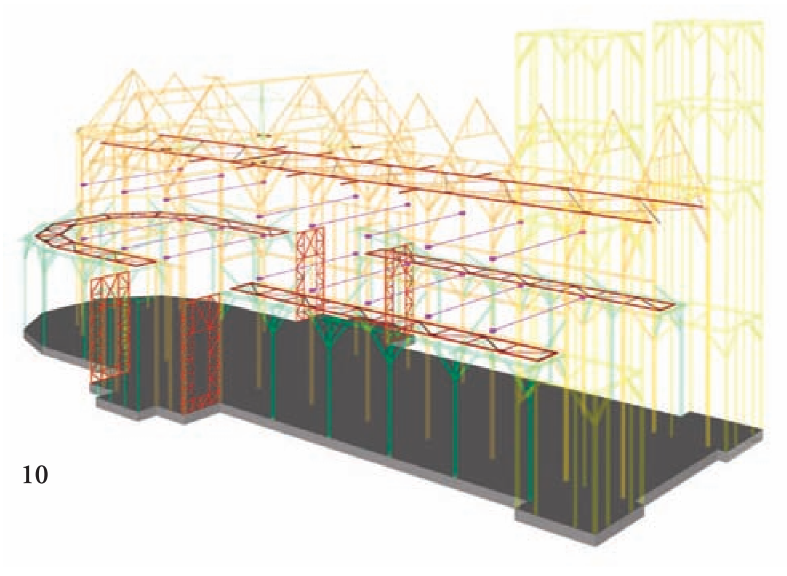

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Figs. 9–10 At top, schematic (at left) and line drawings showing newly made steel trusswork designed to transmit lateral loads.

Figs. 11–12 Above, fabricating new steel trusswork in the cathedral yard (at left) and lateral truss installed over the arcade of one aisle.

Keeping It Straight, the Stability Structures As for the stabilization of the repaired building, we adopted a practical proposal by Wim Polman, who made the first restoration plan in 1999. This plan became the basis for the stabilization structures, with some practical changes and additions.

As we had found, the original timber for the main columns was too slender. The columns could bear the vertical load—just—but gradually had deformed under minimum horizontal pressure. In the end, the horizontal deformations were 10 in. and growing. Also, there was no good provision in the original framing to transfer horizontal forces to the foundations. The latter design flaw could not be corrected by just replacing the columns, and in any case we wanted to maintain their same slender timber size. The only way to accomplish both of our purposes was to reduce the buckling length of the columns and at the same time add structures able to direct horizontal forces toward the foundations.

Measurements of the tilt had made clear where the strengths of the cathedral were. The two towers comprised, along with the front wall, a strong and rigid building component. The half-round apse at the rear was another stiff and rigid part. The rounded shape and closed façade planes provided resistance to deformation. The transept was—surprisingly—less stiff than expected and has over time undergone considerable deformation.

The cathedral is now stabilized by a system of four horizontal steel trusses connected to the strong and rigid components of the structure, the towers and the apse (yellow in Figs. 9–10). Horizontal forces on the sides of the cathedral are directed from the trusses to the foundation. The first horizontal truss is positioned above the nave vaults at 46 ft. high (upper level red in renderings). The next two horizontal trusses are at 23 ft. high on either side of the nave, above the aisle arcades (mid-level red). The last horizontal truss at this height forms a U-shape around the apse. Because the aisle trusses at the level of 23 ft. cannot cross the transept, they terminate over vertical trusses included inside the walls of the transept.

Thus wind loads are transported to the foundation, while the buckling length of the tall columns is reduced to one-third. The vertical trusses hidden inside the transept walls also provide additional support to the four main columns at the intersection of the nave and the transept, where historically there had been major problems.

The implementation of the steelwork involved significant measuring problems. Nothing in the cathedral is straight or level, so much work had to be adjusted to local conditions (Fig. 11).

All fabricated steel structures are reversible and out of sight above the ceilings of the cathedral (Fig. 12). Inside the cathedral, two horizontal arrays of steel rods are visible crossing the nave, linking the main wooden columns at the top of the arcade and again at the clerestory. Theoretically there are no longer tension forces across the nave because the roof rafters have now been trussed (Fig. 8), but the coupling is desirable for a better distribution of wind forces, especially suction.

KDV Architects

Maarten Fritz

KDV Architects

Maarten Fritz

Figs. 13–16 At left, working series of round lands in greenheart to fit template. At middle, power-planing waste to connect lands (traces of one land to be seen midway). At right top, original brace tenoned to bridled post. At right above, bolted steel shoe at butted brace joint.

Wood Damage The cathedral is indeed the house of God, but it also provides shelter and food for a large menagerie of different types of wood-eating termites. Taking advantage of decay, these creatures in the course of time affected the structure sufficiently that the cathedral deformed and began to tilt. Leaks for many years ensured that vital timber joints were constantly charged with water, resulting in rot and weakening of the wood. In principle, the high-quality greenheart of which the cathedral was built is very resistant to termites, which normally would break their teeth in the dense material (64 pcf). But because of the humid environment, wood in the affected areas became soft and was eaten. Only after stripping the column cladding did it become evident that enormous damage had been done in this manner. Even the cathedral's cedar cladding appeared to suffer from the termites, which was quite unexpected. Apparently the bitter protective substance in cedar disappears in the course of many years.

Wood Repairs The A.R.S. approach, to maintain as much authentic material as possible and to repair only rotted parts, and with epoxy resin, is a known method of conservation, but it did not prove unconditionally stable in Suriname. Some of the main wooden columns, with lengths of up to 49 ft., were affected in six places, sometimes for more than 70 percent of their cross-section; once patched they were again infested (after all, connections are good starter homes for insects). Partial repairs of such columns with epoxy resin were unable to guarantee the structural safety of the cathedral (how indeed would the strength of the repair be calculated?), especially since no control was possible on the complete filling of all cavities in the columns and the bonding between damaged wood and epoxy resin is uncertain anyway.

For our part, as a repair method we chose replacement with like materials. Eventually, five main columns were completely replaced and four columns partially. Only in a few cases, where a good member was partially damaged in only one place and verification was possible, did we decide to repair with epoxy. The new columns were made from Surinamese greenheart, the same as the original columns (Figs. 13–14). It was not possible for us to manufacture the 49-ft. columns from one piece. The trees for such huge members must be found far in advance in the forest, and sufficient time was not available. The columns were therefore prepared in three sections of about 16 ft. each and interconnected with bridled scarf joints. Moreover, we had found that the original columns of the cathedral also had been scarfed-joined from several lengths (Fig. 15).

During the original construction of the cathedral, the timber connections were made in the traditional way, with mortise and tenon joints. Once the interlocking puzzle of a proper timber frame is complete, it is not possible to replace a member without affecting at least one end. In the course of the repair work, we decided to make mechanical connections of steelat one end, some in the form of braced shoes (Fig. 16). These sturdy connectors are hidden behind the arches and boarding and have advantages over mortised joints: they do not weaken the receiving timber, nor do they collect water in case of leaks. In traditional joints, as we know, up to a third of the mortised timber section is locally absent, and precisely those most weakened areas appeared to succumb in the failed columns.

Maarten Fritz

Fig. 17 Restored interior of nave with mix of original and new cedar lining applied to groined vaults. First-level and second-level arcades include many replaced capitals. Upper and lower array of applied tie rods attach to wall posts. Apse partly seen at rear.

Figs. 18–21 Facing page, upper left, axial view of nave. Upper right, pairs of newly fabricated and carved capitals. Lower left, aisle roof with gutter before hanging of slates from lattice over waterproof membrane. Lower right, brightly colored front of freshly painted cathedral.

Restoration of the Interior Paneling and Carving Fairly extensive restoration of the interior woodwork was needed because the cedar was infested with insects or could not be saved while being removed to expose the main supporting structure. About one-third of the interior ceiling cladding has been replaced. The young wood was lighter in color than the old, which had been darkened by dust and sunlight. This difference is visible but not disturbing in the perception of the beautiful space; over the years the color difference will soften and disappear (Figs. 17–18).

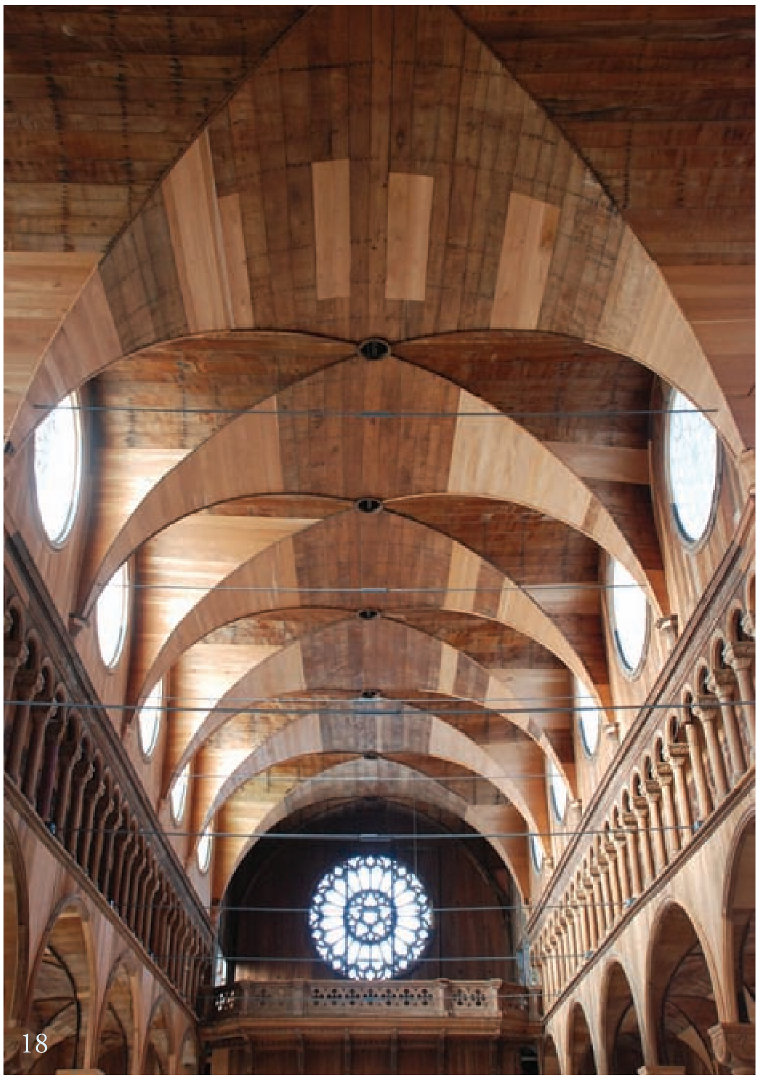
The cathedral's many hand-carved capitals and ceiling rosettes, designed by Father Arnold Borret (1848–1888), a former lawyer, judge and amateur watercolorist, were made with great care and attention, all works of art. The lower-level capitals have clearly been carved with more artistry than the higher ones. Unfortunately, many of them were badly affected by termites; it would have been irresponsible to retain the affected areas (including insects). After extensive research, we decided to replace heavily damaged specimens with hand-carved new work made by the Surinamese artist Jhungry Udenhout (Fig. 19).

The less-affected specimens were repaired with epoxy resin, painted over by an artist in wood color and dipped in a pesticide before remounting. Despite heavy damage to their carving, removed artifacts have not been destroyed. All such work is fully documented and marked to be stored in a safe place at the site, where other wooden parts are not contaminated.

