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BOOKS

Natural Architecture

Earth to Spirit, by David Pearson. A Gaia Book published by Chronicle Books, San Francisco, 1995. 22x26 cm, 159 pp., profusely illustrated. Softbound, $17.95.

DAVID PEARSON is widely known for his first book, *The Natural House Book* (Fireside, 1989). An early contribution to the now-growing bibliography on green building, that book is a compendium of traditional and modern methods of healthy house building. Impressive in its breadth if not its depth, *The Natural House Book* covers a wide array of topics, from acid rain and adhesives to urea formaldehyde and yurts.

In preparing his latest book, *Earth to Spirit* (subtitled *In Search of Natural Architecture*), Pearson traveled throughout the world in search of exemplary buildings that are ecologically sound, materially healthy and possessed of a powerful spiritual presence. The dozens of color photographs (nearly all taken by the author and nicely reproduced) and the sometimes thin text attempt to define the essence of buildings that, in the words of architect William McDonough, "respect the relationships between spirit and matter." This is an ambitious proposal, and if the text sometimes falls short, the illustrations more than make up for it. Perhaps it is a mistake to expect to see defined in words that which can only be experienced by the eye or the body.

The book is organized around six short essays, each of which is followed by up to 20 pages of photographs. (A word about the book itself. Ironically, for a book in search of the "natural," the heavy, glossy paper stock gave off a decidedly petrochemical smell. After two hours of poring over my copy, I had itchy eyes and a substantial headache.) In his first essay, "Ancestral Archetypes," Pearson braids a three-way connection among Nature, architecture, and the spiritual. He argues that by necessity, the architecture of ancient cultures was more closely linked to and expressive of the natural forces of the environment than contemporary building. Likewise, the spiritual life of these cultures was more clearly bound to the rhythms of Nature. Out of this grew an architecture that, beyond shelter, became a symbolic representation of the connection between the physical and spiritual realms. For example, Pearson gives an extensive description of the ritual space of the traditional Mongolian yurt: "Inside, the circular space is divided into four quadrants and everyone and everything has its appointed place. There is a women's side and a men's side with a 'place of honour' near the altar. . . . Saddles, guns, and ropes are placed on the men's side, while churn, kitchen tools and cradle are on the women's side. . . ." Much is made of the richness of the ritual life embodied in the architectural spaces of these indigenous cultures, yet nothing suggested itself to me while reading the yurt description so much as the center-hall tract "colonial" in which I was raised. Here as well, the space was ritually partitioned into four zones, each with its allowed and prohibited activities, the "place of honour" in this case being Dad's chair near the television altar. My intention here is not to mock Pearson's intent, but rather to point out the danger of seeing another culture as somehow more rich or full of content simply because it is foreign or old.

Of much greater interest is the essay on healing architecture. Pearson presents a balanced overview of architects currently working within the broad category of "organic architecture," spending a good deal of time on the followers of Rudolf Steiner, the founder of anthroposophy. Central to Steiner's philosophy is the idea that the built environment has a deep relationship to spiritual well-being. In Pearson's presentation of the architectural principles of anthroposophy, rectangular, regular buildings "cause people to think and act in a predominantly rational, coldly logical, materialistic (and possibly masculine) way." A more organic form allows for enhanced creativity and individuality. Pearson summarizes the words of Dutch architect Ton Alberts: "He maintains that walls built with love contain a certain aura. . . . A building that is constructed from the heart will always evoke love in the people that come into contact with it." I have great admiration for a person willing to speak so openly and unabashedly on these matters of the heart. If you remain skeptical about the place of love, heart, and organic form in architecture, I invite you to withhold judgment until you have a chance to look at the photos which accompany this essay. The buildings, especially those by the Swede Erik Asmussen and the Hungarian Imre Makovecz, are stunning in their beauty and animated spirit.

Pearson opens his third essay, "Harmony with the Land," with an overview of energy issues. He quickly veers off familiar ground,

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however, by attacking the mainstream building trades for narrowly focusing on energy efficiency as the best way to deal with the current resource crisis. This he likens to curing the symptoms of a disease without treating the cause. Pearson presents an alternative view built around concepts of deep ecology, sustainability and self-sufficiency. Of particular interest is his presentation of the work of the Gaia Group of Norway, whose eco-cycle house presents low-tech alternatives for enclosure and mechanical systems, using a straw and clay system similar to that described in *TF* 35.

In essays titled "Vernacular Wisdom" and "Cultural Identity," Pearson argues for looking back to the architecture of traditional cultures for clues to how we might build today. For Pearson, vernacular buildings are remnants of a time when communities were obliged to live and build sustainably or perish. His essay is amply illustrated with unexpected examples from around the world, including beautiful, elegant timber-framed buildings in Korea and timber structures from the Transdanubia region of Hungary.

Pearson makes much of the wisdom and appropriateness of traditional building in its relation to the climate and in its utilization of local resources and skills. While the appeal of vernacular building is clear for these reasons, he misses an opportunity to go further. The appeal of the vernacular is necessarily linked with an individual building's place within a community. The visual richness of a traditional New England village, for example, is due to the interplay of many buildings speaking a common language. It is not simply the beauty of the individual buildings that is spiritually uplifting, but the traces of a community that can be read in the varied yet related facades. It seems clear that the culture that could produce a traditional New England village must have been united with some sort of common vision, one which feels lost to us today. Perhaps it is this yearning for a lost community that has drawn many of us into the revival of timber framing, a remnant of a vernacular culture that has mostly passed on.

Pearson's final essay, "Living the Dream," is actually a series of short profiles of individuals and groups working toward the realization of a "natural architecture." While interesting and varied (those profiled range from restorers of old windows to builders of a model permaculture village), this overview is anything but comprehensive, and mostly focuses on groups based in Europe. It does, however, give a good sense of the variety of work being done today, and in toto, *Earth To Spirit* presents a well-researched vision of what Pearson defines as natural architecture. Pearson also does an excellent job of moving the understanding of the spiritual in architecture from the clichéd (soaring spires, painted domes) to the often-overlooked: an entryway, a hearth, a window seat. The photographs illustrate better than the text the place where spirit resides in architecture. Keep this book close at hand for the times when inspiration fails and design efforts produce less than uplifting results. —ANDREA WARCHAIZER

Andrea Warchaizer designs houses as Springpoint Design in Alstead, New Hampshire.

TIMBER FRAMING

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By Title

Thanks Many Thousands!

On behalf of the Guild's Board of Directors, the 1995 Western Conference Committee wishes to extend a thankyou to the following sponsor companies and advertisers who helped make last November's Semiahmoo conference a success. Funds and in-kind donations totaled several thousand dollars and went directly toward production costs. They helped make the conference rewarding as well as help contain the attendance costs.

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Traditional Techniques and Shortcuts

IT IS a common perception of the past that all tasks in "the old days" were harder or took longer to complete. When we look at the various craft tools in museum exhibits, we think of long days of arduous work. Was this really the case, or has the machine age veiled us to the efficiency of the old hand tools?

In 1976 I would have agreed with the common perception. In looking at old hand-hewn timbers and hand-cut joints, I too got exhausted just thinking of the effort apparently necessary to produce them. In fact, this idea stimulated my curiosity about the past more than any other. I knew that it couldn't have been that laborious if one only had the knowledge of the methods. So off I went to the tag sales and flea markets to procure those instruments of torture: broad axes, adzes, T-augers, etc. I worked on my own time squaring up timbers and chopping out joints as I then thought they might have been accomplished. In 1980, I went into business entirely hand crafting frames and, 15 years later, with the onset of back trouble, tendonitis of the wrist, "tenons" elbow and miscellaneous injuries, I am even more determined now to unlock the secrets of the past. As I age, I must use my head more to rediscover and develop those techniques that allow me to pursue the craft. Brute strength and perseverance can no longer make up for lack of proper technique.

Hewn timbers have always fascinated me. The idea that one could fell a tree, square it up and frame it into a structure is wonderful. I have tried untold different axes and adzes over the years (with accompanying blisters of different sorts) on over 40 different species. I've experimented with different approaches. I've studied the tool marks on old timbers, made rubbings and measured angles to assist my effort. After 20 years in the pursuit of hewing technique, I am now able to square up a log faster, more consistently and with less effort than ever before. In fact, hewing a timber out of the log has proved to be more economical than buying a sawn one in the larger and longer sizes. Sawyers typically sell timber by the board foot, a *volume* quantity. Hewing would be better priced by the square foot of face, an *area* quantity. As timbers increase in volume, the surface area does not increase in direct proportion. The larger the size, the less surface area per unit of volume. Depending on the purchase price of the sawn timber, cost of logs and the pay scale of the hewer, there will be a cutoff point where it makes economic sense to hew rather than buy sawn. In my work, the cutoff point is an 18-ft. 9x9. Anything larger and longer can be hewn and dollars saved. As an example, I recently hewed out a 7x7x33 pine timber. It took 6½ hours to fell the tree, set it up and square it. To purchase such a stick already sawn would have run me over $200 plus tax (135 board feet x $1.50). If I hew it on site, I would expect to pay the timberland owner 8 cents a board foot stumpage, about $11. If I pay myself $20 an hour, a respectable hewer's wage, I still save over $60. If the timber is destined for a house then I save myself planing costs as well. Most customers seem to prefer hand-hewn timbers to any other sort. I don't bother covering them as I might planed timbers, for hewn timbers age gracefully.

In timber-framed barns built in the early 1900s, long after the development of the circular sawmill, the longest timbers were often still hewn. There has always been a premium for long or big stuff. By choosing hewn stuff, the farmer (or framer) was just being practical.

Sometimes it isn't necessary to square all sides of a timber. Common rafters, except those at the gables, need hewing only on the upper face to receive the roof boards. This shortens the hewing time considerably. Though the bark still has to be removed, on species such as hemlock and oak the bark can be sold for tanning purposes. If the bark is removed immediately after felling, it easily separates from the log and can be unrolled in 4-ft.-wide sheets. (On tan-bark species, one can see tell-tale marks of the axe ringing the smooth surface of the log at such intervals.) Letting the bark dry on the log and then removing it with a drawknife (the common method today) is far too time consuming. In a few old structures, we still find the bark on these pieces. These seem to indicate winter-felled pieces which might dry substantially before the warm weather arrived.

An even faster way to produce lumber from the log was riving (splitting). If the logs were straight grained and fairly clear, shorter members such as braces could be quickly riven out. Some quick dressing with the broadaxe was necessary. Occasionally the builder needed a short scantling as a filler piece or nailer. Rather than head back to the sawmill, he might rive the piece out of some larger leftover chunk.

