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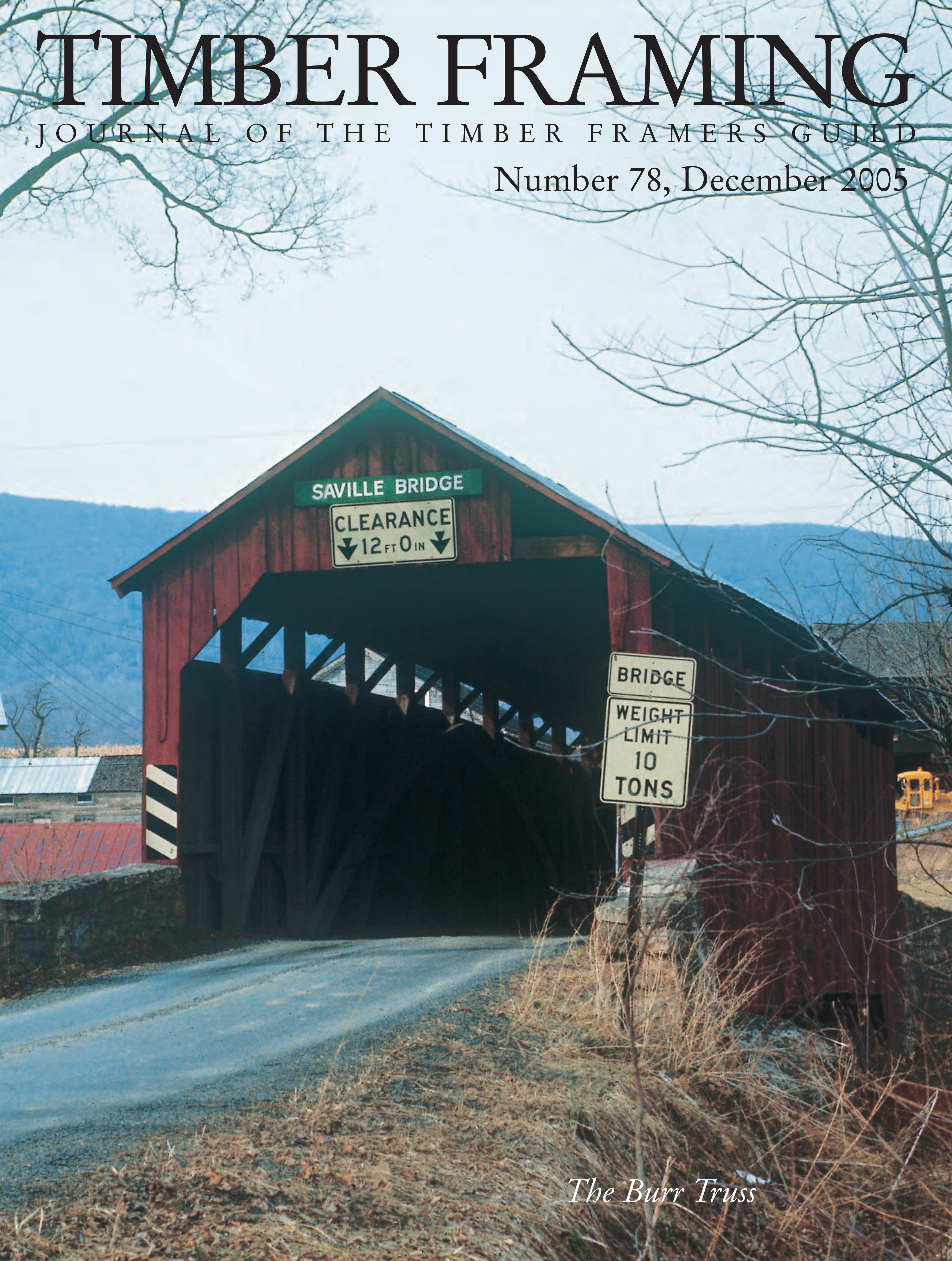

The Burr Truss

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On the cover, Saville Bridge carries traffic across Buffalo Creek in Perry County, Pa. The Burr truss bridge was built by L. M. Wentzel in 1903. Photo by Joseph D. Conwill, 1977. Article on Burr truss bridges, page 4.