Roofing The cathedral was re-roofed with slate on a lattice of battens as was done originally in 1884, all over a modern waterproof membrane. The repaired wooden frame combined with the steel stability trusses appeared well designed for the task. The slates hang by hooks from the battens. Should water ever penetrate the triple-coverage slate layer, because of wind lift or for another reason, it will be transported over the waterproof layer to the copper gutters (Fig. 20).

The largest historic wooden building in all of South America has been restored (Fig. 21). Thanks to the great efforts of the client, the foundation for the preservation of the cathedral (STIBEKA), together with the Ministry of Planning, and funding by the European Union, the cathedral is once again able to stand in full glory, a place where people come together, a place as it was meant to be, a wonderful place. —Philip Dikland and Carel van Hest with Maarten Fritz and Hein Brakel

Philip Dikland (KDV Architects, Paramaribo, info@kdvarchitects.com) and Carel van Hest (Carel van Hest Architecten, Paramaribo, carelvanhest@sr.net) worked closely on the cathedral restoration project with structural engineers Hein Brakel (Pieters Bouwtechniek, Haarlem, Netherlands) and Saimin Redjosentono (IBOCI, Paramaribo), supervisor Tine Pawirodikromo (KDV Architects) and restoration architect Maarten Fritz BNA (architectenbureau Fritz, Bussum, Netherlands). Parts of this article have appeared in different form in Dutch publications.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19

Maarten Fritz above, above right and below right; KDV Architects below


20


21

Island Beauty

Jen Porter

TURNER FARM barn, 40x60 ft., the work of Houses and Barns by John Libby, built 2009–2010 on Penobscot Bay's North Haven Island, 12 miles offshore and one of Maine's 14 unbridged islands with year-round populations. The farm, one of four on the island, yields produce, milk, meats and artisanal cheeses, supplies a local "farm-to-table" inn and restaurant and employs four hands in the winter and seven in the summer. Barn includes creamery (sometimes used for adult education in cheesemaking), farm stand, milking stall and goat pen. Functional cupola ventilates stored hay. HBJL built doors, railings and other ancillary woodwork at its Freeport workshop for installation in the turnkey job. Below, exterior goat pen communicates with sheltered space inside barn via dedicated rolling doors, providing plenty of scampering space for kids, here apparently about to discover principles of leverage. Photo descriptions supplied by Kate Taylor (kate@taylorwrite.com), a freelance writer living on the island.

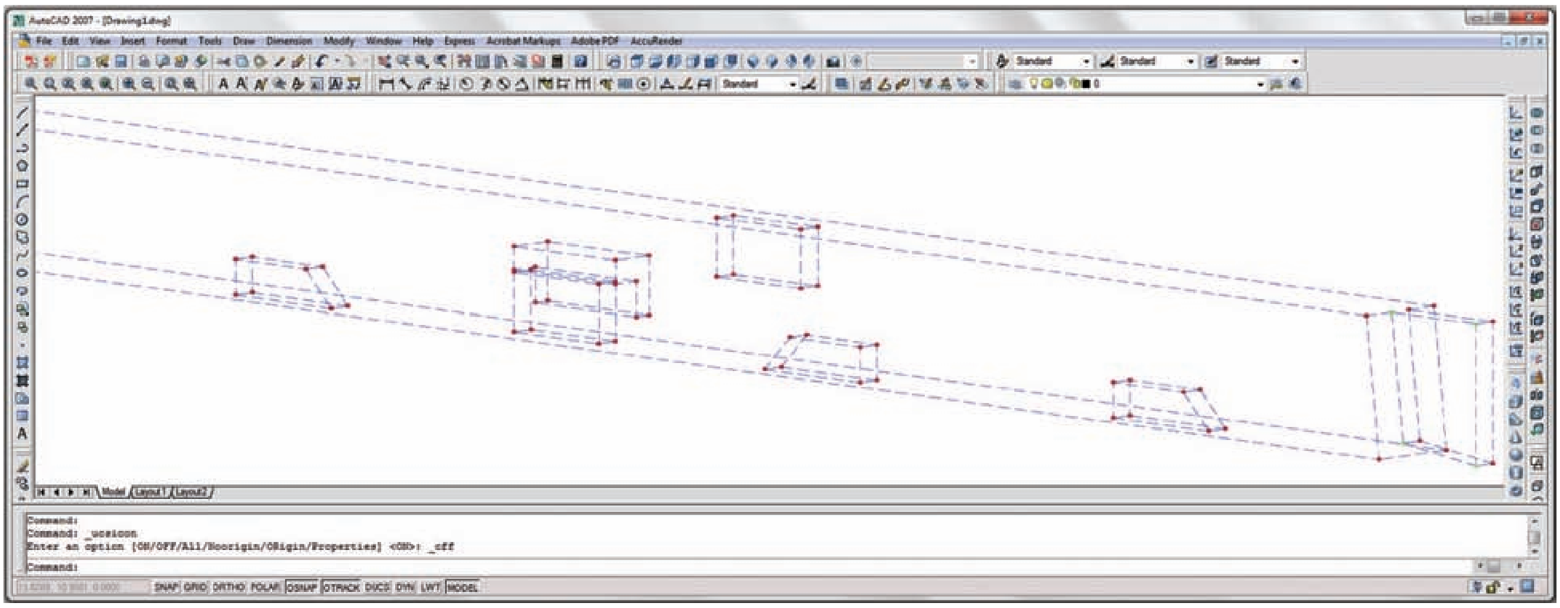
Kate Taylor

Kate Taylor

John Libby (this column and boom truck)

Clockwise from top left, boom truck and straight truck disembark ferry *Island Transporter* onto island of North Haven with Turner Farm white pine barn frame timbers. Top right, raising well under way with full bent (third of six) on the way up. Middle right, lead framer Peter Truslow drives spline peg in connecting girt. Above right, frame complete, with side aisle basement floored over and remaining aisles awaiting smoother winter seas for concrete truck to arrive. Above left, central aisle of completed barn, with pensive builder John Libby contemplating the indoor-outdoor goat pen. "There is nothing I don't like about building on islands," he says.

Why Are We Still Pushing Polygons?



All drawings Raul Aguilar

Fig. 1 AutoCAD drawing for a tie beam section showing the polygons that define some of its joinery.

IF you have ever created a timber frame 3D model with a corresponding set of shop drawings, you have undoubtedly come to the conclusion that doing so with any of the CAD software packages available today is a daunting task. Certainly it seems that there should be a more efficient way than to push polygons around manually (Fig. 1).

Why, you may have wondered, couldn't there be a simple method for defining the timber frame structure and a program that automatically generates the 3D models, shop drawings, schedules and quotes? Why, you may have asked yourself, couldn't I just press a button to enclose the frame automatically with foam-core panels (SIPs) and generate all the corresponding data for them?

After all, unlike the infinite number of things that a CAD software package allows you to draw, you are only interested in timber frame structures. So why couldn't there be a software package limited to drawing timber frame structures, able to do it automatically in a matter of minutes and without your having to push a single polygon? You are well aware that although your company takes great pride in offering to custom design each frame, the number of timber frame styles that you actually use tends to be fairly small. How hard could it be for someone to write a program that automatically created all the data you need for the frame styles that your company uses the most? You accept the fact that this program might not be able to draw everything and anything you want but you appreciate that it might draw a very significant percentage of what your company does—and in a fraction of the time you now spend on shop drawings.

Three-Quarters of a Loaf The Nissan Leaf all-electric car has a range of only about 100 miles, and everybody recognizes that a second car would likely be needed by most drivers or families for longer trips. But you might also appreciate the fact that driving the Nissan Leaf for all the short round-trips from home would greatly reduce your total fuel consumption when averaged in with that of the longer-range combustion-engine car. This is of course not as good as a 100 percent savings but, as far as you are concerned, it's a great start. You also realize that over time, as efficiencies in the battery are improved, the range of the Nissan Leaf can be expected to increase.

So what if you had a program that could create timber frame and SIP 3D models, shop drawings, schedules and quotes for 70 to 80 percent of your designs in a fraction of the time and without your having to push a single polygon? Would that be a valuable tool to have? Should you disregard the idea just because it cannot do all your designs?

How Hard Could It Be? When turning to timber framing from a different career, I was surprised to find that such a program had not been written before, and felt confident that there was no technical reason why such a program *couldn't* be written. The idea seemed fairly straightforward. One needed to find a way for the user to specify the details of the timber frame structure, have the program read that timber frame specification, compute all the coordinates and rotation angles, and perform all the Boolean operations needed for each of the members in the design. In other words, the program would need to do automatically all the things previously done manually. In theory, writing the program should be of similar complexity to documenting every detail (without a single exception) of the things you do manually. The only difference would be that rather than using English as the language of choice, you would need to use a computer language, preferably an object-oriented one.

What If? If one could write such a program, what would be the minimum acceptable set of capabilities that the program would need to support before it was considered useful? To build any size Cape, Colonial or gambrel-style structure and to support kingpost and hammer-beam roof trusses? What if the program were not limited to using a bent-connector system but could also build frames with continuous wall and purlin plates, or with tie beams sitting over the plates? What if each frame could be built as one, one and a half, two, or two and a half stories?

What if the user could specify any number of bays and add any size dormer, shed, or other frame to any of the bays? Add a porch to any or all sides of the frame? What if each frame could be designed with any height knee wall and any roof pitch? What if the floor system had the option of using four different members with two running perpendicular to the others?

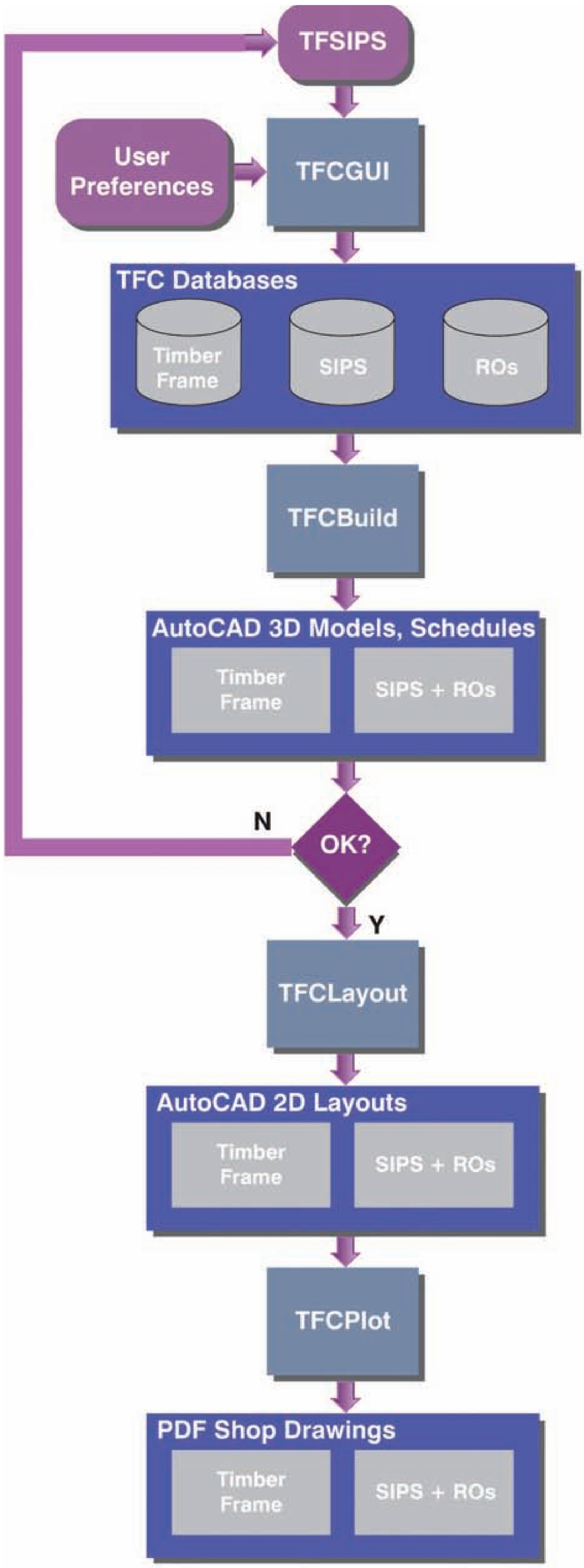


Fig. 2 Timber Frame Compiler (TFC) flow diagram.