When reading accounts of framing jobs in diaries of the 1800s, one is continually impressed with the short time it took to cut frames, especially barn frames. Take as an example the barn that Tobias Walker of Kennebunk, Maine, had framed in 1852 (cited in Thomas C. Hubka's 1984 book *Big House, Little House, Back House, Barn*). Walker's 38x62 five-bay barn, a large frame by any standard, was framed by eight men in four days. That is 32 man-days. I don't think this is a singular example where the builder was racing to set a record. This example was likely a typical one for barns. The frame of the Benjamin B. Murdock house in Northfield, Massachusetts, a large Greek Revival house with ell, was cut between April 14th and May 10th in 1840 by three men (about 66 man-days, assuming good weather). According to an account in *Perspectives in Vernacular Architecture, IV* (edited by Thomas Carter and Bernard L. Herman, 1991), the frame consisted of "hewn sills, posts, girts, plates, and ridgepole; sawn studs (probably at about two feet on center), braces, and second floor and attic joists; and peeled poles for first floor joists and common rafters." With similar manpower using the power tools of today, contemporary shops could not compete with such 19th-century carpenters.

What about the 18th century and earlier? Though Scribe Rule framing requires more time, by many accounts twice the time, building contracts still seem to indicate a rapid pace. Many 17th-century build-

All photos Jack A. Sobon

1. Exposed anchorbeam tenon in a ruinous Dutch barn showing broadaxed surface.

ing contracts required houses to be fully completed in six months. Considering that everything had to be made from truly raw material, this was quick by today's standards. Yes, in the warmer months, the hours were probably longer than ours and the carpenters likely worked six days a week, but this doesn't begin to compensate. How could handwork be faster than power? Were they supermen?

The explanation lies in the techniques of cutting joints and the workers' overall approach to the craft. The carpenters of old didn't waste time paring away tenons 1/32 in. at a time. Joinery was quickly roughed out and then there was only minimal fine handwork. For example, the surfaces of the huge rounded anchorbeam tenons that Dutch barns are noted for show identical tool marks as the surfaces of the timber itself. Obviously, they were scored with an axe and broadaxed to a line *(1)*. A joint that might take hours with a circular saw, mallet and chisel today, might have been done in a half hour then. Yet I have never heard anyone remark that these same Dutch barns had sloppy workmanship. The tool marks are completely appropriate to the material, in fact much more so than on many new frames where absolutely smooth surfaces cut into green timber are distorted by checking and drying. Even smaller tenons show the evidence of an axe to rough them out. A few well-placed axe blows can waste a lot of wood in a short time.

On mortise housings, the framers didn't spend a lot of time checking the bearing surfaces with machinist's squares, paring away 32nds of an inch. The important bearing surfaces were cut to the line perfectly while hidden areas were undercut. With obvious undercutting, it probably wasn't even necessary to pick up a square.

The "snap" (see *TF* 36 and 37) is an incredible time saver. Completely sawing through an 8x8 pine timber takes two to three minutes with a sharp eight-point crosscut saw. The use of the snap saves this through cut as well as splitting off much of the tenon waste. Likewise, sawing the diagonal through cuts on braces is time consuming. I believe the snap was used to avoid these through cuts. Typically, I try to get two or more braces out of the same piece of stock. If laid out properly, one snap could make two tenons. Some quick paring and then sawing the nose could

2. The braces in this Massachusetts barn were thicknessed by pushing them partially into a table saw.

3. Reducing the width of a brace tenon saves on mortising work.

4. Lap dovetail mortises often have the acute angled point squared off at the width of the chisel used.

finish a brace in record time. On many barns, the braces had short tenons, 2 in. long, without pegging. These short tenons were often rip sawed rather than snapped. Since braces are designed to act only in compression, the lack of pegging did not create a structural problem. It was a little inconvenient at the assembly stage, but eliminating the boring of peg holes, especially in the mortised piece, could knock off a lot of time. If the braces were framed with 2-in. mortises 2 in. from the edge, any of the stock thicker than 4 in. had to be reduced. In some later barns one sees evidence of a large table saw having been used to thickness the ends of the braces *(2)*. Many old barns had 60 or more braces. Any time saved on these made a big difference.

In Scribe Rule frames with wider braces, say 3x7s, the tenon was reduced in width to 4 in. or 5 in. to reduce the morticing work *(3)*. Scribe Rule layout was itself a labor-intensive process, but it had its shortcuts too. A big part of the process was the setting out of the frames. Each bent, wall and floor frame was scribed in stages. First the major timbers defining the bent were scribed and assembled square and the upper face leveled. Secondary timbers were laid on and scribed. If these members were mortised, the bent was taken apart, the joints cut, peg holes bored in the mortised piece only and then reassembled with the additional components in place. The bent would have to be squared and leveled again. Peg hole placement for drawboring was marked on the tenon and bored after. Sometimes this process was repeated with tertiary members. Lap joints are time savers because a member can be laid on, scribed, the joinery cut and the member inserted and pegged without disassembling the bent. If even one stage is eliminated, there is considerable savings in labor. Lap joints are quickly cut with saw, axe, and slick, there is no boring except the peg hole. They are perhaps half the work of a mortise and tenon joint. Lap joints also permitted the use of dovetails to provide some tensile strength for braces. Many of these joints had the tip of the dovetail squared off. Removing this tip had little consequence structurally but made the mortise easier to cut. An acute angled corner is difficult to clean out with a chisel *(4)*.

In Scribe Rule frames with only mortise-and-tenoned members there were still shortcuts. In a handful of old frames there are braces that have extra-length mortises filled with a block (cover photo). These blocks are numbered as are the braces. Some blocks are even pegged. To a novice, these might appear to be a way to plumb the frame after it was up, or perhaps to patch a mistake. But they were an attempt to save time. We know that mortises are most practically cut face up. When a brace was scribed to say a post and tie beam lying horizontal, the mem-

5. Shared and blocked-in mortises.

bers had to be taken apart and rolled to cut the mortises and then repositioned to insert the brace. If, however, the brace mortises were cut oversize in length before the primary timbers were first assembled, the braces could be set over their mortises, scribed, cut and inserted without disassembly. The wedge was then made to fill the extra length. In these same barns and most other Scribe Rule structures we find the wall girts sharing a mortise with a brace for a similar reason *(5)*. The girt mortise was cut at the same time to allow extra room for insertion of the brace. After the girts were scribed and their tenons cut, the post bottoms were spread to allow the girts to be inserted. Often plate braces would share the same plate mortise. Thus each brace could be separately scribed, inserted and its peg hole marked. Of course, additional time would be saved combining the mortises because there were two fewer mortise ends to square up.

Where rafters join at the peak of the roof, the most common joint found in the old frames seems to be the simple half-lap secured with a square peg. It can be cut rapidly using the snap. It holds well enough, even as the members twist drying. The open mortise and tenon (tongue and fork) by comparison takes far longer. But then again, it is a better joint and the one I most often choose. After cutting hundreds of these open mortises by hand and trying different methods, I have settled on a particular technique as most efficient. I rip-saw the sides of the mortise first, then bore a through hole the width of the mortise and the block falls out. The near end is then chiseled square. While examining rafters on a 1700s house recently, I found marks showing the same technique *(6)*.

In some frames, there was simply a level cut where a rafter sat on the plate. These diagonal cuts are a chore to saw. I've found structures where they were not sawn, but chopped out with axe and adze. With the rafter supported on horses, the angle is such that these tools can do a respectable job with little effort. The big rafters of Dutch barns are birdsmouthed at the plate with wide diagonal surfaces. From surviving examples, it appears that it was more efficient to bore and then chisel these surfaces rather than saw them *(7)*. On the rafters of some barns, the work of chiseling out the corner was eliminated by boring a hole over the lines that completely removed the corner. It may also have been done to reduce the tendency of the rafter to split at the corner *(8)*.

6. Rip-sawed rafter peak mortises in a Cohoes, New York, Dutch house.

In a few positions in old structures, we find timbers with axe cut ends from either the felling or bucking of the log or timber. If the timber was a floor sleeper or attic timber that would be ultimately concealed, there was no need to square the end. (In this era of chainsaws, we may find it hard to believe that logs can be cut to length faster with an axe than a saw, but even in today's woodsman competitions, they still buck 14-in. diameter logs with axes in 6 to 10 seconds.) Only the axe had to be carried into the woods, it wouldn't bind in the cut as might a saw, and sharpening an axe was quicker than sharpening a crosscut saw. The axe has always been a remarkable tool when one considers its low purchase cost, low maintenance, durability, versatility and great output. Unfortunately, most of today's timber framers have little experience with axes.

7. Dutch barn rafter butts showing evidence of bored and chopped birdsmouths.

8. In this Orange County, New York, barn, the hole was likely bored over the line to save chiseling work.

In the later barns where crosscut saws were used to cut logs to length, the lengths cut in the forest may have been nearly exact. I have seen posts where both ends have tenons with very uneven end cuts, which seems to indicate that the builder thought it prudent to cut the logs to their overall length to avoid resquaring. This saves even more time than the snap. This practice of course doesn't allow shifting the layout to avoid defects, but that was hardly necessary with the straight-grained and relatively clear old-growth timber available.

Though most of us don't associate the use of nails with a finely-crafted timber frame, virtually all timber frames made use of them. From the Medieval era to the wan-

9. Sawn kerfs for nailing a stud to a brace, Middleburg, New York.

ing of the craft, nails were often used to secure rafters to the plate, jack rafters to valley and hip rafters and studs to rafters and braces. In the pre-industrial age, the use of hand-wrought nails might seem extravagant, but it was obviously the expedient way to build where angles, especially compound angles, were involved. It is far quicker to cut a jack rafter end with a miter and secure it with nails than to cut a compound-angled tenon and its corresponding mortise. In a Middleburg, New York, barn, the builder used an interesting technique to prevent splitting when nailing studs to braces. Kerfs were sawed to insert the nails. By angling these kerfs, splitting planes were avoided *(9)*.

There were shortcuts to expedite the assembly process. To haul up and position the plates and purlin plates, typically 40 to 50 ft. long on barns, a technique called parbuckling was probably used. It was a common method of rolling logs up a couple of inclined supports onto a sled or truck. By passing a rope or chain around the log (or timber being raised) and securing it to some immovable object, the log becomes a "pulley" rolled by the ropes. In the raising of plates, one end of the rope is secured to the post tops and the other passed under the timber and up to the hands of the lifters who are lifting only half the timber's weight. The plate is rolled up the wall safely without strain *(10)*.

11. Original roof boards on a house in Cohoes, New York, with beveled lapped edges preserved by a later ell roof.

The old carpenters had their tricks for saving time sheathing structures. Consider the full-length groove found in some plates and gable tie beams for insertion of the vertical board siding. This was done for economy. Though it saved on nails, I believe its real reason was to save on scaffolding. A carpenter standing on the ground could insert the board into the groove, tap it sideways, snug to its neighbor, and nail it on the sill and girt. No ladder or staging was necessary. Though it may have taken an hour to cut such a groove, the time saved applying boards on a 40-ft. wall was substantial.