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1985

TOPICS
French Rendezvous

THE only sounds that disturbed the tranquillity of the beautiful walled grounds of Château du Mesnil Geoffroy in Normandy were the solid thud of axe on oak and the rhythmic swish of two-handed saws. Some 30 carpenters, framers, architects, restorers, ethnologists and experts in historic buildings and traditional crafts gathered at Ermenouville, France, for a week in mid-September for the *Rencontres Charpentiers d'Europe,* organized by François Calame of the *Direction Régionale des Affaires Culturelles* for Haute-Normandie, and run by François with Axel Weller of Dresden, Germany. The aim was to begin restoration of two timber frames on the grounds of the 18th-century château, home of Prince Hany and Princess Anne-Marie Kayali. Both build-

Omission

In TF 77, "Introduction to Scribing 2," Will Beemer's list of workshop instructors under the cruck picture on page 9 omitted the name of Neil Godden. The author regrets the omission.

ings dated from around the late 17th or early 18th centuries, one thought to have been a workshop and the other a barn. Both showed the ravages of time and weather, especially on their south and west sides, as is common in Normandy. By the time we arrived, the roof tiles and some of the infill of both buildings had been removed. The oak frames sat on low brick and flint walls and were constructed, none too strongly it seemed to me, from a large number of relatively closely spaced posts. A main task in the restoration of both buildings was to replace the sills along their west gable ends. In addition, in the workshop building, new lower portions of the corner posts had first to be scarfed in. A start was also to be made on extending the purlins at the eastern end of the barn to build an overhanging roof protecting a new external staircase. This style of roof (photo at right) is common in the area, even on modern buildings, and looks most attractive.

Doug Miles

Once the wall plate had been securely jacked up, the posts were removed and laid out in sequence beside the building. François then marked these using a traditional French carpentry numbering system (photo back cover). The new sill was hewn from a single oak, mainly by Petr Růžička, master carpenter of Ars Tignaria Ltd. in Prague, and his young apprentice David Stejkal (photo below). Their skill with axes is such that one would have been hard pushed to achieve similar accuracy with a bandsaw. But this was equally true of many of the European carpenters, who made light work (it seemed) of reducing oak boles to dimensioned beams in a few hours.

Trunks hewn square were marked out to yield intermediate size timbers and set up on an above-ground equivalent of a pit-saw apparatus. Here the top sawyer balanced precariously on the wood being sawn, which was chained and wedged to protrude from a three-legged frame, while his companion, the pitman, worked from ground level. Ian Ellison of Cape Cod (pitman) and son Tanner (photo facing page) made one such team. The speed and accuracy achieved by some sawyers was phenomenal.

Once the new sill had been mortised, it was fitted temporarily into position so that the tenon shoulders on the lower ends of the posts could be scribed and cut. Although some of the original posts appeared superficially to be in poor condition, I was surprised how sound the oak was a few millimeters below the surface. The final installation of the sill and posts required considerable coordination among a large team of people, and not a little brute force. One end of the sill was lashed in its more-or-less-correct position while the other rested on temporary packing well below the correct height. The 20-odd posts were fitted into it and steadied in their mortises by the band of helpers. The free end of the sill was then slowly levered upward. As it was raised, the upper tenons of the posts were jiggled in sequence into the corresponding mortises in the wall plate. A couple of attempts were needed because of uncooperative joints. Finally the free end of the sill could be packed to its full height, ready to be pegged to the corner post. —Doug Miles

Doug Miles (doug.miles@ntlworld.com) is a member of The Carpenter's Fellowship (UK). This article appears simultaneously in longer form in the British carpentry journal The Mortice and Tenon, *available through the Guild Website.*

Burr Truss Bridge Framing

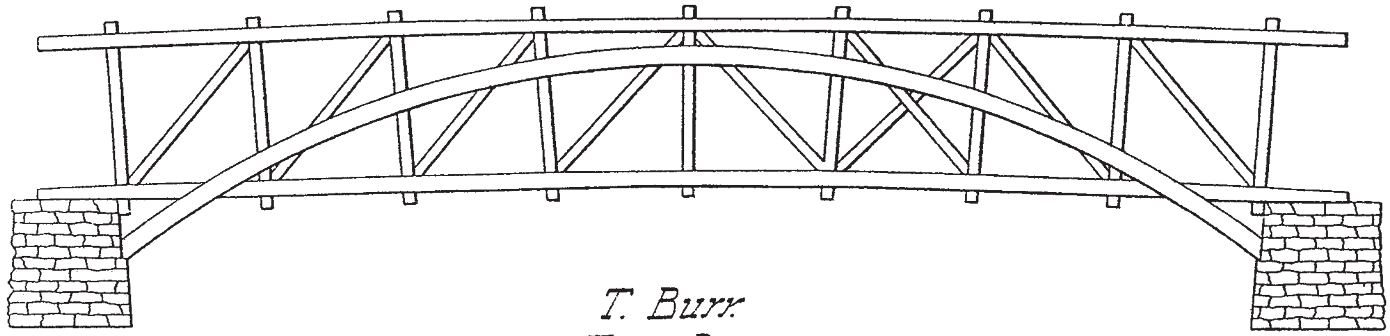


Fig. 1. Theodore Burr's 1817 patent drawing (label relocated).