As for the roof, what if it could be built using common purlins or common rafters and common rafters had the option of overhanging tails? What if every single mortise and tenon style and pertaining dimensions in the design could be easily specified?

What if the user were allowed to define a custom set of default preferences for every parameter in the design and each parameter were controlled via a set of hierarchical graphical forms? What if the user were allowed to have any number of default preferences?

What if the user could also specify the panel types to be used in the design together with maximum panel size, gypsum spacer, eaves overhang, gable overhang, spline size, header height, minimum header length, wall and roof screw spacing, etc.? Easily specify rough openings (RO) based on coordinates relative to the area where they belong? What if, for a typical design, the method allowed the user to specify the entire frame with panels and RO locations in less than 20 minutes and automatically generated the timber frame and panel 3D models, shop drawings, schedules and quotes?

And, finally, what if the effort required for adding new design capabilities were of the same magnitude as the effort required to produce the same data using existing methods?

Only One Way to Find Out For several years, I couldn't get all those what-if thoughts out of my mind. Every polygon that I pushed manually appeared to nurture only more what-ifs. Finally, one day after pushing one polygon too many, I decided to see if I could develop such a program for my own use. I considered all the what-ifs to be the minimum set of capabilities that should be supported. I named the program *Timber Frame Compiler* (TFC) and partitioned it into four distinct modules, explained below. Fig. 2 shows the flow diagram of the TFC program.

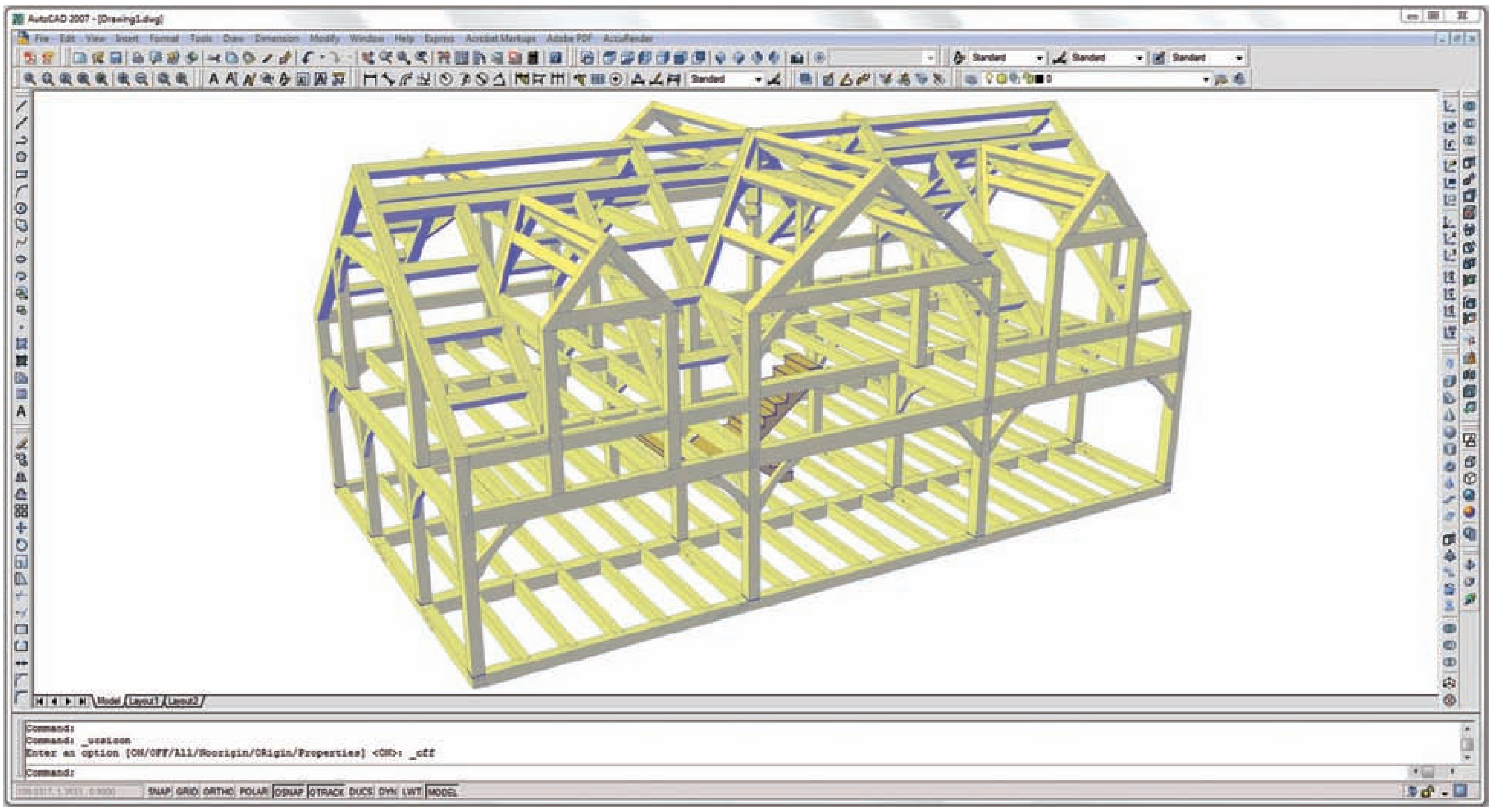
TFC Graphical User Interface (TFCGUI) The TFCGUI module allows the user to enter the specification values for a particular design. Although every parameter in the design has a default value stored in the User Preferences file, the user is allowed to change any of those values using a set of hierarchical graphical forms. Those unique values specified by the user are referred to as the Timber Frame and SIP Specification (TFSIPS). It takes about 20 minutes to specify all the parameters for a typical design using the TFCGUI module. The output of the TFCGUI module is a set of three databases: one for the timber frame, one for the panels and one for the rough openings.

TFC Build Module (TFCBuild) The TFCBuild module reads the three databases generated by the TFCGUI module and computes the final placement coordinates and rotation angles for every member in the design. The TFCBuild module also performs all the Boolean operations necessary to produce the specified joinery details as well as all the panel cuts. The only information the user must provide the TFCBuild module is the name of the project.

TFC Layout Module (TFCLayout) The TFCLayout module reads all the 3D models created by TFCBuild and generates all the corresponding layout views. The TFCLayout module also formats the Table of Contents as well as the timber and panel schedules. The only information the user must provide to the TFCLayout module is the name of the project.

TFC Plot Module (TFCPlot) The TFCPlot module reads the layout views created by TFCLayout and converts them to PDF format for uploading to a website or transmission to a printer.

Examples of Module Output Typical output follows, drawn from a moderately complex one-and-a-half-story frame with dormers



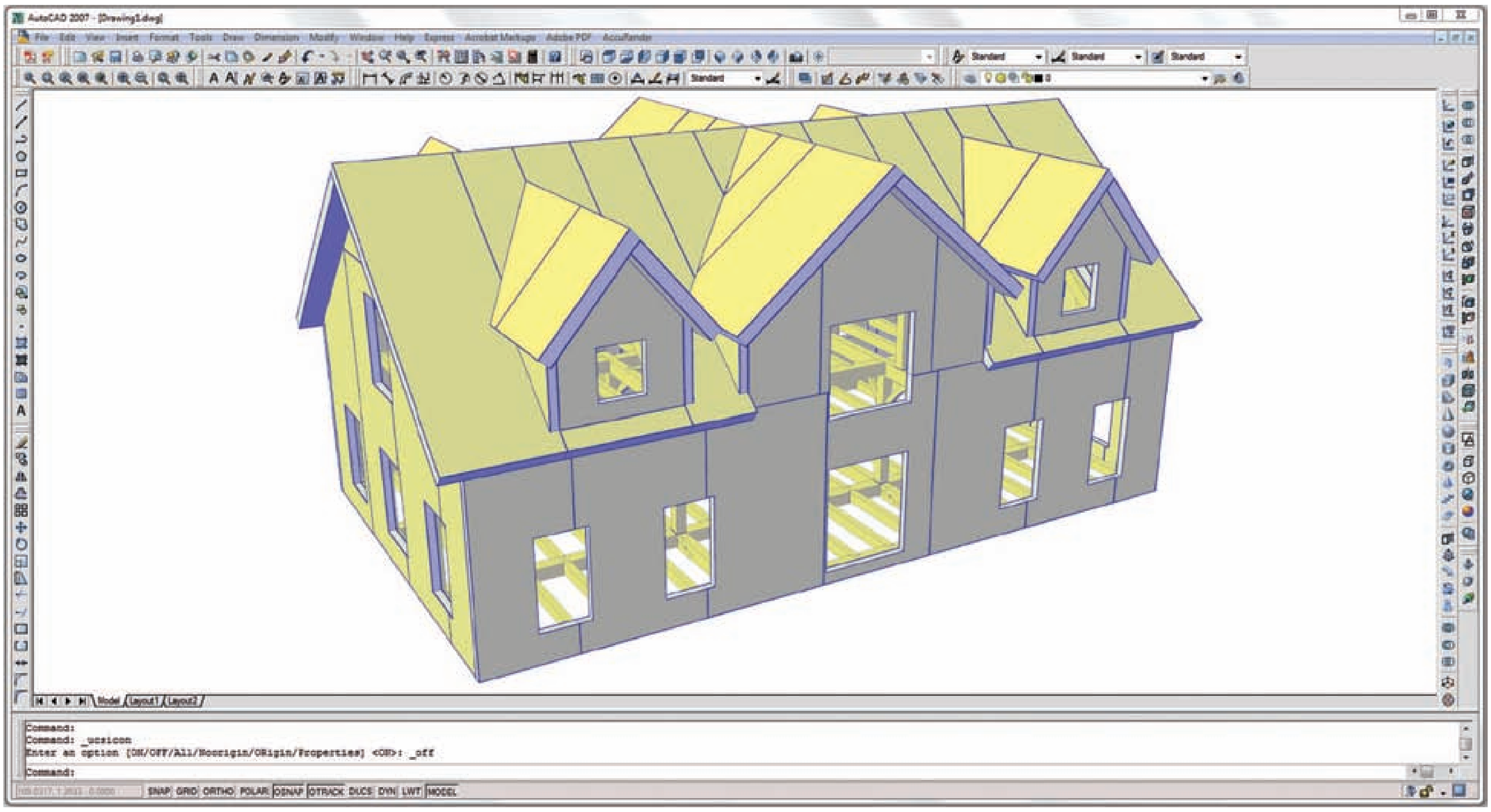
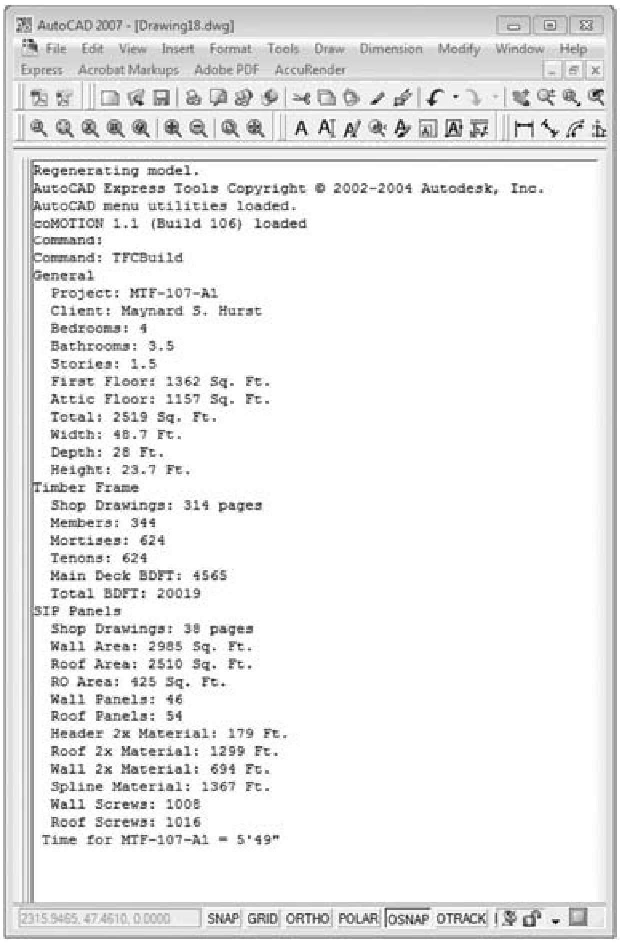