When the dropped tie beam barn frame became the prevalent type, many barns retained end wall ties flush with the plate. Why? I am now convinced that this was again done for economy. If the barn's sidewall and endwall boards were the same length, the *logs* could be cut to the proper length prior to sawing. The boards thus sawn from these logs could be applied directly to the barn without trimming. A close inspection of original siding will often reveal that the boards have slightly uneven or non-square end cuts, but matching ones. Imagine the time saved by not setting perhaps 150 boards on horses, not measuring their length, not squaring and not cutting their ends!

In some older Dutch barns and houses, one finds roof sheathing boards beveled on their horizontal edges as though designed to shed water *(11)*. I have not found any that show evidence of weather exposure and in fact there are often large gaps where wane has reduced the width of the boards. Also, the roof pitches are not steep enough for the angles to work. From documentary sources, we do know there were board roofs on early Dutch buildings. The examples that I have seen however were not likely done to shed water but for a completely different reason. The boards typically span from 4 to 6 ft. between rafters. Unless the boards are 18 in. or more in width, there can be a lot of deflection between adjacent boards. The beveling had a stiffening effect on adjacent boards and could be cut fairly quickly with a drawknife in clear-edged boards. Shiplapping or tongue and grooving the edges with planes would have taken longer.

Techniques I have described—and I am confident that I am only scratching at the surface—can reduce the cost of new traditional timber-framed buildings considerably. There are undoubtedly many other techniques still waiting to be rediscovered. We need to use such knowledge and expand upon it. If today's timber framers could frame a barn such as Tobias Walker's in 32 days at a labor cost of perhaps $8,000 (say 10 hours per day at $25 per hour), there would be a lot fewer pole barns and metal buildings. —Jack A. Sobon

10. Parbuckling a 40-ft. 8x10 plate on a barn, Lenoxdale, Massachusetts.

Load Behavior of Connections with Pegs II

DURING renovation and reconstruction, as well as during construction of new framed buildings, engineers and carpenters are continually faced with the problem of having, on the one hand, to fulfill the challenge of preservation of historical monuments, and, on the other hand, not being allowed to use wood pegs as load-bearing members, because in the authoritative German Industrial Standard (DIN) 1052 no permissible loads are given. As a rule, steel details are used for load transfer of small, short-duration tension forces caused by wind load. It may be assumed, however, that the structural stability of century-old, wood frame buildings without steel details has been proven. The knowledge gained from previously-studied wood connections [1-3] was the basis for this research project, which was supported by DGfH (German Society for Wood Research) and DITB (German Institute for Building Technology), and whose goal was the investigation of the minimum values of connection parameters and the permissible connection strength for joints with wood pegs in double shear.

2. Experimental Program. For this study, 80 tensile tests were conducted with a 90° connection angle and 30 tensile tests with a 0° connection angle, using boxed-heart specimen cross-sections $b \times h$ = 20 x 18 cm and $b \times h$ = 14 x 14 cm with a single drill hole. [*Translators note: this suggests that the connections were not drawbored.*] The test specimens, made from freshly-cut oak timber *Eichenkantholz* (DIN 1052-medium quality) and dry spruce timber *Fichtenkantholz* (DIN 4074-S10), were assembled with mortise and tenon connections using two wood pegs. In order to provide the widest possible arbitrary range of specimen characteristics, the test specimens were fabricated by two separate carpenters in four different lots within a period of one-half year.

The test specimens are portrayed in Figs. 1a and 1b, including specimen dimensions that remained constant throughout all tests, and variable connection parameters named with letters. Variable connection parameters are the member sizes and the edge and end distances, which for each test series can be found in Table 1.

The pegs with diameters of 24 mm, 32 mm and 40 mm were machined from straight-grained oak. After one rough cut the oak was stored until equilibrium weight was achieved in the standard environment of 20°C and 65% Relative Humidity according to DIN 50 014.

Afterward strips were cut with a cross-section width a_n corresponding to the drill-hole diameter d, while the width a_n was reduced by 1 mm for the diameters d = 32 mm and d = 40 mm (Fig. 2a). In a second operation, the strips were brought from a square shape into a regular octagonal cross-sectional form (Fig. 2b). A concluding beveling of the cross-section edges, as well as a full wax coating, were applied to ease driving the wooden pegs into their holes.

The tests were conducted in accordance with DIN EN 26 891, "Timberframe Construction—Connections with Mechanical Fasteners—General Procedures for the Investigation of Load Bearing Capacity and Deformation Behavior," using motion-controlled hydraulic test cylinders (photo page 11) in conjunction with an electronic data acquisition system to record all essential measurement values. To better evaluate the failure, the mortise housing deformation was measured by means of an inductive displacement transducer perpendicular to the grain at the connection; also the deformation of the tenon was qualitatively observed.

3. Results. Typical failure modes in the tenon, pegs and mortise housing for the 90° connection, and in the side timbers for the 0° connection, could all be differentiated. These causes of breakage showed up either singularly or combined. The three failure modes for the 90° connection are depicted in the photographs on page 10. Shear failure of the side member for the 0° connection is shown in the photo on page 11.

The measured maximum load F_{max} according to DIN EN 26 891 for the 90° and 0° tests are plotted in Figs. 3a and 3b. In the graphs the range from the smallest to the largest maximum load for each test series is marked and is supplemented by the value listing. The accompanying mean value $\bar{F}_{max}$ of each series is marked by a circle. The influence of wood type on the load-bearing capacity of the wood peg connection can be recognized in Figs. 3a and 3b through the comparison of the series with identical connection geometry out of oak (*EI*) and spruce (*FI*)—that is, series *B* in Fig. 3a, series *C* in Fig. 3b.

Ten test specimens of the 90° connection from different series were preloaded while green to 40 percent of the estimated maximum load. The purpose was to load the specimens to failure after a seasoning period of 100-321 days. The results show that the wood moisture content has no clear influence on the load-bearing capacity of the wood peg connections.

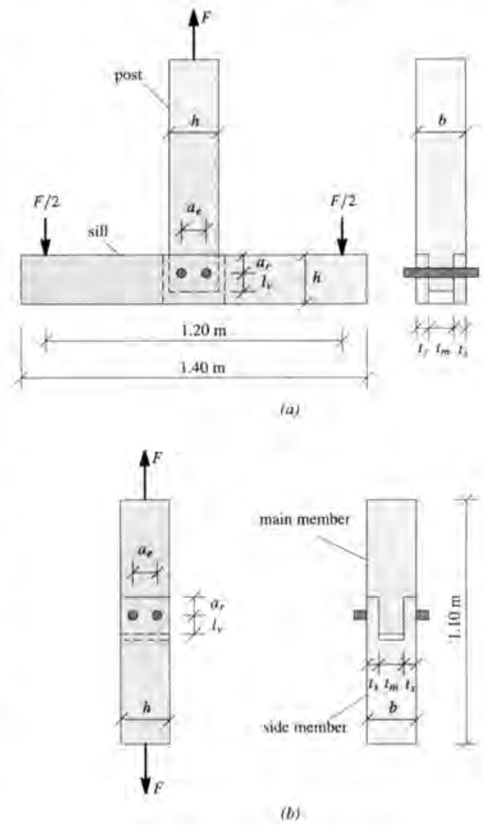


FIGURE 1: TEST SPECIMENS, DIMENSIONS IN METERS
(A) 90° CONNECTION, *(B)* 0° CONNECTION

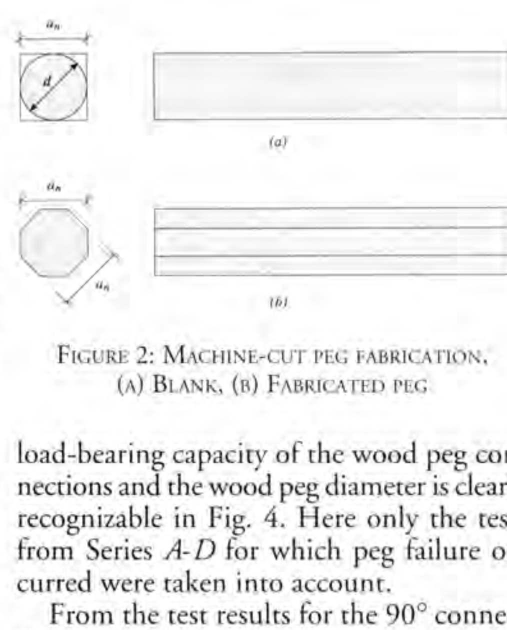


FIGURE 2: MACHINE-CUT PEG FABRICATION, (A) BLANK, (B) FABRICATED PEG

The expected relationship between the load-bearing capacity of the wood peg connections and the wood peg diameter is clearly recognizable in Fig. 4. Here only the tests from Series *A-D* for which peg failure occurred were taken into account.

From the test results for the 90° connection, significant influences of the connection parameters on the load-bearing capacity and on the cause of breakage could be deduced. To illustrate this, Table 2 shows an overview of causes of breakage for Series *A-D* without differentiating among the three peg diameters.

From the number of breaks in the tenon, mortise housing, and peg, it is clearly recognizable that the edge and end distances for series *B* and *C* led to an even distribution in the type of failure of the connection, involv-

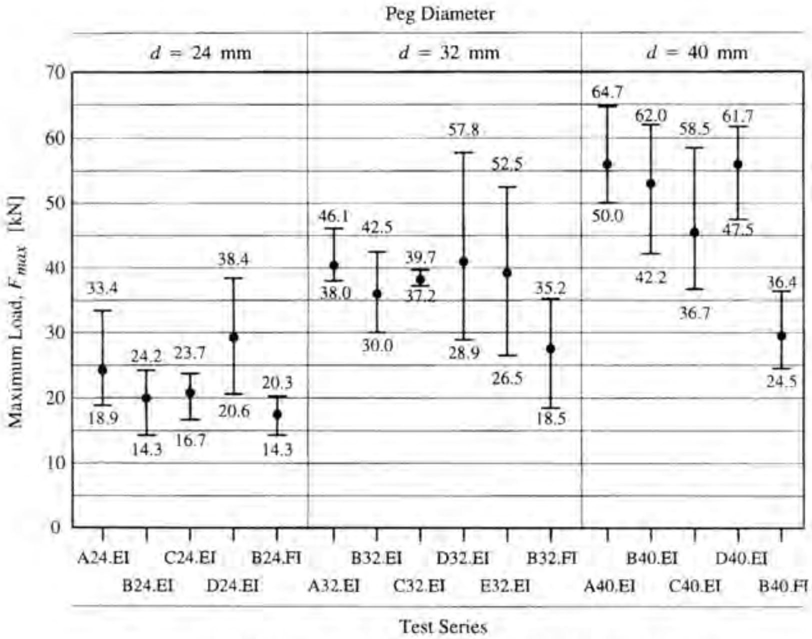


Figure 3a: Smallest and largest maximum load F_{max} and mean value $\bar{F}_{max}$ for the 90° connection.