COVERED bridges offer some of the most sophisticated examples of traditional American timber framing. They were labor intensive to build, and skilled labor was not always easy to find in the rapidly expanding United States of the early 19th century. Many designers tried to eliminate traditional joinery using various modern connections, but others kept with the old ways.

Theodore Burr (1771-1822) was one of America's premier bridgewrights. He began his career experimenting with several modernized designs of his own inspiration. Eventually he settled down to a truss-with-arch combination using a traditionally framed multiple kingpost truss to which he added a segmented timber arch. This configuration is known today as the Burr truss—the term includes the arch. The concept predated Burr, but he was the first to develop it. The Burr truss is one of the most widespread timber bridge designs, with over 200 examples in the United States, about 28 percent of the nation's existing covered bridges.

Burr received two patents, in 1806 and in 1817. The first was lost in the 1836 patent office fire, but the second has been recovered. The patent office has one drawing, and the text has been reconstructed from other sources. The drawing shows the Burr truss as we know it today. One randomly chosen panel has a counterbrace, which is thought to show that the truss could be built either with or without them (Fig. 1).

Before describing the patent concept and its real-world application, we must dispel a widespread misconception in the secondary literature—that the truss patented and used by Burr differs in important joint framing details from the truss used later by others. Nothing of the sort is true. In his text, Burr did mention a possible new way of framing braces into the panel points, using suitably mitered ends to eliminate shoulders on the posts. This would make framing easier and deliver the stresses directly at the panel points instead of offsetting them and creating bending moments on the posts. Burr did not mention the latter point although it seems obvious; he was mainly interested in ease of framing. But he also described the traditional method using shoulders on the posts and, so far as is shown in old photographs, he used this method in his own bridges. So did nearly all subsequent builders. There is no basis whatsoever for dividing the Burr truss tradition into "pure Burrs" and "vernacular Burrs" as some writers have done. The form as we know it today traces directly to Theodore Burr himself in its major details and in many of its variants.

Burr's Contribution to Bridge Framing. Most bridgewrights of the early 19th century took the multiple kingpost truss as a point of departure. In pure form it dates back at least to Palladio, but Americans combined it with an arch in various ways. Timothy Palmer (1751-1821) used arched top and bottom chords with multiple kingpost stiffeners in between, but none of his bridges survives. Lewis Wernwag (1769-1843) experimented widely but also usually relied on a very heavy arch with various kinds of trusswork as stiffeners. Except in early work, his truss chords were level and he framed a separate arch inside his trusses, but the posts were usually set flared, oriented more or less perpendicular to the arch so that they inclined outward toward the ends of the bridge. None of Wernwag's work survives, either.

Theodore Burr used a multiple kingpost truss of conventional design except that he preferred to use counterbraces too, which the later tradition more often left out. To this truss was bolted a separate segmented arch, usually on both sides of the truss (Fig. 2). The arch sprang from skewbacks in the abutments below the truss seats, but the load is less obviously dependent on the arch in a Burr truss than in Palmer or Wernwag designs.

Burr proposed several framing variants of his plan, and later builders sometimes introduced other minor changes. The Burr truss is found today throughout the midwestern and eastern United States except for the deep South, and also in modified form in New Brunswick, Canada. None of Burr's own bridges survives, and the early evolution of his thinking involved several dead ends. It will be best to describe a typical existing example and then go on to the major framing variants by Burr himself or by others.

A Typical Burr Truss. The following description depicts a typical Burr truss with special reference to the building tradition of southeastern Pennsylvania. Many minor variants in member sizes and joint types are found throughout the truss range. (Major variants will be considered separately below.)

The Burr truss is used for spans from approximately 60 ft. to somewhat over 200 ft. For bridges shorter than 60 ft., builders in the Burr tradition sometimes used a multiple kingpost truss by itself, or reinforced with straight braces in kingpost or queenpost profile, instead of an arch. Longer than about 225 ft., a bridge would be framed in two or more separate spans. (Theodore Burr built a record-setting single span of 360 ft. 4 in. at McCall's Ferry on the Susquehanna River, but apparently not a Burr truss as we know it.)

Fig. 2. The typical Burr truss. Kauffman's Distillery Bridge, Lancaster County, Pa. (built by Elias McMellen in 1874). Blocks on top of arches, with steel rods to the bottom chord, are later additions.