Fig. 3 At top, drawing of kneewall (or high-posted) Cape timber frame design with six dormers in two sizes, created by TFCBuild module. User also specified that center-bay dormer ridges and valleys should connect (along with main house ridges) to central boss pin.

Fig. 4 Above, drawing of matching panel enclosure with rough openings created by TFCBuild module.

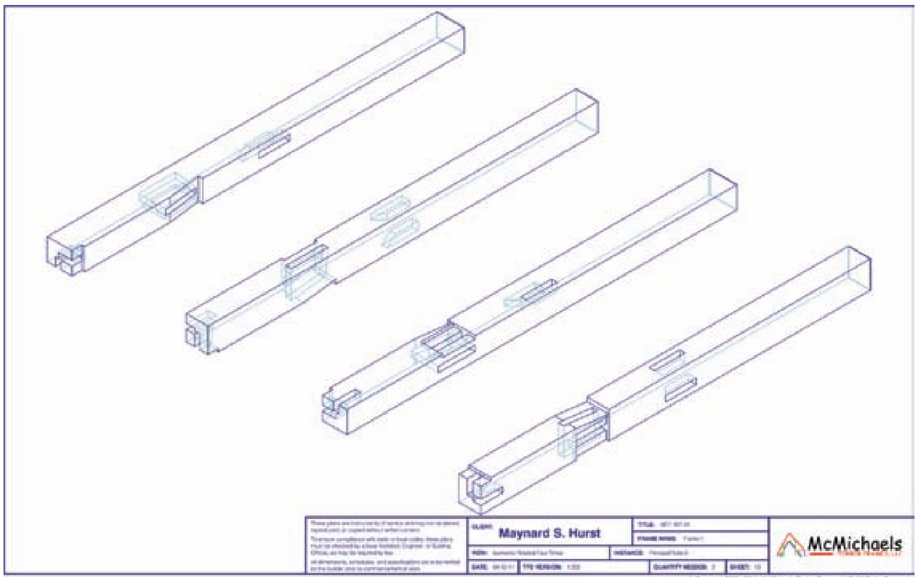
Fig. 5 Facing page upper left, report summary displayed upon completion of TFCBuild module. TFCBuild generated 3D models as well as all information needed to compute timber frame and panel quote in under six minutes and without user intervention.

Fig. 6 Facing page lower left, elapsed times for project shown in Figs. 3 and 4. TFCGUI module is sole module to require user intervention. Times reported for other modules are computer times and require virtually no intervention. While TFCBuild module often runs multiple times to achieve desired results, TFCLayout and TFCPlot modules typically run once.



ELAPSED TIMES

TFCGUI	
Timber Frame Entry	10 minutes
SIP Entry	5 sec
RO Entry	10 minutes
TFCBuild	5 minutes, 49 sec
TFCLayout	30 minutes, 20 sec
TFCPlot	20 minutes, 8 sec
Total User's Time	20 minutes, 5 sec
Total CPU Time	56 minutes, 52 sec



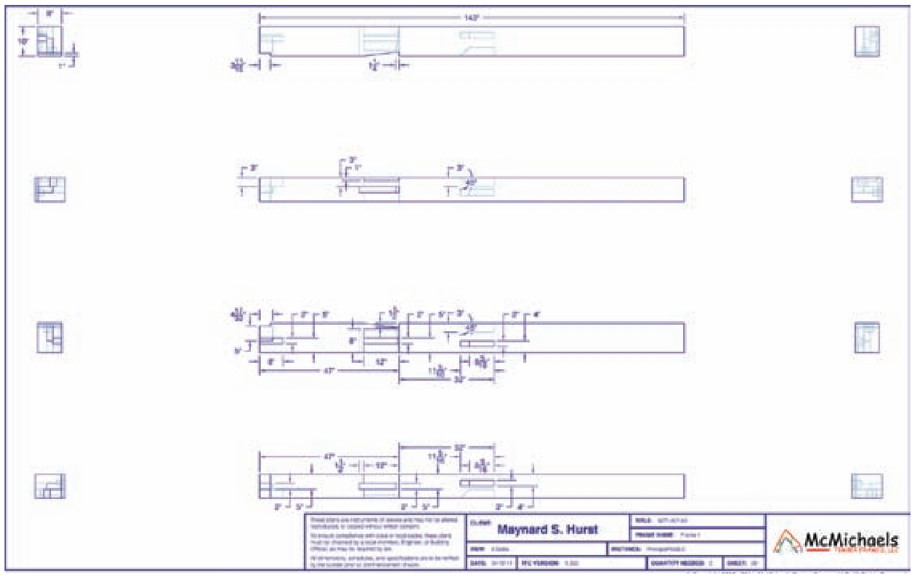


Fig. 7 At top, timber shop drawing isometric generated by TFCLayout module.

Fig. 8 Above, timber shop drawing plan view of each face with dimensions, generated by TFCLayout module.

(Figs. 3–5, 7 and 8). Notice that the TFCBuild module created a frame requiring 20,019 bd. ft., 344 timber members, 624 mortise and tenon pairs, 46 wall panels, 54 roof panels, 179 ft. of header material, 1299 ft. of 2x material on the roof, 694 ft. of 2x material on the walls, 1367 ft. of spline material, 1008 wall screws and 1016 roof screws—in under six minutes of processing unit time (Fig. 6).

Hard vs. Time-Consuming I clearly remember the day when I first asked my wife, How hard can it be? Well, that was several hundreds of thousands lines of code and six years ago, and since then I have learned to appreciate the difference between *hard* and *time-consuming.* I was certainly correct in thinking that it wouldn't be hard, but I am embarrassed to admit that the job took much longer than I originally anticipated. Twice as long would have been no surprise to me—after all, it seems that every project I embark on usually ends up taking twice as long as I expect—but this project definitely took even longer than that.

Not a Replacement for Existing CAD Software Just as an owner of a Nissan Leaf still needs a second car for longer trips, this design approach may still require its user to push polygons from time to time. An approach like this is meant to work in conjunction with existing CAD software, not as a replacement for it. While it might dramatically improve the productivity of the designs your company does the most, it may not work for all your designs.

The Dare I am not a computer scientist. My programming skills are probably about average for a typical engineer. (I was fortunate enough to work with real computer scientists in the past, which allows me to recognize the difference.) Even with my limited set of programming skills, however, I was still able to write this TFC program single-handedly and demonstrate its usefulness. I can only begin to imagine how much better the program would be if a group of expert CAD developers had done it. It's my hope that this article inspires CAD developers to add similar modules to their existing products. The productivity improvements to be achieved using this approach are simply too great to ignore. It's conceivable that the percentage of designs using this approach could increase asymptotically over time to a point where pushing polygons would be considered the exception rather than the rule.—Raul Aguilar

Raul Aguilar (raul@mcmichaelstimberframes.com) is an electrical engineer who spent over 20 years designing integrated circuits for AT&T, Sharp, Honeywell and other companies before founding McMichaels Timber Frames in the Pocono Mountains of eastern Pennsylvania.

Wood Decay and Protection

THE decay and protection of wood products are rich areas of study. Humans have been protecting and preserving the wood we convert from trees to use for art, shelter, transportation and tools since our prehistory. Biodeterioration agents and the processes they employ to return converted wood back to the environment are not the only threats to the longevity of wood. Fire, sunlight (ultraviolet radiation) and normal weathering (erosion) must also be addressed if wood in our built environment is to last.

We are accustomed to thinking of wood as a degradable—a biodegradable—material. We have celebrated this characteristic of wood and thus termed it a "natural" building material. Of course, for any biology this has to be the case lest the world be overrun.

A British civil engineer wrote in 1868: "Though sometimes, in ignorance, the perishable character of all surrounding things may be lamented, yet on the other hand, it must not be forgotten that perpetual destruction and perpetual renewal are in reality the essential causes of all life, beauty and harmony" (Clark 1868). We may translate this to mean that death and decay are life processes.

Wood degradation from sunlight and weathering may be inevitable, but its progress is often measured in centuries—about ¼ in. of thickness per century on average, according to the Forest Product Laboratory's *Wood Handbook*, a standard reference.

We are all aware of circumstances where wood has continuously performed its structural, protective or artistic function for centuries, in Japanese temples, stave churches and other ancient timber buildings throughout Europe, China and elsewhere. One attribute these structures share is protection from the organisms (or nonexposure to them) that use wood as their food source or shelter. On the other hand, we all have experienced the wood failures resulting from bioagents. One estimate is that 10 percent of all US domestic lumber production is purchased for replacement of rotted material alone, not including damage by more mobile agents (Lyon undated).

Marine borers have bedeviled navigators and harbor masters, particularly in warmer waters, for as long as both have existed. It has been proposed that throughout history more ships were lost to the ravages of borers than to poor seamanship (Hochman 1973).

By the early decades of the 19th century, the British had learned much about the nature but not the cause of decay (Wade 1815). They knew that moisture, oxygen and moderate temperatures promoted dry rot, and that the absence of those conditions and the addition of certain chemicals and salts—preservatives—retarded its growth. But it was not until the 1870s that fungi were recognized as the cause of decay rather than a result of decay.