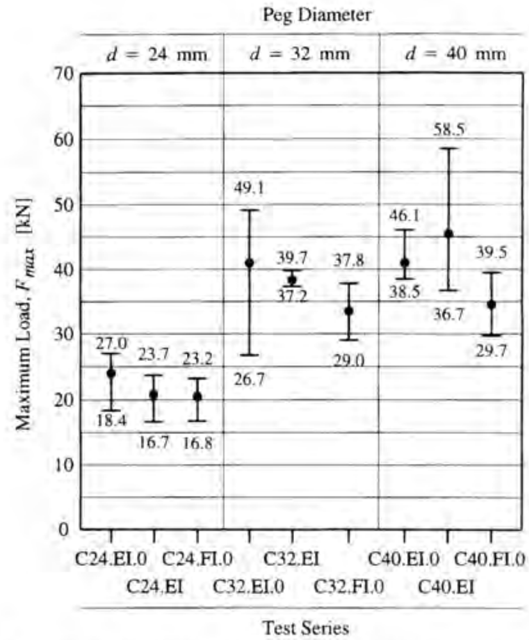


Figure 3b: Smallest and largest maximum load F_{max} and mean value $\bar{F}_{max}$ for the 0° connection.

ing all three types of breakage. In contrast, the load-bearing capacity of the tenons in test series *A* and the load-bearing capacity of the mortise housing in test series *D* were barely reached because of the chosen edge and end distances, even though the mean maximum loads $\bar{F}_{max}$ for these series were greater than those for series *B* and *C* (see Figure 3a) for each diameter group.

A comparison of series *B* and *C* shows that, tied to the mortise edge distance $a_r = 1.5d$, is an increase in mortise housing failures, and for the diameter group $d = 40$ mm a reduction in load-bearing capacity.

Test Series	Peg (# x *d*)	Connection Angle (deg.)	Member Dimensions h	b	t_s	t_m	Distances a_r	a_e	l_v	# of tests
A24.EI	2 x 24	90	140	140	45	50	2.0*d*	2.0*d*	2.0*d*	5
B24.EI	2 x 24	90	140	140	45	50	2.0*d*	1.5*d*	1.5*d*	5
C24.EI	2 x 24	90	140	140	45	50	1.5*d*	1.5*d*	1.5*d*	5
D24.EI	2 x 24	90	160	140	45	50	3.0*d*	2.0*d*	2.0*d*	5
B24.FI	2 x 24	90	140	140	45	50	2.0*d*	1.5*d*	1.5*d*	5
C24.EI.0	2 x 24	0	140	140	45	50	1.5*d*	1.5*d*	1.5*d*	5
C24.FI.0	2 x 24	0	140	140	45	50	1.5*d*	1.5*d*	1.5*d*	5
A32.EI	2 x 32	90	180	200	60	80	2.0*d*	2.0*d*	2.0*d*	5
B32.EI	2 x 32	90	180	200	60	80	2.0*d*	1.5*d*	1.5*d*	5
C32.EI	2 x 32	90	180	200	60	80	1.5*d*	1.5*d*	1.5*d*	5
D32.EI	2 x 32	90	200	200	60	80	3.0*d*	2.0*d*	2.0*d*	5
E32.EI	2 x 32	90	160	140	45	50	2.0*d*	1.5*d*	1.5*d*	5
B32.FI	2 x 32	90	180	200	60	80	2.0*d*	1.5*d*	1.5*d*	5
C32.EI.0	2 x 32	0	180	200	60	80	1.5*d*	1.5*d*	1.5*d*	5
C32.FI.0	2 x 32	0	180	200	60	80	1.5*d*	1.5*d*	1.5*d*	5
A40.EI	2 x 40	90	180	200	60	80	2.0*d*	2.0*d*	2.0*d*	5
B40.EI	2 x 40	90	180	200	60	80	2.0*d*	1.5*d*	1.5*d*	5
C40.EI	2 x 40	90	180	200	60	80	1.5*d*	1.5*d*	1.5*d*	5
D40.EI	2 x 40	90	200	200	60	80	3.0*d*	2.0*d*	2.0*d*	5
B40.FI	2 x 40	90	180	200	60	80	2.0*d*	1.5*d*	1.5*d*	5
C40.EI.0	2 x 40	0	180	200	60	80	1.5*d*	1.5*d*	1.5*d*	5
C40.FI.0	2 x 40	0	180	200	60	80	1.5*d*	1.5*d*	1.5*d*	5

Table 1: Test program, lengths in [mm].

4. Design Recommendations. The edge and end distances are optimally set when all the failure strengths are reached simultaneously. According to Table 2, series *B* fulfills these requirements best and is therefore the basis for the recommendations cited in Table 3 for the permitted tension load F^* of the wood connection from oak or spruce with a 90° connection angle and two oak pegs in double shear for short-duration loads.

Series	Number of Breaks in: Tenon	Mortise	Peg
A	3	10	9
C	7	7	9
B	8	11	9
D	11	1	15

Table 2: Number of breaks in the tenon, mortise housing, and peg for oak tests. Connections with 90° angle.

In Table 3 (overleaf) the recommended permissible tension load F^* was determined as the minimum value of the following three quantities:

- Mean value $\bar{F}_{max}$ of the maximum loads F_{max} divided by factor of safety of 3.
- Mean value $\bar{F}_{1.5}$ of the loads at a connection displacement of 1.5 mm.
- Minimum value $F_{max,min}$ of the maximum load F_{max} divided by factor of safety of 2.25.

The initial displacement modulus k_i (according to DIN EN 26 891) given in Table

3 can be used as the displacement modulus C in the sense of DIN 1052. [*Translators note: The term "initial displacement modulus," which is the literal translation of the German word "Anfangsverschiebungsmodul," is assumed to be synonymous with "initial axial stiffness."*]

—Martin H. Kessel and Ralf Augustin

Prof. Dr.-Ing. M.H. Kessel is Director and Professional Engineer, and Dipl.-Ing. R. Augustin is Co-worker, at the Laboratory for Wood Technology, Technical University Hildesheim/Holzminden, Germany. *This article first appeared in German in the journal* bauen mit holz *(Building with Wood), pp. 484-487, June, 1994, published by Bruderverlag, Karlsruhe. The article was translated by Matthew D. Peavy, Undergraduate Research Assistant, Department of Civil and Architectural Engineering, University of Wyoming at Laramie (WY 82071) and Richard J. Schmidt, Associate Professor in the department (schmidt@uwyo.edu). A previous article on pegged connections by the same authors and translators appeared in TF 38.*

Peg Dia. (Oak)	Minimum Spacing a_r	a_e	l_v	Wood Type	Minimum Dimensions b	t_s	t_m	$\overline{F}_{max}/3$	$\overline{F}_{1.5}$	$\overline{F}_{max,min}/2.25$	F^*	Initial Axial Stiffness k_i
24	48	36	36	Oak (Eiche)	140	45	50	6.7	16.4	6.4	6.4	20
32	64	48	48		200	60	80	12.2	26.5	13.3	12.2	24
40	80	60	60		200	60	80	17.4	40.3	18.8	17.4	32
24	48	36	36	Spruce (Fichte)	140	45	50	5.8	11.0	6.4	5.8	8
32	64	48	48		200	60	80	9.0	16.6	8.2	8.2	8
[mm]	[mm]	[mm]	[mm]		[mm]	[mm]	[mm]	[kN]	[kN]	[kN]	[kN]	[kN/mm]

Notes: The standard gross density of oak pegs must meet a minimum value of 570 kg/m^3 (35.6 lbs/cu. ft.).
One in. equals 25.4 mm.
One kiloNewton (kN) equals approximately 225 lbs.

Table 3: Recommended allowable load F^* for the 90° connection angle with two wood pegs according to Figure 1a for short-duration loads (additional loads according to DIN 1052).

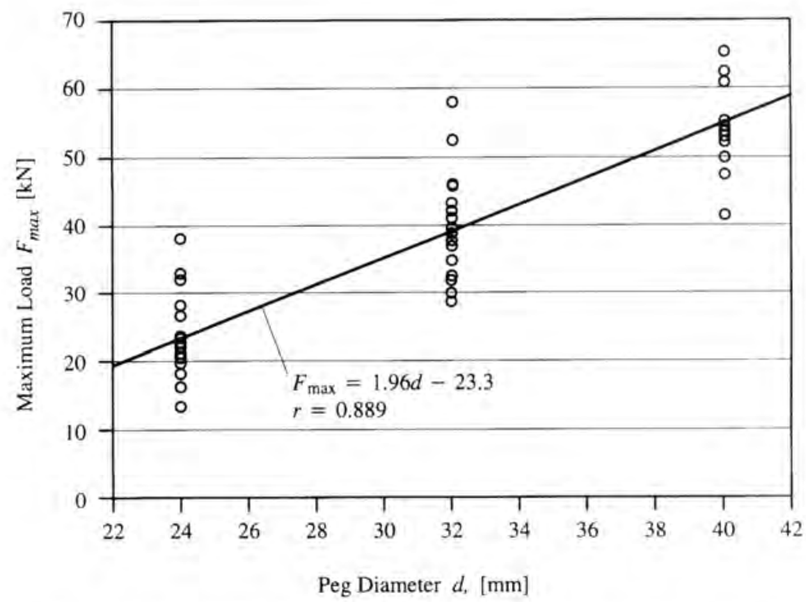


Figure 4: Relationship between maximum load F_{max} and peg diameter d from the series *A-D* with peg breaks.

Mortise housing break, 90° connection.

Peg break (left) and shear break in the tenon, 90° connection.

References

1. Kessel, M. H., *Investigations of the Load Bearing Capacity of Wooden Peg Connections* (*Preliminary Tests*), Laboratory for Wood Technology LHT, Technical University, Hildesheim/Holzminden. Report 2/1987.
2. Ehlbeck, J. and Hättich, R., "Load Bearing Capacity and Deformation Behavior of Wooden Pegs Loaded in Single and Double Shear," *Preservation of Historical Buildings* (monograph), Special Research Area #315, University of Karlsruhe, Yearbook 1988, pp. 281-298.
3. Kessel, M. H. and Augustin, R., "Investigation of the Load Behavior of Wood Connections with Oak Pegs," *bauen mit holz* (*Building with Wood*), Vol. 92, pp. 246-250, April 1990.

Photos Ralf Augustin

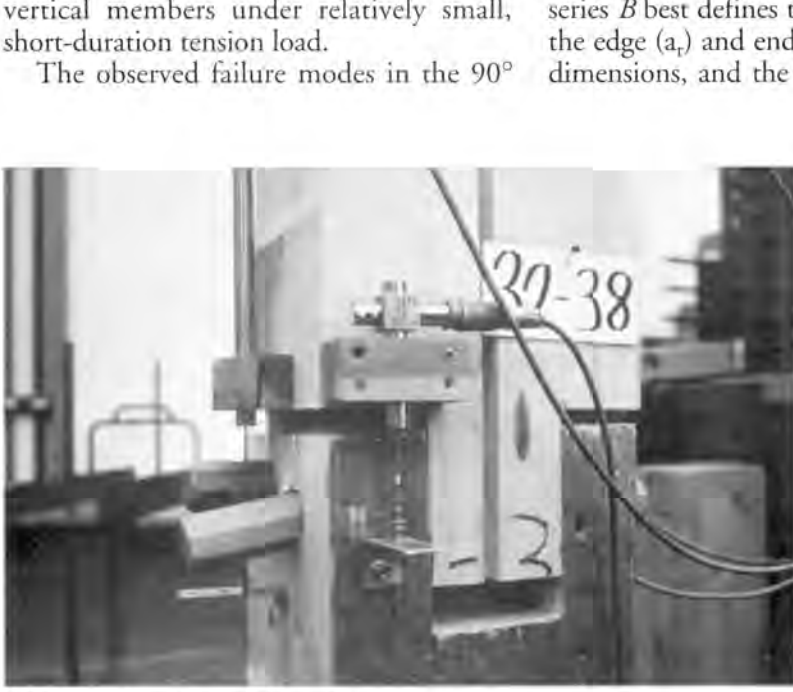
Hydraulic test apparatus.