All photos by Joseph D. Conwill

The Burr truss nearly always has an even number of panels, whose length is about 9 ft. There is a single brace in each panel, inclined toward the center. A few builders, especially early ones, used a counterbrace too, making an X profile. The counterbrace is usually cut in the middle, since it is in the same plane as the brace. America's oldest existing covered bridge at Hyde Hall, New York (ca. 1825), is a Burr truss with counterbraces in every panel. In the rare cases where the number of panels is odd, we may find an X in the center panel only, or even an empty panel there.

A timber arch made of solid segments butted together is bolted to both sides of the truss. Arch timber section varies, but 6x12 is frequent. The rise of the arch varies widely according to the length of span and the preference of the builder. The arch load is carried by the truss posts and shared with the braces. Some builders notched the arches slightly into the posts, but many others did not, and Burr mentioned both possibilities in his 1817 patent text. Many Burr trusses were modified early in the 20th century to transfer more load to the arch by adding steel hanger rods to the bottom chord. Burr arches normally follow a circular arc rather than a parabola, but in some bridges they are poorly formed. Apparently the curve was difficult to lay out. Much of the elegance of top-quality bridges by builders such as Elias McMellen of Pennsylvania or the Kennedy family of Indiana lies in the perfection of their arches.

The arch is usually notched around the truss where it crosses below the bottom chord, because the chord is thicker than the rest of the truss (Fig. 3). This is a potential weak point in Burr truss design if the arch-ends rot from poor maintenance, or if the skewbacks punch through because of poor masonry construction. In such cases, pressure from the sagging arch will crack the bottom chord (Fig. 4). The problem is known but rather rare, and never found in well-built and well-maintained bridges.

Fig. 3. Bottom chord is notched to let arch pass. Huffman Mills Bridge, Perry-Spencer counties, Indiana (W. T. Washer, 1864). Bottom chords accumulate dust and debris; this one needs cleaning.

Fig. 4. A problem with the arch ends of this bridge is affecting the bottom chord and the entire truss. Schlicher's Bridge, Lehigh County, Pa. (builder unknown, 1882).

Top chords vary from about 7x8 to 11x10 and use single sticks assembled with simple joints of various kinds. They are always in compression except for multi-span bridges framed continuously over the piers, but in Burr trusses the spans are framed separately. The size of the posts varies widely; about 8x10 would be average. They are mortised and tenoned into the top chord, generally in a housed joint to prevent shifting. Almost always the housing is parallel, but very rarely it may be diminished; the direction of thrust is toward the center of the bridge. Non-housed joints are occasionally found in poorly framed bridges, but this configuration places much stress on the tenon. The joint is secured with two treenails, sometimes as small as ⅞ in. or as large as 1¼ in., but 1 in. is common. Occasionally the holes may be bored smaller if roughly shaped treenails are used. The posts may look oversized, but recall that they are in tension and only as effective as allowed by their critical least section at the joints.

Bottom chords are heavier because they carry the weight of the floor and the live load. Two 6x12 members may be used, spaced apart slightly to allow for free air circulation between panel points. Ideally, the sticks are as long as possible, built up to length using a joint capable of carrying tension, often a stop-splayed scarf with multiple tables. Generally a separate piece is added at the joints in the space between the two halves of the chord to minimize section loss. The posts pass between the two chord sticks with a relish of about 8 in. The inside faces of the chords and the posts are notched to secure the joint, and the whole is clamped together by a bolt (Fig. 5).

Brace size also varies widely but averages about 7x9, often a little narrower than the posts. Braces bear either on daps cut into the posts or on specially widened shoulders. They are in compression but, to prevent shifting due to vibration, they may be spiked or bolted at the ends. (Horses were required to change to a walk, and soldiers to break step, when crossing bridges in former times. The regular vibration could damage trusswork, and the brace-post joint is an obvious problem area.) Rarely, Burr trusses used a full-housed connection at this joint, instead of an open dap or a shoulder on the post. This gives a neat appearance and prevents the brace from shifting, but also makes it impossible to inspect the joint for maintenance.

There is usually no attempt by the designer to proportion posts and braces to the load. Builders probably expected the arch to help equalize the load throughout the bridge, but the trusses do significant work too, as we know from the distress various overloaded bridges have shown.

The floor system in a Burr truss bridge consists of a single beam per panel whose size varies widely but might be typically 8x14, placed on the bottom chord at the panel point, in front of the post (i.e., the side opposite where the brace bears). Atop these are usually lengthwise stringers whose size varies from bridge to bridge, but about 6x6; visually they often seem too light, and in many cases the placement looks random as if they had been carelessly thrown in (but not in Fig. 5). Atop these are crosswise planks, and there is often a second layer of plank on top.