Biodeterioration Agents There are four principal groups of biodeterioration agents that attack converted wood: marine borers, fungi, insects and bacteria. Bioagents attack wood for food and for shelter. Sustenance is by far the most significant and frequent reason. Wood and woody fibers are primarily cellulose, hemicellulose and lignin, which together make up 95 percent of the woody substance. The cellulose and hemicellulose, comprised of starches and sugars, offer significant energy stores for all of these organisms, and the lignin is used by some of them as a food source as well.

Besides a source of food, the other requirements for survival of the bioagents are moisture, oxygen, warmth and an acceptable environmental pH level. Without all these necessities the growth of the organisms will not occur or will cease.

Because these organisms cannot generally bring their own moisture, maintaining a low equilibrium moisture content (EMC) in the wood is the easiest way to forestall, arrest or end an infestation. Equilibrium moisture content is a function of the temperature and relative humidity of the air surrounding the wood, and is defined as that MC at which the wood is neither gaining nor losing moisture (Fig. 1).

To be susceptible to attack, wood must be at or above 20 percent EMC, and as high as 30 percent for sustained growth of decay, marine borers and bacteria. Drywood termites, as their name suggests, are not limited by this requirement.

Few natural environments in North America experience humidity and temperature regimes high enough to sustain colonies. Man-made environments, such as crawl spaces, may however provide conditions for such a high EMC.

Temperatures amenable to bioagent growth are the same as for any plant life. Growth virtually ceases at temperatures below 2°C (35°F) or above 38°C (100°F). For decay, growth slows outside of the range of 10°C and 35°C (50°F to 95°F), and for marine borers warm waters between the Tropics of Cancer and Capricorn are much more susceptible. Termites and other wood-eating insects exist only between the latitudes of 50 degrees north and 50 degrees south.

Oxygen, not controllable in any practical way, is readily available to these organisms, at times even under water, sustaining bacteria and marine borers. For decay and insects, submersion terminates growth because these organisms require airborne oxygen to survive.

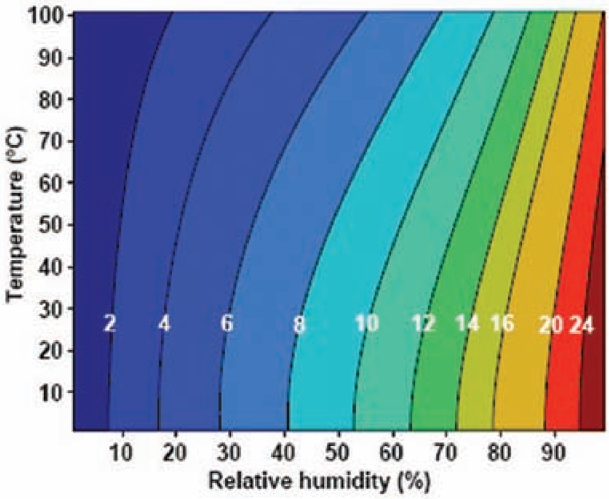
For pH, decay fungi prefer the more acidic environment that naturally occurs in wood. Thus high alkalinity, even a pH-neutral environment, curtails growth. For marine borers, control of the acidity is difficult. For insects, very high or low pH levels have negative effects on their ability to consume the wood.

Bacteria Bacteria are ubiquitous, one-celled organisms, some of which aid in putrefaction, and distinct from typically multicelled decay fungi (Fig. 2).

The soil teems with bacteria, so it's inevitable that they are found in wood. Despite their abundance, bacterial deterioration is not common in wood. Bacterial degradation, frequently accompanied by a sour smell, is most often associated with fully submerged logs (such as in log ponds), in below-water foundation and marine piles or in piles installed in highly moist soils. Very high moisture content, at least as high as the fiber saturation point (FSP), seems to be necessary for infestation. Progression in log ponds can be rapid, occurring over several months, but structural deterioration occurs only over prolonged exposure.

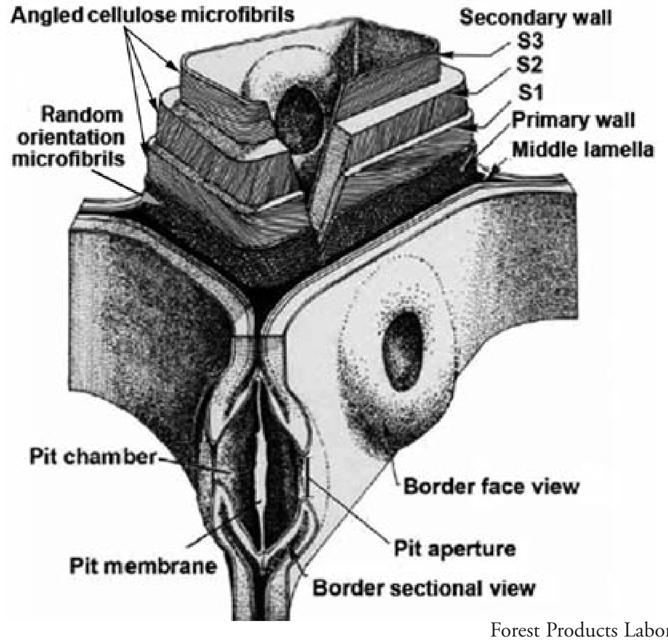
Bacteria feed primarily on the cellulosic starches in the sapwood, traveling from cell to cell by destroying the pit membranes—the thin carbohydrate semiporous remnant of the primary wall (Fig. 3.)

They progress radially inward from the outside surface of the wood or log via the ray cells and transverse resin canals. The destruction of the pit membranes, creating passages between the cells, is responsible for increased absorptivity of the affected wood, the principal effect of the bacterial degradation. The damaged wood absorbs stains, paints and sealers more readily, leading to uneven finishing, discoloration and wet spots. Generally, this is a cosmetic not a structural issue, but prolonged exposure, measured in decades, has been reported to lead to significant crushing strength losses in softwood foundation piles ranging as high as 20 to 60 percent (Scheffer 1973).



Forest Products Laboratory

Fig. 1 **Equilibrium moisture content as a function of relative humidity and temperature.**



Forest Products Laboratory

Fig. 3 **Wood cell wall cutaway. Layers begin with middle lamella. Primary wall shows random orientation of cellulose microfibrils. Secondary wall has three layers, each with specific microfibril angle. Bordered pit sectional view drawing overlaid on near corner of cell wall.**

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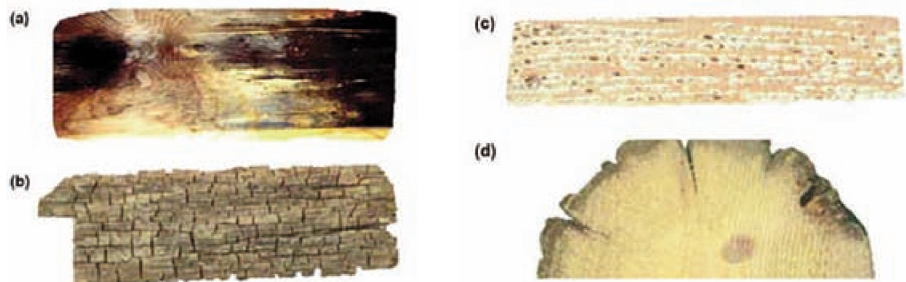
Fig. 2 **There are typically 40 million bacterial cells in a gram of soil and a million bacterial cells in a milliliter of fresh water.**



Forest Products Laboratory

Fig. 4 **Four types of wood rot: a) mold discoloration; b) brown rot (dark color and cubical checking); c) white rot (bleached appearance); d) soft rot (shallow depth).**

Cornell Fungi

Patrick Moffett

Bruce Lindsay

Figs. 5–7 **From left, brown rot in timber, white rot in house trim and sapstain in newly manufactured lumber.**

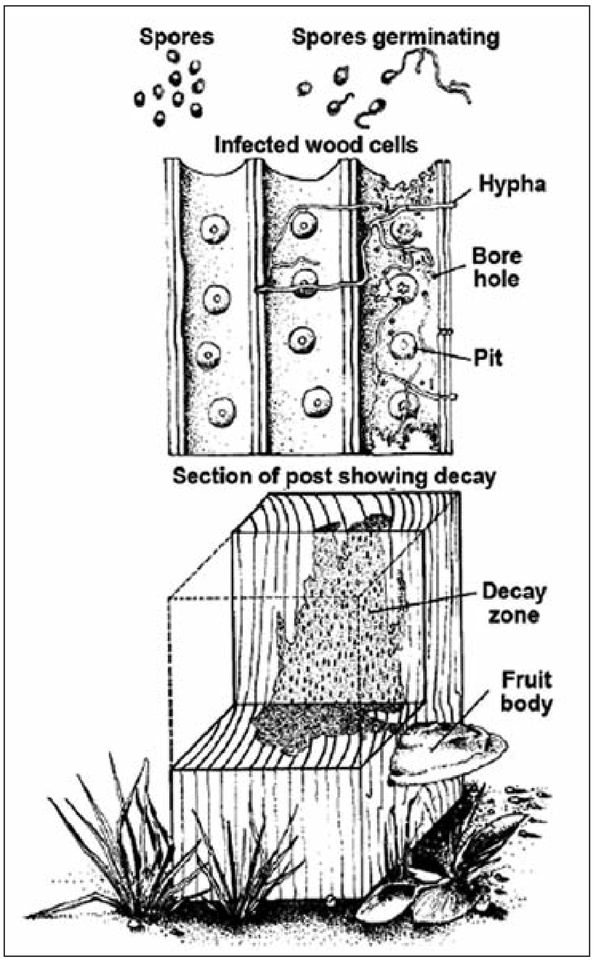
Fungi Dry rot, one of the two ancient scourges of wooden ships, is a common name for the damage caused by decay fungi. Fungi, including decay fungi, number over 60,000 species and, like bacteria, are microorganisms. It's convenient to classify the economically important fungi by the damage that they do (Fig. 4).

They include the decay fungi that cause brown and white rot as well as three other types of damage: soft rot, stain and mold. These five types of fungi (four types of damage) taxonomically belong to two phyla: Ascomycota and Basidiomycota. Their economic and wood-strength impacts differ greatly, but their needs and behavior have more similarities than differences. Together they account for more economic damage than all of the other bioagents combined.

Brown and white rot fungi (phylum Basidiomycota) are decay fungi that attack the cellulose and lignin of cell walls, consuming stored energy and eventually destroying the structure of the wood (Figs. 5 and 6).

Soft rot (phylum Ascomycota) works from the outside in, much as bacteria do, weakening or softening the surface of the wood, but does not typically extend very deeply beyond the surface (Fig. 4d). As the name indicates, staining fungi of the phylum Ascomycota mostly damage (the value of) wood by staining it, sometimes deeply (Fig. 7).

Mold fungi, also of phylum Ascomycota, act similarly to discolor the wood though they are mostly a surface phenomenon.



Forest Products Laboratory

Fig. 8 At left, the decay cycle (top to bottom). "Thousands of spores produced in a fungal fruiting body are distributed by wind or insects. On contacting moist, susceptible wood, spores germinate and fungal hyphae create new infections in the wood cells. In time, serious decay develops that may be accompanied by formation of new fruiting bodies" (Forest Products Laboratory 2010).

inspectapedia.com

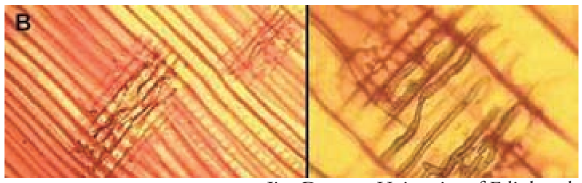
Fig. 9 Advanced *Meruliporia incrassata,* also known as poria.