Commentary

CONSISTENT with his previous research (see *TF* 38, December 1995, for a translation of that work), Dr. Kessel focused his attention on relatively large-diameter (roughly 1-in. to 1½-in. diameter), machine-cut, octagonal pegs. The 90° specimens (Fig. 1a) were of primary interest to Dr. Kessel and he tested 80 such specimens. The practical use for a joint with a 0° connection angle (Fig. 1b) is not explained. However, this detail might find use as a splice for long, vertical members under relatively small, short-duration tension load.

The observed failure modes in the 90° specimens (relish failure in the tenon, peg bending failure and cross-grain tension failure of the mortised member) were consistent with those seen in U.S. tests by Ben Brungraber. However, it seems that Dr. Kessel did not observe the outward bending failure of the mortise cheeks caused by prying of the pegs. Since he used relatively large-diameter (and hence, stiff) pegs, it is reasonable to expect that the bearing stress between the pegs and the mortise cheeks would be more uniformly distributed across the bore hole in the mortise cheek than when smaller-diameter, more flexible pegs are used. The bearing stress between a smaller peg and the mortise cheek would be concentrated near the inside mortise face.

Dr. Kessel uses the term *optimal* to describe the set of joint proportions that produce a *balanced design*. Due to the relatively high variability in material properties of wood, a joint designed according to Table 3 is just as likely to experience a peg failure as a mortise failure or a tenon failure. Dr. Kessel feels that, for his research, the optimal design of a tension joint is one in which all strength limits are reached at the same time. Of the 20 oak specimens in test series *B*, eight tenon failures, 11 mortise failures and nine peg failures occurred. (The total number of failures exceeds the number of specimens because multiple failure modes were observed in individual specimens.) So, series *B* is used as the basis for the design recommendations. By restricting himself to the series B data, only results from 30 specimens (20 oak, 10 spruce), or 38 percent of his test data, were used to develop his recommendations for design tensile strength and stiffness. Whereas this approach might appear to ignore substantial data, it is in fact a reasonable way to establish minimum design criteria. That is, for a given peg size, series *B* best defines the *minimum* values for the edge (a_r) and end (l_r) distances, member dimensions, and the attendant design loads given in Table 3.



Side member shear failure, 0° connection.

To use Table 3 in design-office practice, a required joint capacity is determined by structural analysis and the peg size is selected. Then, the minimum joint proportions that correspond to that peg size are checked. If any of the required proportions cannot be satisfied, the design strength F^* cannot be used and the joint, and possibly the frame, will have to be redesigned. If all proportions listed in Table 3 are just satisfied, a balanced design is achieved. Clearly though, edge/end distances and member sizes can exceed those listed in the table without adversely affecting joint performance.

IN most cases, structural design of buildings does not follow the balanced design concept. Balanced design is more common in structures such as aircraft and spacecraft in which minimum weight is a principal design criterion. Instead, buildings are usually designed according to the *weakest-link* concept. Each of the various failure modes can be regarded as a link in a chain that holds the structure together. It is not necessary that all links have the same strength (a balanced design). Instead, the weakest link in the chain need only be strong enough to carry the expected loads.

In the event that the designer regards one failure mode as *less desirable* than another (such as a brittle relish failure compared to a ductile peg failure), that link in the chain can be designed with a larger factor of safety than the other. This philosophy suggests that only certain failure modes are acceptable as the weakest link. However, in light of the high variability of material properties, it might not be realistic to suggest that the designer has such tight control over the structure's behavior.

The applicability of Table 3 to mortise and tenon joint design is certainly limited to oak and spruce members with oak pegs. Unfortunately, the subspecies of oak or spruce is not specified so it is unknown whether the recommendations are generally applicable across the species group. The data for spruce might be extrapolated to other softwoods using correction factors that adjust for specific gravity of the species.

Current practice for joint design in the United States follows the AFPA *National Design Specification for Wood Construction*, which uses a yield model approach for connections with steel bolts or dowels. That is, the strength of a joint is determined from an equilibrium analysis of possible joint failure modes and uses basic material properties (mainly dowel bearing strength of the surrounding wood and yield strength in bending of the fastener) as input. This is a general approach that should be applicable to any combination of dowel (in this case, wood pegs) and timber member. Dr. Kessel's work is not cast in the form of the yield model. However, until the yield model has been formally extended to include the relish failure mode and wood pegs as the fastener, Dr. Kessel's recommendations should be useful design guides. Dr. Kessel's results will also be valuable data for correlation to subsequent research in tension joinery for timber frames. — DICK SCHMIDT

Joint Engineering II

IN THE last issue of TIMBER FRAMING, we discussed engineering the joinery for joists to girders, girders to posts and braces to posts or beams. For our final example, we look at the traditional joint between common rafter and plate. This most basic roof system features 5x9 commons on 4 ft. centers, double-notched into an 8x8 plate (Fig. 1). Combined live and dead roof load (including rafter weight) is 45 lbs per sq. ft. (psf), measured on the horizontal plane. Apply this load over a 4-ft. swath and you get a line load per rafter of

$$48 \text{ in} \times 45 \text{ psf} \div 144 \text{ in}^2 = 15 \text{ lb/in}.$$

Factoring in the rafter run of 168 in. (remember that we're dealing with a vertical load distributed on a horizontal plane) yields a total plumb load of

$$f_y = 168 \text{ in} \times 15 \text{ lb/in} = 2{,}520 \text{ lbs}.$$

For the purposes of this discussion, we ignore roof overhang. There being no other place for it to go, all of this gravity load lands on the plate (absent kingpost or ridge, the peak joint can't deal with vertical load). So each common rafter deposits a ton and a quarter of gravity load on the plate. But as we all know the rafter—unrestrained by collar or tie beam—also pushes out as well as down. How to quantify this roof thrust?

To sort out this question we need to go back to basics, to the laws of static equilibrium.

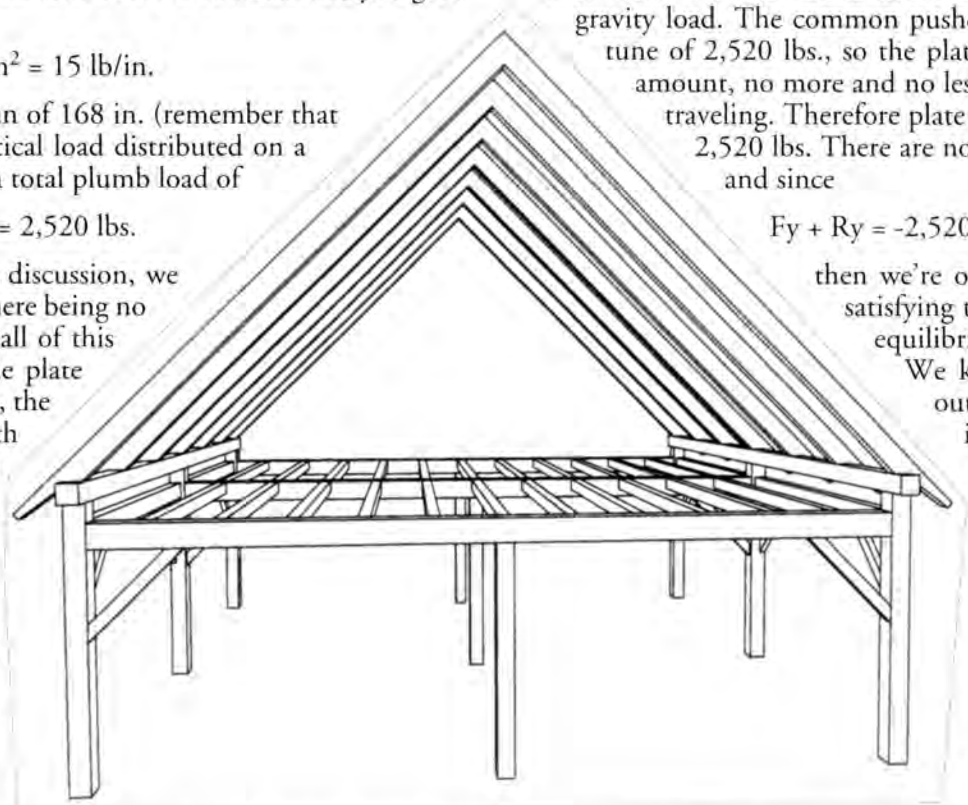


FIG. 1. MODEL HOUSE FRAME. RAFTER RUN (HALF-SPAN) IS 14 FT.

Take a body at rest, say a timber frame. If it remains at rest when acted upon by a force or system of forces, the frame is said to be in a state of *static equilibrium.* This equilibrium comes in two flavors: translational and rotational. That is, to remain at rest, all the forces acting on the body must sum to zero so that it does not move, and any moments acting on the body must also zero out so that it does not spin.

While our frame is three-dimensional, we can reduce a rafter pair bearing on the plate to a planar (two-dimensional) structure since there are no forces acting in the Z direction. Specifically, in a planar structure, translational equilibrium requires that the sum of all forces in the X and Y directions equal zero

$$\Sigma F_x = \Sigma F_y = 0,$$

and rotational equilibrium is satisfied if moments around the Z-axis sum to zero

$$\Sigma M_z = 0.$$

How does this help us? Let's focus on the common rafter. When we achieve the stasis we're looking for, not only is the frame in equilibrium, but so are all of its parts. We can isolate the common rafter (in what is called a free-body diagram, Fig. 2), knowing that the forces and moments on the individual rafter add up to zero, otherwise it would be moving or spinning.

So what are the forces and reactions on the rafter? We learned above that it carries a line load of 15 lb/in taken over 168 in. for a total gravity load of 2,520 lbs. The effect of a distributed load on a body is equivalent to a single force vector summing that load and acting through its center of mass. In our rafter free-body diagram we express the load on the common rafter as a 2,520 down vector at midspan (Fig. 2) denoted as $F_y = -2{,}520$ lbs.

What are the other forces in the system? There is no other load on the rafter, so remaining forces take the form of reactions to this roof load. We established above that the plate carries all the gravity load. The common pushes down on the plate to the tune of 2,520 lbs., so the plate must push back the same amount, no more and no less or else our rafter would be traveling. Therefore plate vertical reaction equals R_y = 2,520 lbs. There are no other Y-forces on the rafter and since

$$Fy + Ry = -2{,}520 \text{ lbs} + 2{,}520 \text{ lbs} = 0,$$

then we're one-third of the way toward satisfying the three conditions of static equilibrium on our planar structure.

We know that the rafter thrusts out (and the plate pushes back) in the X direction. We don't know how much, but we do know that the horizontal plate reaction must be paired with an equal and opposite horizontal reaction, and that this can only come from the opposing rafter at the peak.

So all the cards are now on the table, albeit some of them still face down. On one side of the table, we've got the original roof load as $F_y = -2{,}520$ lbs, on the other side the known plate vertical reaction of $F_y = 2{,}520$ lbs and the two unknown horizontal reactions at plate and peak. To break the logjam, we go to the third equilibrium equation and solve for net moment around the rafter foot. We know it has to be zero (otherwise we'd be in a spin) and we know there are three possible sources for the terms of the equation: reactions at the plate, load at midspan and reaction at the peak. But since we're measuring moment at the rafter foot, the plate makes no contribution. (Moment is torque caused by a force acting at a distance, and all the force in the world can't impart a spin with a zero lever arm.)

Therefore we have to contend only with the forces at midspan and peak, which can be accounted for as follows:

When calculating moments, lever arms are always measured at right angles to the direction of force. So, with a pivot at the plate, the horizontal lever arm for the midspan vertical load is 7 ft. and the vertical lever arm for the horizontal peak reaction is 14 ft. (Fig. 2). By convention in free-body diagrams, counterclockwise moments have positive sign, clockwise ones are negative, so if the unknown horizontal peak reaction is R_{xp}, then at the foot

$$\Sigma M_z = (R_{xp} \times 14 \text{ ft}) - (2{,}520 \text{ lbs} \times 7 \text{ ft}) = 0$$

and

$$R_{xp} = 2{,}520 \text{ lbs} \times 7 \text{ ft} \div 14 \text{ ft} = 1{,}260 \text{ lbs}.$$

In other words, the thrust in our 12:12 pitch roof is one half the gravity load.

If you'd rather avoid the math, there's a neat graphical solution the this problem, based on the following axiom: To achieve rotational equilibrium in a planar system ($\Sigma M_z = 0$) all forces in the system *must act through a single point,* otherwise a net moment results. It takes a minute of two for this to sink in. (Draw arrows on a couple of slips of paper, oppose them on your desk and then try sliding them around. You'll get it.) To draw the figure on the free-body diagram, extend the vertical and horizontal lines of force from midspan and peak until they meet. This is the common origin of all forces in the system and a line connecting this point to the rafter foot gives the angle of attack of resultant force on the rafter which is then easily resolved into its separate X and Y components.

Whether you come at it by the algebraic or the graphical method, it's possible to generalize a principal about thrust in simple rafter roofs: *The resultant force always acts at an angle to the level whose pitch is twice the roof pitch.* So in a 12:12 roof the vector sum of thrust and gravity load is pitched at 24:12, in a 6:12 roof the resultant acts at 12:12, etc. Hence roof thrust can be quantified as follows: For simple rafter roofs (no collars, struts, kingposts, etc. to muddy the waters), with roof slope S (in degrees), the thrust is equal to the roof load divided by twice the tangent of the slope, or

$F_x = F_y \div 2 \tan S.$

Our 2,520-lb. roof load induces thrust of 1,260 lbs. in a 12:12 roof. In a 9:12 roof, the same load would impart 1,680 lbs. of thrust. Load and thrust would be equal in a 6:12 roof, and by the time you get down to 3:12 pitch, thrust has grown to 5,040, twice gravity load.

Getting back finally to our rafter seat, we can vector sum the vertical load of 2,520 lbs. and thrust of 1,260 lbs. to a force of 2,817 lbs. acting along the 24:12 line. Resolving this force into components parallel and normal to the roof plane, we find that axial force in the rafter is 2,673 lbs., shear force 891 lbs. (Fig. 2). Given a 3-in. deep rafter tenon in the notch (Fig. 3), bearing area for both the axial and shear forces is

$3 \text{ in} \times 5 \text{ in} = 15 \text{ in}^2,$

giving an axial bearing stress of

$2{,}673 \text{ lbs} \div 15 \text{ in}^2 = 178.2 \text{ psi},$

normal bearing stress of

$891 \text{ lbs} \div 15 \text{ in}^2 = 59.4 \text{ psi}$

and shear stress on the 5x9 rafter of

$f_v = 3V/2bd = 3 \times 891 \text{ lbs} \div (2 \times 5 \text{ in} \times 9 \text{ in}) = 29.7 \text{ psi},$

all well within acceptable limits.

With the 2,817-lb. net force delivered by the rafter to the plate and the latter's 64-sq.-in. cross-section reduced by the notch, plate shear can be calculated as

$f_v = 3V/2A = 3 \times 2{,}817 \text{ lbs} \div (2 \times 55.6 \text{ in}^2) = 76 \text{ psi}.$

One new concern. The rafter delivers its thrust near the top surface of the plate, which is in turn restrained on its lower surface (by post tenons). This 1,260-lb. force acting through a distance from the base of the plate imparts an overturning moment to the plate with troubling implications for the post to plate joint.

This is a tension joinery question beyond the scope of this article. Tension joinery deserves treatment on its own in a future article. So, for the moment we leave Pauline tied to the tracks, train whistle echoing in the distance. —Ed Levin

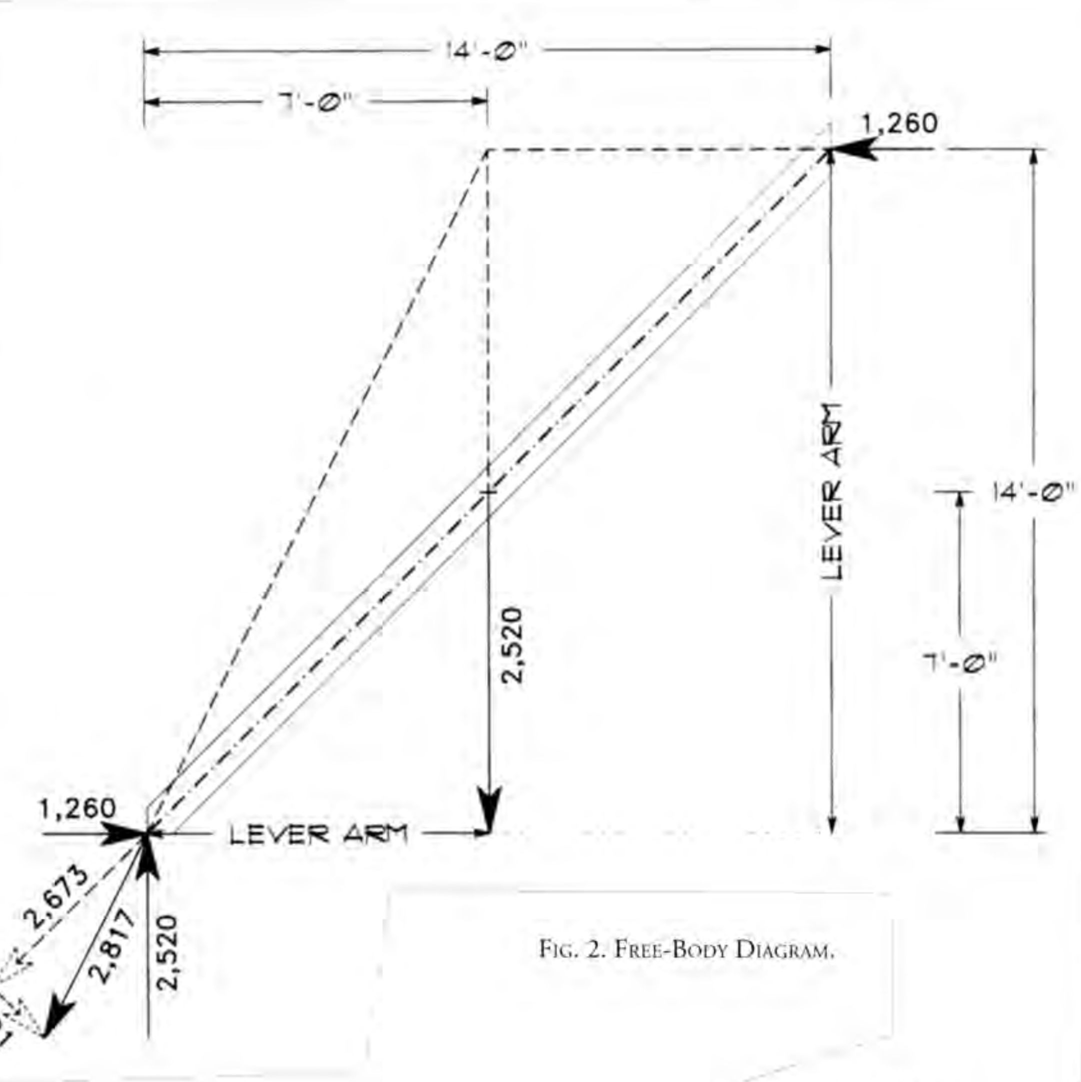
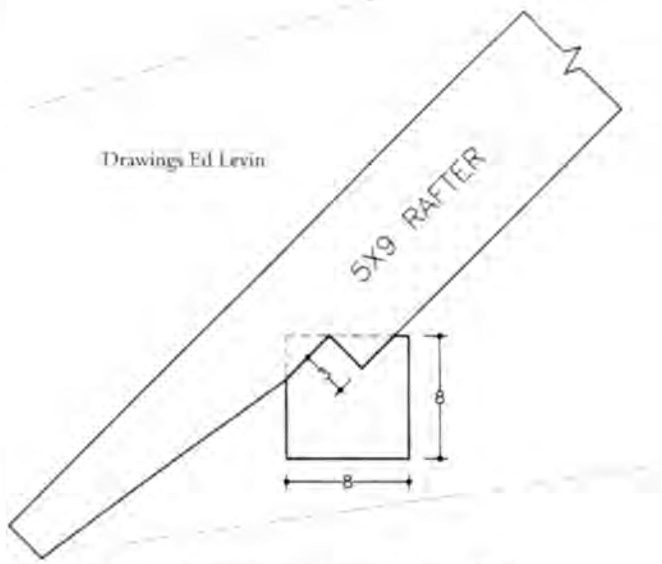


Fig. 2. Free-Body Diagram.



Drawings Ed Levin

Fig. 3. Section through Rafter Seat.

Spiraling Dragons: The First One

"Thus the constructions of culture, the moral and esthetic laws (*nomoi*) that we fashion and revere, though shot through with human frailty, ignorance and local variation, are actually fashioned in response to a divine presence always imperfectly known, but *there* to witness and measure the justice in our answer to its call."