123rf.com

Fig. 10 Furry mold growth. Color results from pigmented hyphae.

USDA Forest Service

Fig. 11 Sapstain can often begin in log, continues in timber or lumber.



Jim Deacon, University of Edinburgh

Figs. 12-13 Sapstain fungi seen in thin sections of wood stained with safranin. At left, section through two parts of the ray parenchyma traversing the xylem. At right, darkly pigmented fungal hyphae growing in the ray parenchyma.

Although the Basidiomycetes (brown and white rots) cause the most damage, the Ascomycetes (soft rot, stain, mold) often prepare the wood for the more damaging Basidiomycetes.

Fungi spread via spores, which are analogous to seeds. Spores are spread by wind, water, insects and contact, and millions can be produced by a single fruiting body (think mushroom). Once the spores find purchase on a moist wood surface, they divide and grow into *hyphae*, rootlike threads composed of haploid cells—cells with a single set of chromosomes. These hyphae branch and grow, "decaying" the wood as they do (Fig. 8).

Fungi have no chlorophyll, so they must obtain their energy requirements from plants that once did. To initiate the biochemical reaction, fungi secrete catalyzing enzymes that weaken and break the bonds of the crystalline cellulose in the cell walls and lignin polymers in and between the cell walls. The solubilized molecules released in this reaction can then diffuse back to the hyphae.

The biochemical process requires high moisture content. Water provides the solvent for the enzymes and causes swelling of the molecular polymers, stretching the bonds of the crystalline structure and allowing access for the larger enzyme molecules. Water conducts the enzymes away from the hyphae to break down the cellulose and lignin and conducts the catalyzed sugars back to the hyphae for consumption.

Wood is susceptible to these organisms only under specific conditions. Fungi prefer the same temperatures that green plants do and cease growing at temperatures outside this normal range. And, despite the misnomer "dry rot" (likely referring to the dry, cracked appearance of the wood after the brown rot decay has progressed significantly), decay and discoloration fungi of almost all species require high moisture content in the wood—around or above the fiber saturation point (usually 25 to 30 percent MC).

Under most circumstances, wood will not decay or discolor if it is kept air dry (generally considered to be 15 percent MC), and any decay or discoloration already present from prior infection will not progress. For decay to progress, wood must be exposed to water. Naturally occurring humidity, even at high levels, is generally not sufficient for these fungi to grow unless sustained by such surroundings as a damp crawl space. There is also an upper limit to suitable moisture content, usually at or above the saturation level for the wood species. Submerged wood will not decay from fungi as the oxygen necessary to sustain the decay fungi—which can be as little as 1 percent—is unavailable.

An important exception to this general rule is *Meruliporia incrassata* (the "house eating" brown rot fungus) found in the Gulf States, California and along the West Coast north to the Pacific Northwest. This fungus grows thick hyphal strands called rhizomorphs, which act like vines carrying water, typically from the ground, to the fungal infestation sites, thereby sustaining the fungus even when the surrounding wood is initially dry. If not arrested, this aggressive fungus can destroy large areas of wood construction in months (Fig. 9).

The two principal decay fungi are brown rot and white rot (Figs. 5 and 6). With some exceptions, brown rots prefer softwoods and white rots prefer hardwoods. Early in the infestation, decay fungi often penetrate the cells via the pits but move to boring holes through the cell walls very soon. Both types of rot create cavities parallel to the cell axis and the microfibrils, the bundles of crystalline cellulose that align longitudinally to give wood its distinctive grain structure and strength. Lignin is the "glue" that bonds these microfibrils together, allowing them to act in concert. Brown rot fungus processes and consumes the carbohydrates by dissolving the layers of the cell walls. The lignin portion, mostly in the middle lamella and primary wall of the cells, remains, giving brown rot its name.

As the cell walls are progressively consumed, the weak lignin lattice fails and the cell structure collapses, causing the wood to shrink and crumble. Brown rot also shortens the length of the cellulosic polymers, even in the early stages of the infestation, which is manifest in the distinctive cross-grain cracking and dramatically degrades the strength of the wood.

Natuurhistorisch Museum Rotterdam

Figs 14–17 Marine borers, here all *Teredo navalis.* Above, indication of individual creature's length and appearance. At right, white boring shells at head. At far right, a dense infestation. Drawing above right shows siphons that remain at entry end of borehole to pump seawater and clear the hole of debris.

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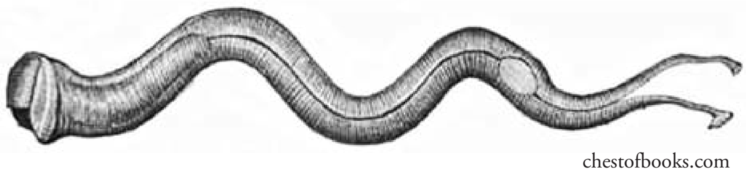

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US Geological Survey

Filip Nuyttens, US Geological Survey

White rot fungus, besides consuming the cellulose, also breaks down and consumes the lignin. By removing most of the color constituents (pigments) of the wood including the lignin, white rot leaves the wood with a bleached appearance. In a white rot infestation, the fungus dissolves and consumes the cell walls starting at the lumen (cell void) surface, thinning the cell wall layer by layer to the middle lamella. This gradual thinning leaves the wood shape and structure largely unaffected until the late stages of decay. Highly degraded wood is spongy to the touch, because the internal structure is far more open and less dense. The deceptively sound appearance of earlier stages can have significant structural implications.

Soft Rot Fungi A third, generally less important, kind of decay is soft rot. Soft rot fungi belong to the Ascomycota phylum and are related to stain and mold fungi rather than to decay fungi. Their hyphae move through the lumen and the rays, attacking the S2 cell wall layer (see Fig. 3) and creating diamond-shaped, spiraling cavities. Like bacteria infestations, they primarily travel from cell to cell through the pits, living on the stored carbohydrates. Soft rot effects are also similar to bacteria infestation effects, typically affecting the outer surface of wood and resulting in relatively shallow damage. The affected wood is significantly degraded and soft when wet; however, immediately beneath the zone of rot, the wood may be firm (Fig. 4d).

Because soft rot usually is rather shallow, it is most damaging to relatively thin pieces of wood, such as slats in cooling towers. It is favored by wet situations but is also prevalent on surfaces that have been alternately wet and dry over a substantial period of time. Heavily fissured surfaces, familiar to many as weathered wood, generally have been quite degraded by soft rot fungi.

Mold and Stain Fungi Like soft rot fungi, these fungi attack mostly sapwood. Though stain fungi may be better known for attacking softwood, stain and mold fungi attack both hardwood and softwood. Both discolor the wood; sap or blue stain (which manifests in a variety of colors, not just blue, in specks or streaks as well as uniformly over the entire sap band) can go deep into the wood and cannot be surfaced off, while molds are mostly surface fungi, often with a furry growth that can be brushed off and surfaced clean (Fig. 10).

The discoloration is caused by pigment within the hyphae, so various species of fungus color the wood differently. The hyphae have been reported to pass through the cells mechanically rather than chemically, pushing through the pits and the ray parenchyma cells, rather than through boreholes as the decay fungi do (see Fig. 3). This is likely because these stain fungi consume stored carbohydrates in the sapwood rather than the wood itself, except in long-term exposures when they act more like soft rot fungi. As most producers and users of wood know, stain fungi infest sapwood rapidly when the circumstances are favorable—freshly cut logs in humid conditions. As long as the wood remains wet, stain and mold fungi can infest it at any time in the manufacturing, storage, transportation or construction process (Figs. 7 and 11–13).

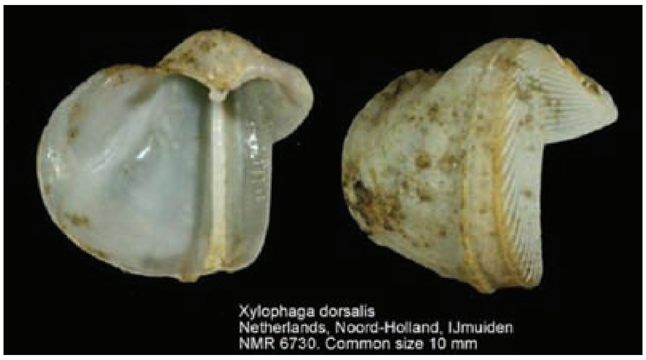
Strength Effects of Fungi Infestations All fungi affect the strength of wood, if in somewhat different respects. Soft rot and mold and stain fungi reduce toughness and impact resistance, as much as 30 percent. The other common effect of these fungi, like that of bacteria, is to increase the absorptivity of the wood at the damaged surface. The affected wood may absorb disproportionate levels of paints, stains, adhesives and sealers. Most important, greater absorbency means the wood will take up higher levels of water, putting the affected wood at increased risk of attack by decay fungi.

Decay fungi have a far greater effect. Laboratory tests demonstrate that a mere one percent loss in weight can result in a loss of toughness as high as 50 percent (Forest Products Laboratory 2010). Bending, tensile and compressive strength do not diminish as quickly; however, with only a 10 percent loss in weight the loss in mechanical strength properties ranges from 20 percent to 50 percent depending upon the property. In existing structures, this level of weight loss is not easily detectable. Further, both brown and white rot damage is latent; the wood retains its appearance except for a loss in luster until far into the decay process, after substantial loss of weight. If the damaged wood is structural, the building and its occupants may be at risk. Additionally, tests have shown that damaged wood fails rapidly, in a brittle fashion, much faster than undecayed wood (Scheffer 1973). An awl thrust into a timber to any appreciable depth likely indicates a significant loss of structural capacity.

Marine Borers Marine borers are an ancient scourge of wooden boats and waterside structures. Relative to fungi, marine borers consist of only a handful of species, but even within species their behavior, appetite and resistance can vary from harbor to harbor, making control of them challenging and unpredictable.

Marine borers belong to two different phyla: Mollusca and Arthropoda (subphlyum Crustacea). Molluscan borers or shipworms, such as the *Bankia* and *Teredo* genera, active along the borders of North America from Alaska to Maine, are bisexual bivalves, though most species do not retain that structure over their lives (see below). Crustacean borers, such as *Limnoria* and *Sphaeroma*, resemble insects also classified within Arthropoda.

Teredo, Molluscan borers, start life at a diameter of about 250 microns (less than 0.01 inches) and free-swimming, expelled by the adult borers after insemination. In a year's time, they can grow 35-fold in diameter (Figs. 14–17).



Natuurhistorisch Museum Rotterdam

Figs. 17–18 Examples of Pholad genera that maintain bivalve morphology. *Martesia*, at left, prefer warmer North American waters. *Xylophaga*, at right, live at depths of 2000m worldwide.

Auguste Le Roux

Fig. 19 Distinctive seven pairs of legs help identify *Limnoria quadripunctata*, also known as gribble, male and female shown above. The most common North American crustacean borers, they range the Atlantic, Pacific and Gulf coasts, attacking wooden docks and piers.

R. T. Springthorpe, Australian Museum

Ming Bell, Endless Blue

Figs. 20–24 Sphaeromatidae family members resemble pill bugs, comprise over 65 genera and range the world. Cabable of destroying marine structures, they generally are less destructive and perhaps more photogenic than *Limnoria*.