—Dudley Young, *Origins of the Sacred*

ON THE morning that I was to meet my *oyakata*, or carpentry master, I sat in a large, very cold room in a Rinzai zen hermitage tucked into the hills just outside Nara. I sat and I waited. And I waited. . . and to pass the time, the priest poured tea and drew my attention to two scrolls hanging side by side in the *tokonoma*. On the left, a wash of ink and empty space depicted a dragon searing *up* through sky and cloud. On the right, another dragon (or the same one?) swept *down* into a misty sea. The priest made a spiral movement with his hand towards the two paintings and explained "there are always the *two* dragons, you see. Coming and going. Constant regeneration. . ." Eventually the carpenter showed up and I forgot all about the paintings for nearly the next three years.

But now the image comes back to me, from time to time, especially when I try to describe to others what I have come to see as the living pulse of carpentry here. Somehow, the craft has come to grips with this very simple, slowly spiraling dynamic of decay and renewal.

The dynamics which orchestrate the rise and demise of crafts traditions everywhere are, I believe, fundamentally identical. What differs is merely the *movement* of the uncountable cultural, psychological and economic forces involved. This movement is not precisely a wave shape or a circle, for two movements are always occurring simultaneously; for every going there is a coming round.

The traces of a *coming round* are ultimately a response to far more factors than we can ever fully inventory. Few of these factors are "personal" in any way. Armies march; craft just rolls. The Dragons themselves are entirely indifferent to the values we place on deterioration and re-generation. Theirs is but to propel the dynamic. Though they are wholly *human* and largely contemporary concerns, our willful acts of preservation and renewal gain much of their vitality from tapping into their antediluvian origins—*and may in fact succeed only to the degree that they once again assume their original mythic proportions.*

It is doubtful that the current practice of building most Japanese homes utilizing traditional timber frames will outlast the first decade of the coming century. I have no doubt that traditional building will survive in some fashion, but it will depend on the increasing use of imported energy and material, and costs will probably limit the traditionally-built home to the extremely rich or to unheartfelt commissions solely for the sake of display.

Photos Michael Anderson

The twin dragons hanging in the tokonoma of the hermitage in Nara.

The decline is now swift. The number of young people apprenticing to become the next generation's *daiku-san* has reached an all-time low, prompting government intervention at the local and national levels. Since the mid-80s, Japan has seen a large increase in the number of state-subsidized trade schools which aim to provide the education and manual training hitherto provided for by the traditional apprenticeship system. (Even 20 years ago, the idea of training carpenters in a *school* would have sounded like a joke. Several years ago, in Nara prefecture's Sakurai City, a school was opened called Tonkan Daiku Dojo, offering students both classroom and site training. The reactions of tradesmen in this city long famous for its wood and the carpenters who use it, were both mixed and amusing. It simply didn't make sense. Nobody had ever heard of apprentices studying in schools!)

Unless craftsmen work only for other craftsmen, what prevails over their destiny is not craft itself, but the attitude with which the rest of the world regards them and their product. Japan's overall attitude with regard to the preservation of its so-called "traditional" culture is best described as melancholic resignation. A simultaneous barrage of influences ranging from domestic to international to acts of God seems to have the old on the run. Most fear the worst, anticipating the virtual "museumization" of the vast bulk of the country's historical culture. Architecture stands to figure highly among the coming museum's exhibits. (Or perhaps, as an ultimate extension of the *minka-en*, or living outdoor folkhouse museums, the architecture will be its own museum, that is, more than a little *dead.*)

This situation is by no means unique to Japan. In the world at large, lurks a vague sort of craft-angst. We fear that our work will be more informed by the machine than the human hand and its allied sensitivities. Will a once lively architecture succumb to merely mechanical reproduction? And if it does?

Though understandable, this fear has little to do with the machines "out there," loose in the world of computer automation, faceless production systems or drudging mechano-slavery. In truth, power tools and discreetly applied mechanical production methods have done far more for *preserving* the traditional architecture than any other factors in the 20th century. Without these aids, traditional architecture would have been economically unfeasible and probably would have completely died out decades if not a half century ago or more.

Rather, it is the inner machine, the cogs and ratchets of ossified thinking, that leaves its mechanical stamp on the artifacts of otherwise human production. Indeed, in a very palpable sense, Japanese architecture had already succumbed to an uninspired mechanical way of thinking and—even a mechanical sort of working—some centuries *before* the first winds of the Industrial Revolution struck these shores. The first-time sojourner to Japan, distracted perhaps by the apparently unassuming intimacy of the natural materials and the unfamiliarity of the architectural forms, is not at first aware of this. He sees buildings which appear exotic and yet remind him of what he presumes to have lost in his own country. An extended stay is necessary for the deeper, mechanical quality to become apparent. For example, on the same day visit the potter Kawai Kanjiro's house in eastern Kyoto, then go to Katsura Rikkyu on the far west side of town. There is an icy sterility about the latter, more highly praised buildings which is wholly lacking in Kanjiro's rambling row house. At Katsura it is possible to detect as much if not more of a whiff of the mechanical than when standing at the foot of New York's Seagram Building. It should also be kept in mind that stultifyingly rigid codification and a binding orthodoxy were already at work in the Edo (1615-1868) and even earlier periods, largely in the interest of enforcing class differentiation.

If the machine is indeed the enemy, it has been in our midst and tampering with our dreams for longer than is generally acknowledged.

WHAT threatens the future of carpentry in Japan is a little different from what came about in the West. If only through sheer tenacity, Japanese carpentry weathered the industrial revolution quite well. It took over a century for rival building technologies to reach a point where they seriously threatened to replace timber framing as the dominant residential construction system.

The greatest threat is not North American-inspired 2x4 framing as was once feared, but prefabrication technologies pioneered right here in Japan. Unique panelization, lightweight steel frames and hybrid structural systems now offer the "look" of a traditional Japanese home and are gaining a rapidly widening wedge of the architectural pie.

Interestingly, cost performance is not necessarily what has turned the tables on traditionally built homes, as prefabricated housing is often *more*, not less expensive. Superficially, "industrial housing" casts itself as a solution to an architectural problem (low-cost housing), but one must be careful here, for any such highly capitalized venture usually exists primarily to serve a *production side* agenda. Industry (much like its societal counterpart, bureaucracy) is self-serving and self-*pre*serving; the business of industry is industry. By and large, the business of industrial housing is to serve the interests of its sub-industries, the steel suppliers, prefab component makers, hardware makers, and so on. Were the sincere aim actually to produce more, adequate, affordable housing, the solution would be sought *within the venue of currently existing production methods*: that is, change the way the carpenter works—don't *eliminate* the carpenter!

Assembling a typical house maker's steel-framed house.

What I see happening is a playing to the Japanese weakness for marketing and image manipulation. The streamlined sales tactics of the house *maker* (as opposed to the carpenter-architect setup referred to now as a house *builder*), seem to offer relief from the stress of dealing with architects and not knowing exactly what you're going to get.

To further understand the attraction of the house maker's product, one should note that, despite its "natural" appearance, what Japanese characteristically look for in traditionally-built wooden architecture is anything but natural. Material must be perfect and flawless (qualities not naturally found in wood); workmanship must likewise be uncannily precise and, again, flawless (qualities not naturally found in the work of the human hand). Ironically, what set the stage for this taste for the unnatural in architecture was the Japanese tea ceremony and its architecture which supposedly celebrated the naturally rustic, the simple and the unpretentious. But the rough post had to be *perfectly* rough, and in just the right way. The cedar used in the tea house had to be the very best cedar available. The workmanship demanded of the teahouse (modeled, by the way, after a peasant's farm hut) had to be galaxies beyond what a real peasant was capable of actually building.

The result of this is that many Japanese home buyers, to satisfy their expectation for machine-like workmanship and flawless materials, would rather purchase a manufactured home with the proper "look" than hire a real carpenter to use real wood and then have to suffer the indignity of living among knots, checks and a few paper-thin gaps in the joints. This is because economics has pushed the "real" orthodox tradition beyond the reach of the average income. *Affordable "traditional" architecture must re-define the standards by which it wishes to be judged, or relinquish its hegemony to industrially-produced "looks."*

As long as the look is fair enough, many Japanese are relatively satisfied. But here we touch on a problem perhaps more endemic to the Japanese culture than North America. The word "look" is enough to turn up many a North American nose. They don't want just the "look," they want the REAL THING! Such a reaction is less common in Japan, where the distinction between the so-called "real" and its myriad simulacra has been smudged beyond recognition, and, occasionally, even care. This is not entirely a criticism; in Japan, there is a long historical precedent for this, particularly in the arts, known as *mitate*: jellied candies masquerading as persimmons, miniature landscape gardens recalling distant Chinese vistas, and, most fascinating, *shoujin-ryori*, meals served at (vegetarian) Buddhist temples in which vegetable matter is prepared to mimic huge steaks, fish and other prohibited munchies. Japan is a country of surfaces. As long as the correct surface appearance of "traditional" architecture is maintained, surprisingly few people are overly concerned with whether the artifact is "real" to the core. The result is an atmosphere particularly favorable to the makers of industrial housing.

Real damage is only done when awareness of the deception is intentionally obliterated, thereby eroding the very source on which form depends for its meaning. There will no doubt be a "coming round" with regard to architectural fakery, but it will take perhaps a decade for dissatisfaction to set in, and then another decade for Japanese consumers (largely voiceless and advocateless) to convince manufacturers they deserve something better.

The damage inflicted by rival building systems goes further. The services which industrial house makers are able to provide have drastically changed what a client now also expects of traditional builders. In nearly all cases, before a client approaches an architect or builder for a custom-designed house, he has first approached (or been approached by) one of the large prefab operations. He has been shown completion schedules, material samples and colorful computer renderings which the small designer-builder cannot possibly provide his clients. (Some companies now provide the housewife with a pair of virtual reality goggles so she can experience her kitchen layout while still in the planning stages!) Chief among these new expectations is construction period. Twenty or 30 years ago, it was unthinkable to ask a builder to finish a traditional wooden home in less than about 10 months. Today, many clients would like to see the same home done in 5 to 6 months or less. The builders need work, and so they comply. The result? Cracked walls from improper plaster and stucco curing, poor woodwork from not being able to observe a joint's performance over a sufficient period of time, inadequate wood curing; the list goes on. To avoid having to go back to fix a problem resulting from a compressed construction schedule, traditional builders simply stop building anything which requires time—and this means just about all of the bag of tricks and adornments constituting his tradition. But compressed schedules do not imply reduced man-hours. These may in fact increase due to additional management needs, so the *time = money* equation is not itself responsible for eliminating "time-consuming" traditional work.

In time, things might have righted themselves towards an architecture earning its merit from intrinsic quality. *Might*, I say, were it not for the earthquake.

IN CHARACTERISTIC fashion, our first dragon reared his head in Kobe, early on the morning of January 17, 1995. While technically a geological event, a serious earthquake is experienced as an architectural phenomenon. The disruption of life and livelihood in the aftermath of a quake is by and large the disruption of the architectural continuum and the space with which it accommodates our lives. More bluntly, the earth merely shrugs; it is the falling building which kills. When the dust settles and all accounts are taken, our minds turn to rethinking the architecture. More than any other factor in recent Japanese history, it is this rethinking which will bring the biggest changes in Japanese wooden construction.

I have little doubt that history will record the death blow dealt orthodox traditional architecture as the 1995 Great Hanshin

Earthquake. (The Hanshin region includes Kobe and Osaka.) After righting the furniture and picking up all the broken glass, I went out on my balcony to watch the red glow of Kobe burning. It was so quiet, I thought for a moment the ground had sucked down all the sound waves. Within days, the word was out that it was the "traditional" homes that had collapsed, while those built with new prefabrication techniques or by the imported "2x4" method had escaped relatively unscathed. A week later, the subways were hung with advertising fliers bearing slogans like "*Takara prehaabu: anshin no ie!*"—Takara prefabs: the house for peace of mind!

While the damage of misinformation struck fast, it was at a typically Japanese pace—nearly two months—before research teams started to get at the real reasons for building failure (see *TF* 36). The common denominator in nearly all cases was building *age* rather than style or basic construction system. By and large, buildings built in the last ten years fared significantly better than older structures. Among these were a large number of prefabs and "2x4s." Also among them, though not figuring in the formation of public opinion, were a huge number of traditional structures, built to more recent earthquake-resistant standards.

But the damage was done. The argument could not have been more compelling (nor less informative): boxy shingle-roofed "Western" style buildings, miraculously intact, surrounded by piles of sticks crowned with the rubble of shattered gray roof tiles. The quake did more in five minutes towards promoting the industrial house makers' rival product than five years of fierce advertising might have.

Reconstruction statistics paint a dim prospect for traditional Japanese architecture in general and traditional framing in particular. In the most heavily hit areas (Chuo, Nada and Higashi-nada wards in Kobe, Ashiya and Nishinomiya, Hyogo Prefecture), nearly 80 percent of reconstruction is of houses officially designated as "totally destroyed." Though reports indicate that 90 percent of those rebuilding their quake-damaged homes are incorporating up-to-date standards (the remaining 10 percent are likely just those who have not had their houses inspected or have circumvented the usual channels for their building permits), a recent poll by the Yomiuri Shinbun revealed that only 57 percent of those rebuilding after the quake would build a traditional house.

Nearly 25 percent indicated they would build using the "2x4" method, citing its purported superior earthquake resistance. Studies also revealed a dramatic 450 percent increase in the number of light-weight steel or reinforced concrete residences in the quake-stricken area.

This trend is likely to self-propagate, as children generally grow up to build homes similar to the ones they grew up in, it is likely that the number of pre-fab or industrial housing starts will continue to climb in the future, even if not for directly economic reasons. Growing up in these houses with little or no basis for comparison may engender a genuine liking (or at least a comforting sense of security and familiarity) and therefore a not entirely rational preference for the house maker's wares.

Those who opted to rebuild traditionally have, however, taken the new precaution of attaching full surface plywood or composition boards as exterior sub-sheathing (a technique borrowed from 2x4 construction), more diagonal bracing and lighter roofing materials. The traditionally-constructed tile roof will probably suffer the greatest decline. (It was reported that, days after the quake, while stock in construction companies rose sharply, stock in roof tile makers plummeted.) Of 107 rebuilt homes investigated, only six will have the tiles set in mud as they were before the quake. Throughout the Kansai, older houses whose frames may have remained fully intact often suffered roof failure due to the enormous weight not just of the tiles, but of the mud used to set them. New houses with copper-nailed roof tiles fared considerably better without all the mud weight to sway about during the temblors.

The issue of diagonal bracing in traditional Japanese architecture is an interesting one. Historically, it simply wasn't used much until the middle of the 20th century. On my inspection tour of Kobe following the quake, I even found houses that were built only 20 years ago which still employed the traditional system of horizontal *nuki* bracing let in between posts. Heinrich Engel in his renowned book *The Japanese House: a tradition for contemporary architecture*, (Charles E. Tuttle Co.), claims the rejection of the diagonal was not made for aesthetic reasons, as is often suggested, but rather because the country's "historic lack of inventiveness proved to be too strong to overcome." Recently, however, some "modern traditional" timber frames attempt to reconcile diagonal members with the traditional aesthetic of revealing most if not all of the main structural members. The results are rarely pleasing to the eye, as this usually means moving the normally-hidden sill-to-top-plate diagonal brace closer to the face of the revealed posts. The resulting floor-to-ceiling slanting member hardly seems comfortable among its rectilinear elders. The more balanced-looking, aesthetically-pleasing knee braces found in western timber framing have yet to make any serious inroads into the Japanese tradition except in cases where the builder is consciously attempting a "Western look." Revealed structural cross- or X-bracing is found occasionally but this too sits poorly in the Japanese line of sight. The X symbol, called *batsu,* in Japanese means (as it does, though less intensely, in the West) "NO! Stop that!" One of I. M. Pei's buildings in Hong Kong was rejected by a Chinese *feng shui* (geomancy) expert on the grounds that its structural frame consisting of numerous huge steel Xs would hinder the path of the dragons though the city, bringing ruination on the heads of the building's occupants. Pei overcame this problem without changing the design. "These are not Xs," he explained, "it's these holes here we should be concerned with. See, they're diamond-shaped, and that's very *good*!"

IN RAPIDLY-evolving contemporary Japan, a great deal of cultural unraveling is conveniently (and incorrectly) ascribed to the corrosive effect of Westernization. Having spent a long decade living in the so-called East, I can say with some authority that the West takes more blame than its proper due with regard to Westernization of the non-Western (wherever or whatever *that* is). Much of what gets branded as Western influence is domestically grown: the inevitable result of embracing such things as greed, function over aesthetics, heavy-handed management techniques, maximization of building size for minimum cost and so forth. Such narrow-sightedness is by no means only Western. It is endemic to all societies and arises, at least in large part, *internally.*

Similarly, it is assumed that the influx of foreign building styles has lead to the decline of traditional carpentry techniques. Not so. One need only look at the western style buildings built in the Meiji and Taisho periods (1868-1912 and 1912-1926) to see that even very elaborate imported styles posed and pose no serious threats to the local carpentry tradition. These structures, most notably Tokyo's Sogakudo music school (1889), a western Classical Revival style building complete with cornices, cupolas and elaborately sculpted moldings, posed little challenge to the Japanese carpenters of the day. For all practical purposes early Western-style buildings were constructed using all traditional Japanese carpentry techniques, right down to the timber frame skeleton. The decline of carpentry skills in Japan is likewise a domestic problem. I would place the blame squarely on the shoulders of the Japanese architects. As most carpenters no longer design their own buildings, they can only teach their apprentices techniques required by the architect's plans. Architects have little or no knowledge of traditional woodworking, and so hand in plans wholly lacking in the richness and nuance the carpenter's own designs might have (and certainly *would* have if the master carpenter is conscientious about teaching his apprentices).

Similarly, many Japanese see the squarish boxiness of contemporary housing as the Westernization of the Japanese residence. In reality, this is the result of shrinking building lots and expanding needs for space. Square houses are the result of building on square lots right up to the required setbacks —clearly the influence of Japan on Japan.

AT A MORE subtle level, the deterioration of the Japanese tradition can be traced to the introduction of prefabricated building components or *kiseihin*. Only 20 years ago, it was unthinkable to frame a building using the finest cypress and cedar without also providing the finest in traditional *tategu*.

Tategu are the doors, windows and sliding partitions which have always been constructed on principles and towards an aesthetic identical to that of the building frame itself. The fittings continue in an unbroken, smoothly-graded curve the local articulation of the frame itself—a curve which bends right into the very nature of material.

Faced with the impossibility of showing an uneasy client exactly what, say, a custom-made entrance door will actually look like, architects now simply reach for the catalogue. Now, even the finest homes are usually fitted out with aluminum sash and doors. While these too are very finely made, superior to most of what I have seen in North America, their proportions, feel and ambiance are informed by factors so outside of the sphere of most traditional wooden architecture as to have absolutely no connection, aesthetic or otherwise, with the rest of the building. As these are the sites of our most intimate physical relation with architecture, the corrosive effect of this misfit cannot be overstressed.

Makers meanwhile claim they are more durable and "cleaner." Recently, there has been a slight increase in the number of makers selling (or importing) wooden sash, but still this continues the cognitive separation of the building's frame from its openings. Other *kiseihin* makers offer ready-built *genkan* thresholds, entire ceiling packages, floors, wall units, even complete drop-in bathrooms. With the multiplication of off-site constructed architectural "units," the frame becomes ever more hyper-objectified. It becomes a "grand" element, within which the rest of the business of architecture must set to work. The spirit of a once holistic building tradition retreats from the details and now seeks its expression solely in the main structural frame. In this way, much of Japanese traditionally-framed architecture is rapidly coming to resemble current Western timber framing practices.

On both sides of the Pacific, a building's frame is now regarded as merely *part* of the architecture rather than as *the* architecture. In Japan the frame seems to be separating itself from the architecture. The progressive trends here are dominated by self-conscious attempts at delicate structural acrobatics, producing what I call "decorated birdcages." North America as well has not been immune to this tendency to aggrandize the skeleton. We might dub the American counterparts to the Japanese trend "fenestrated barns." By no means do I intend a blanket condemnation here. There are virtues to the self-conscious frame; for one, it is more easily separated from the building for later recycling. What I do find lamentable, however, is the loss of a great deal of richness and mystery when our bones are no longer cloaked in flesh and fiber, but merely "stress-skinned" to reveal as much of the skeleton as possible.

In Japan, this preoccupation with a building's frame as a hyper-distinct aspect of the architecture is thought-provokingly underscored by the recent adoption of the word *tinbaa fureemu* ("timber frame") to describe the new concoction.

For the first time in the history of Japanese house building, frame cutting is about to be regarded as a separate specialty. General contractors have found they can cut expenses by having their frames cut in the *inaka* (rural) areas where the *daiku-san's* daily rate is significantly lower than those working in the cities. In many cases, the quality of work is also higher in the countryside, probably due to the carpenters being exposed to more traditional frames during their apprenticeship.

Finally, a tremendously destructive effect has been inflicted on the tradition by popular ideas of cosmetic durability and "maintenance." The newness of this idea to the tradition canon is suggested by the adoption of the English word, pronounced *menteh* in Japanese. Prefab makers and makers of steel or reinforced concrete buildings have convincingly launched a highly successful campaign promoting the superiority of their products in terms of minimum upkeep and maximum longevity. This is a somewhat hollow sales point, given the fact that the average lifetime of most homes in Japan, regardless of their construction, is about two decades.

A thing is preserved not because it *can* last, but because we *want* it to last. We maintain only that which we deem worthy of maintenance; this is as true of our houses themselves as it is of the building traditions from which they were born.

—MICHAEL ANDERSON

This is the first part of a two-part article.

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