Teredo has about two days to find a place to bore before losing the ability to do so. After landing on wood, it crawls around on the surface using an amoeba-like foot, seeking a bore site. Given its size, it needs only bore a small hole to start a burrow. Once inside the wood, the borer rapidly grows a pair of boring shells on its head to consume the wood and extend the hole (Figs. 15–16). The bivalve structure is lost by this point. The borer also develops a siphon, a tubelike structure, to pump seawater through its body to obtain nutrients and to clear the hole of debris. As the borer extends the depth of the burrow, its siphon end remains at the initial borehole. Imprisoned within this tunnel, *Teredo* can grow up to 35cm (14 in.) in length and 1cm (⅜ in.) in diameter in a year. The small entry hole masks the extent of the damage, which in highly infected waters can lead to rapid infestation and unexpected collapse of wood structures.

Bankia, also shipworms, live a very similar life to *Teredo*, though the eggs and sperms are separately ejected via the siphon into the surrounding water where fertilization occurs. *Bankia* species spend up to a month free-swimming as larvae before infesting wood. After finding a home, *Bankia* can grow to lengths of 1.2m (4 ft.).

Pholads A third important genus of Molluscan borer is *Pholas*. Pholads such as the *Martesia* and *Xylophaga* species retain their bivalve structure to maturity (Figs. 17–18).

Pholas's life cycle is identical to *Teredo's*, from free-swimming larvae to lifelong imprisonment in their burrow of choice. Their clam-like structure limits their burrow to shorter but wider dimensions. Pholads generally do not exceed 65mm (2.5 in.) in length or 25mm (1 in.) in diameter. They also leave little evidence of their presence because they do not enlarge the initial borehole, just their burrows as they tunnel. Pholads are active in Hawaii and other Pacific islands, off the coast of Florida, and to some extent, off the South Carolina coast. They are not generally seen in waters off the western United States north of San Diego. They have been found at depths as great as 2200m (1.4 miles).

Crustaceans Borers such as those of the *Limnoria* and *Sphaeroma* genera are typically small, segmented animals with seven pairs of legs that end in sharp, hooked claws. The much more common and economically important *Limnoria* species (often called gribble) are 3 to 6 mm (⅛ to ¼ inch) in length and about 1 to 2mm (1⁄16 in.) wide (Fig. 19).

The *Sphaeroma* species, which resemble pill bugs and do much less damage, are typically larger, growing to 13mm (½ in.) in length and 6mm (¼ in.) in width. These borers move freely on the surface of the wood until they find suitable places to burrow (Figs. 20–24).

In low borer-population densities, only one male and one female inhabit a tunnel. The female settles in the blind end. Once tunneled in, they reproduce and spread within the timber, subsequent generations creating their own branching tunnels. They burrow just below the surface of the wood and often puncture the roof of the tunnel for ventilation. These shallow tunnels are prone to erosion by tidal action and floating objects. The erosion exposes the borers, causing them to tunnel ever deeper. Eventually, this process gives rise to the distinctive hourglass shape often seen on eroded piers at low tide. The attacked wood can become spongy and friable.

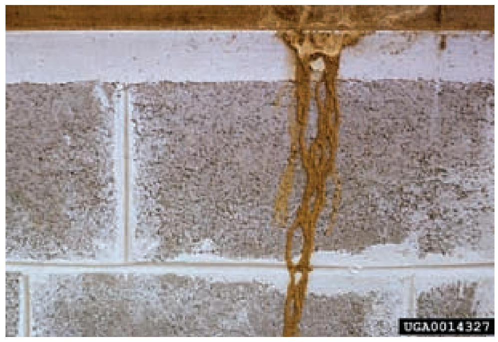
All marine borers are affected by temperature. Relatively small changes in temperatures such as 6°C (11°F) can increase the growth rate by sixfold in a month or 27-fold in three months (Hochman 1973). Salinity and oxygen, though not wholly independent of temperature, also play a role in growth rates. These factors are important for river estuaries where variations in river flow can change the levels of both oxygen and salinity, promoting infestations that had not previously occurred. Restoring health to a river system can also create the unforeseen consequence of improved

Scott Bauer, USDA

Fig. 25 Formosan subterranean soldier and worker termites *Coptotermes formosanus* feeding on Sudan-red-stained filter paper. Tracking termites stained with dye allows estimates of foraging range and population size.

Gerald J. Lenhard, Louisiana State University

Fig. 26 Enlarged view of *Coptotermes formosanus* adult worker (top) and soldier. Note soldier's powerful wood-destroying mandibles (open here) and dark, oval head contrasting with broader pale head of worker. Wing length 14–15mm, maximum head width 1.5mm. Worker often misnamed as wood-eating white ant.



USDA Forest Service

Fig. 27 Shelter tubes on concrete block surface, built by subterranean termites *Reticulitermes Holmgren* to communicate with ground, shown in Gulfport, Miss.

Rudolph H. Sheffrahn, University of Florida

Fig 28 Multiple castes, workers and soldiers, of West Indian drywood termites, *Cryptotermes brevis*.

conditions for infestations. Not merely boats but boathouses, docks and and piers are potentially at risk of infestation by borers.

Insects Though wood-eating insect damage is frequently more apparent, often quite severe and still economically significant, its aggregated cost is not nearly so great as the cost of damage by decay and stain fungi. From the familiar termite to the more obscure timber worms, all are classified as Arthropods, as are the Crustacean marine borers, and all belong to the class Insecta (no surprise there). There are hundreds of thousands of species within Insecta, and thousands of species that consume or otherwise destroy wood, wood fibers and trees. We'll focus on only the most important families, genera and species that destroy converted wood.

Most wood-attacking insects prefer wood with a high moisture content, either for nourishment or for ease of burrowing. Unlike in the case of decay fungi, keeping wood air dry is not always sufficient to forestall infestations. Even if the wood is air dry at 15 percent MC, species such as the Pacific powderpost beetle attack seasoned sapwood, often repeatedly until the wood is pulverized. Species such as subterranean termites can source their water from the soil they nest in and bring it to the infestation site. But most species of wood-attacking insects prefer wood with MC near or above the FSP. Beetles and weevils are thought to attack wood with high MC because they obtain nutrition from the decay fungi that precede them.

Most species of insects leave telltale signs of their presence, though the damage they cause is often hidden. Some termites build tubular covered passageways on surfaces. Powderpost and other beetles leave tiny accumulations of fine, powdery, flour-like dust, or frass, outside pinholes, even on vertical surfaces. Carpenter ants and bees, which tunnel in wood for shelter not food, carry or push the sawdust and wood particles outside the entries of their burrows, where an accumulation of the spoil signals their presence.

Termites Termites belong to the order Isoptera. Social insects, they live in colonies in a well-defined caste system of adults, workers and soldiers. Subterranean termite colonies can grow extremely large and require warmth, high levels of moisture and carbon dioxide, and low levels of light, making damp soil an ideal environment. Subterranean termites connect their colonies to feeding sites by building exposed, covered passageways that run around or over obstructions and up concrete or masonry walls, piers or slab edges (Figs. 25–28).

They prefer slab-on-grade construction, where wood is close to the soil, or crawl spaces, damp, dark and enclosed. Subterranean termites live worldwide between the latitudes of 50 degrees north and 50 degrees south, though they are better established in the warmer climes.

Nonsubterranean or *drywood* termites (Fig. 28) do not require high moisture levels or a connection to the soil. They can establish colonies in timbers and successfully develop in environments with EMC as low as 5 to 6 percent. They multiply more slowly, but left alone they can seriously damage a structure over years.

Wood-inhabiting termites can be transported in lumber and furniture to establish new colonies in distant locations. Their US range is currently limited to Hawaii and to a narrow strip of land that extends from central California down the coast, across the South to Florida and up the East Coast to Virginia.

All termites possess large, sharp mandibles, a distinctive and indispensable anatomical apparatus they use to tear off wood fibers before passing them to their crop, where the wood particles are ground and ingested. Termites rely upon protozoa or bacteria in their gut to digest the cellulose and obtain the stored energy, but they do not digest the lignin. Subterranean termites prefer to consume wood with high moisture content, and they prefer earlywood to latewood, which might explain why they typically tunnel longitudinally with the wood grain.

Powderpost Beetles These insects are members of the order Coleoptera (beetles), which contains over 350,000 species. Three families, Anobiidae, Bostrichidae, and Lyctidae, constitute the most economically significant wood-destroyers besides termites in the Insecta class. Unlike most wood-damaging insects, all three families of beetles attack seasoned wood.

Anobiidae are known as *death-watch* beetles because of their characteristic ticking sound, associated in folklore with the rapid passage of time as a forewarning of death. The death-watch beetle produces sound by striking the back of its exoskeletal head on the first segment of its thorax.

Bostrichidae and Lyctidae only attack the sapwood of broad-leaved species (hardwoods), consuming the starch and stored carbohydrates in ray parenchyma cells. The heartwood is not attacked. Anobiidae beetles, however, attack both sapwood and heartwood of softwoods and hardwoods (Figs. 29–30).

All three families of beetles bore small diameter holes (1 to 2mm or 1⁄16-in.-dia.) when they are in the larval stage. The wood is reduced to a flourlike consistency and accumulates in the galleries and at the entrances.

Pinhole Borers Two important families of pinhole borers, the Scolytidae and Platypodidae, belong to a group of beetles known as *ambrosia* and *bark* beetles. The adults, which do the boring, are 3 to 6 mm (1⁄8 to 1⁄4 in.) long and cylindrical in shape (Figs. 31–33).

Not as economically important as powderpost beetles, they attack hardwoods and softwoods, dead or dying trees, trees with damaged bark, newly cut trees (boring into the bark) and unseasoned lumber with a moisture content of 50 percent or more. Ambrosia boreholes are roughly round, 1.5 to 3 mm (1⁄16 to 1⁄8 in.) in diameter. When attacking newly felled trees, pinhole borers leave a light-colored frass at the entry point.

Ambrosia beetles do not consume the wood. They bore branching galleries to cultivate for consumption certain stain fungi (Ascomycota) that stain the wood black, degrading its appearance while not reducing its structural value.

Timber Worms Two families, Brentidae and Lymexylidae, also of the order Coleoptera, comprise only a few species each and define this group. Brentidae, designated as straight-snouted weevils, and Lymexylidae, called *ship-timber* beetles, do their damage as larvae (Figs. 34–35).

Timber worms, as adults winged beetles, are small, 4 to 20mm (5⁄32 to 25⁄32 in.) long, with narrow, parallel-sided bodies. The adult females drill holes the same size as ambrosia beetles in the wood and lay their eggs in the holes. The adults do not consume or damage the wood. The larvae feed on the wood, extending the burrows as they do. They also feed opportunistically on fungi in their burrows. Timber worms prefer hardwood species such as oak, beech and poplar, and they attack already damaged trees and newly cut logs.

Old-house Borer *Hylotrupes bajulus,* common name *old-house borer,* belongs to the family Cerambycidae and prefers seasoned softwood (Figs. 36–37).

Often infesting during the tree stage or in lumber yards, brown or black adults 15 to 25mm long (5⁄8 to 1 in.) deposit the larvae in natural cracks and crevices in the tree or checks in the lumber. The larvae grow to be 30mm (1¼ in.) long and bore into the wood, scraping the sides of the tunnel with their mandibles before consuming it and leaving the digested remains behind.

The larvae have been variously reported to take two to three years and five to seven years to mature. The differing reports may reflect differences in the moisture content of the wood affecting growth rate. The long larval stage may suggest a reason for the beetle's name, though at seven years a house would hardly be thought old.

The borers become apparent when they emerge as adults from the 6 to 10mm-dia. (¼ to 3⁄8 in.) oval holes they cut. Damp spaces, poorly ventilated attics and leaky roofs reportedly can experience serious damage in short periods of time. The old-house borer makes an audible rasping sound while chewing with its hard jaws. Its range is from Maine to Florida and as far west as Texas and Michigan.

Hymenoptera: Carpenter Ants and Bees Belonging to the family Formicidae and the genus *Camponotus*, black and brown carpenter ants, with variant colors including red, are widespread and common in North America (Fig. 38).

They burrow in wood for shelter and can do considerable damage while creating extensive galleries over periods of months (Fig. 39). While they prefer wet or moist wood for ease of burrowing and because immature ants require a high relative humidity, they are found in many species and under many conditions of wet or dry, in logs, stumps, porch structures and foundation timbers or plates.

Carpenter bees, small and large varieties, belong to the family Xylocopidae (Fig. 40).

The larger bees, similar in appearance to bumblebees, nest in trees, wood and wood structures. Carpenter bees nest in most species though they prefer seasoned wood of the softer species—pines, cedars and redwood. They excavate chambers by vibrating their bodies as they rasp the sides of the burrow (Fig. 41).

The nests are as large as 15mm wide and 50cm deep (9⁄16 by 18 in.). The gallery may be compartmentalized for nursery and food storage purposes, and branching tunnels have been reported. They do not eat the wood, either discarding the frass or using it for partitions. Carpenter bee damage is not economically significant.

—Mack Magee

This article is the first of two on wood decay and protection. The second article will treat protection and preservation methods. Mack Magee (mmagee@fraserwoodindustries.com) is Business and Market Development Manager for FraserWood Industries in Squamish, British Columbia, and a principal at Fire Tower Engineered Timber in Providence, R.I.

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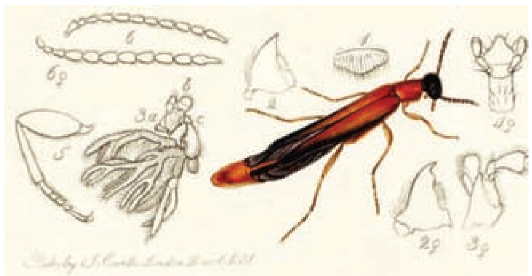
Kira Metz, USDA

Whitney Cranshaw, Colorado State University

Figs. 29–30 Powderpost beetle (Bostrichid), photo much enlarged, and signs of its work.

Clockwise from top left, E. Richard Hoebeke, Cornell University; Ladd Livingston, Idaho Dept. of Lands; Gerald J. Lenhard, Louisiana State University

Figs. 31–33 Ambrosia beetles and their typical pinholes.



John Curtis

William H. Hoffard, USDA Forest Service

Figs. 34–35 At left, ship-timber beetle, *Lymexolon navale*. Adult female beetle makes borehole in surface and lays eggs isnside. Larvae, at right, hatch out and and excavate lateral galleries. Damaged trees and newly cut logs are hosts.

Clemson-USDA Cooperative Extension Slide Series

Pest and Diseases Image Library

Figs. 36–37 Old-house borer larva, photo much enlarged, and adult.

Gary Alpert, Harvard University

Daniel H. Brown, USDA Forest Service

Figs. 38–39 Red carpenter ant, photo much enlarged, and damage in oak.

Jim Baker, North Carolina State University

USDA Forest Service

Figs. 40–41 Carpenter bee, photo much enlarged, and typical gallery in softwood.

Wooden Jewel of the Langhe

Photos Ceretto Aziende Vitivinicole

THE city of Alba in the province of Cuneo, in northwest Italy's Piedmont region, is part of a hilly area called the Langhe, famous for vineyards. Alba, famous also for white truffles, is the historical capital of the Langhe, and from its vineyards a new artifact of the wine world arose in 2009. The Acino, a tasting and conference room at the Ceretto winery, is a 1600-sq.-ft. transparent room with a 360-degree view projecting over vineyards below.

Designed at Studio Deabate by architects Marina and Luca Deabate (Torino) and engineered by Paolo Minuto (Alba), with woodwork by Denaldi Legnami (Casale Monferrato), the little building recalls the shape of a grape (*acino* in Italian) and comprises four parts in different materials—concrete, timber, steel and polymer. The Italian word *divino* means "holy" or "divine," but if we read it as the two words *di vino,* it can mean "from wine" as well. The pun is suggestive of the value that Alba vineyards have for the local landscape, the *genius loci*, as the specific vineyards have for the Ceretto family, which has been making wine for three generations.

The main concrete structure of two separate pillars works as a foundation for the engineered glulam oak timber frame (recalling the traditional oaken barrels built by skilled craftsmen), which supports a second steel structure, completed by the wooden floor and the calotte, the skullcap-shaped cover in stainless steel and ETFE (ethylene tetrafluoroethylene), the latter a very lightweight, self-cleaning and resilient alternative to glass.

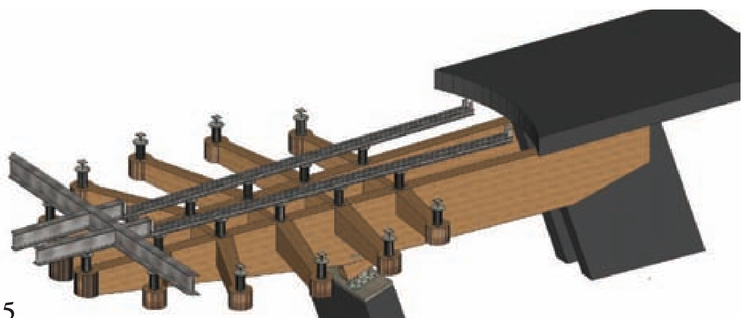
The elliptical plan results from the two cantilever-shaped linear beams joined with five transversal beams and five pairs of projecting branches on the external sides, recalling, as seen from the vineyards below, one of nature's evocative and representative elements, a leaf. The leaf-shaped oak structure is visible from the bottom of the valley.

All around the interior, a wooden bench designed to cover the air-conditioning system marks the elliptical shape of the room, creating at the same time a gap between the wooden floor and the calotte, between matte and transparent materials, between horizontal and vertical lines, between land and sky, providing to both a positive value of personality, an individual identity, even with the amazing view in any direction.

The Norwegian phenomenologist Christian Norberg Shultz (1926–2000) and the architect Sverre Fehn (1924–2009), fathers of the *genius loci* theory, were not so much obsessed by the right material with which to get the perfect architecture as by the right way to use it, to use the *materia* to bring out the hidden genius of a place through architecture. The Acino reminds me of Fehn's Norwegian Glacier Museum at Fjaerland, Norway, where the long exterior path to the entrance and the striking relationship of the museum with the mountains behind are a reverse of Alba: here we need to walk from inside to outside through a covered path, and our attention is captured to look down the valley rather than up to the mountains. In both experiences, the relationship between architecture and nature is masterfully evoked.

—Thomas Allocca

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



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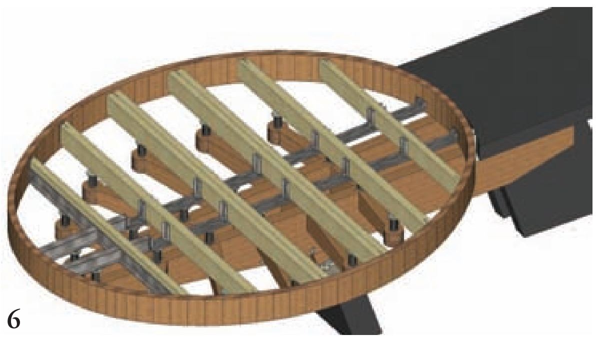

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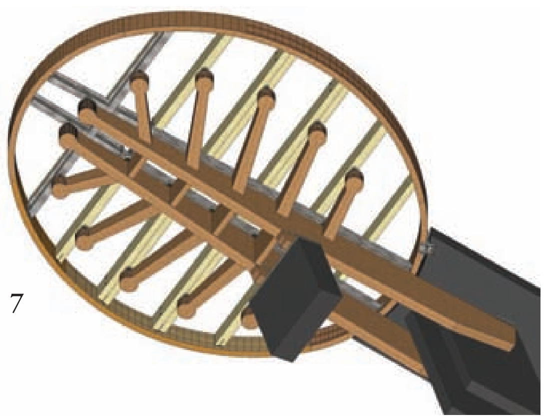

7

Fig. 1 Facing page, Acino's elliptical wooden platform on laminated oak framing has major and minor diameters of about 39 ft. 4 in. and 34 ft. 5 in. respectively. Thickness of about 2 ft. conceals climate control machinery. Underside is finished in oak.

Fig. 2 At top, view of Acino against Ceretto's vineyards and hills of Langhe beyond. Dome rises about 18 ft.

Figs. 3–4 At middle left, stainless steel hoops support ETFE cladding over oak finish floor and continuous bench set in from perimeter. Space is dedicated to meetings and wine tasting. Middle right, articulation of Acino with main building, tunnel clad in Cor-Ten steel. Cantilever over fulcrum is 18 ft.

Figs. 5–7 Above and at right, renderings of framework with details of oak laminates and steel fittings.


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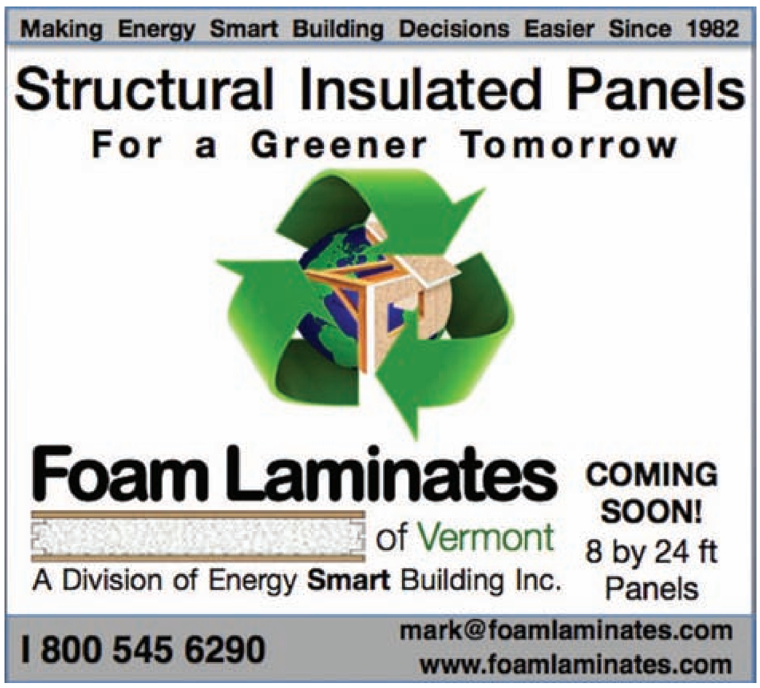
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THE TIMBER FRAMERS GUILD
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