Floor framing shows many individual and regional variants. Some bridges have two floor beams per panel, one on either side of the panel point. Builders in some areas such as Berks County, Pennsylvania, used multiple floor beams distributed throughout the panel, and sometimes the stringers were then eliminated. The richness of the historical record is much diminished in recent years by a fad to cut out the old floor system entirely and replace it with

Fig. 5. Underneath Rex's Bridge, Lehigh County, Pa. (builder unknown, 1858). Floor beams are on same side of posts as main braces because check braces are on the other side; bolts in solid beams are likewise unusual. It is difficult to find one Burr truss bridge typical in all details.

steel beams; unfortunately, such action is applauded even by some official preservationists.

Overhead tie beams vary from region to region, but the most common system uses beams about 8x10 mounted directly atop the top chord. Crosswise sway bracing occupies the upper corners of the travel lane. It may be mortised and tenoned into the tie beams and the truss posts, secured with a treenail, or else it may be bolted. Between the tie beams overhead is lateral bracing in the form of an X, mortised and tenoned and secured with wedges.

Some builders in central Pennsylvania and in western Indiana used iron rods between the top chords instead of timber tie beams on top. Noted Indiana builders J. J. Daniels and J. A. Britton ran these tie rods through the post-chord joints. The lateral bracing cannot be joined to the rods as it would be to wooden tie beams, so it is simply mitered at the ends, or else it may bear on a special metal shoe. These builders did not use diagonal sway braces in the upper corners of the roadway; the lateral bracing is called upon to perform their function, and the iron shoe helps spread the rather large stress over a wider area. Whatever method is used for the upper lateral bracing, there is usually lateral bracing between the floor beams below, too, or else between the bottom chords underneath the floor beams. Roof rafters usually rest atop the top chords.

VARIANT FRAMING IN THE BURR SYSTEM. Major variants in Burr truss bridges are conveniently considered by location in the frame and, in one case, by geography.

The Post-Brace Joint. Usually the brace bears either on a shoulder in a reduced post (Fig. 6), or else on a dap cut into it (Fig. 2). A shoulder involves more labor, but it does have the advantage of reducing the dead load of the posts, since extra thickness beyond the least section left by the brace cut does nothing.

Some complicated design issues arise at the brace-post joint. It carries tremendous loads, and there is danger that shear parallel with the grain may fracture the relish on the post ahead of the brace abutment. This is less of a problem at the bottom because the large relish that helps support the floor system also helps resist the brace thrust. At the top, most Burr trusses terminate the post at the lower face of the chord, and this is where the problem lies. A significant length of shoulder is needed, but the brace thrust is then delivered so far below the panel point that it may bend the post. Many skilled builders understood the right balance between bearing length and rigidity of the post, and required no special treatment here. Some preferred to introduce a short diagonal piece known as a check brace (or kicker), opposite the brace bearing area, to counter the bending moments; if used, it was usually found both top and bottom (Fig. 6). Other builders used a short secondary chord piece near the top, between the posts near the level where the braces join. Both these methods worked, but they involved extra labor.

Double Top Chords. The bottom chord in a Burr truss is nearly always made double. The top chord is usually single, and the post-chord joint seems light (Fig. 6). But rarely if ever does the joint develop a problem, probably because much of the force is carried away by the next brace instead of being transmitted as tension at the post-chord joint. Even so, West Point engineering professor D. H. Mahan criticized this joint as too light in an 1871 commentary.

Some builders chose instead to use a two-part top chord, just like the bottom chord. Burr described this possibility in his 1817

Fig. 6. Post-top chord joint, with check brace. Canyon Bridge, Jeffersonville, Vt. (builder and date unknown). Tie beam offset from its usual position over the post requires sway brace to be joined asymmetrically.

Fig. 7. Kennedy family bridge details from Indiana. Norris Ford Bridge, Rush County (1916). Note double top chord, tie beams slightly offset from panel points because of relish on post tops, arches slightly notched into posts. Many Indiana bridges display the builder's name, but more often on the portal.

patent text. The treatment is found in Ohio and reaches its perfection with the finely crafted bridges of the Kennedy family in eastern Indiana (Fig. 7). A double top chord also allows relish on the post tops, which renders unnecessary a long shoulder for the brace, with all its potential problems. The wide bearing area for the tie beams on a double chord provides extra stability against wind, for the Kennedys also did away with sway bracing in the upper corners of the roadway. One minor drawback was that the post top relish did not allow placement of the tie beams directly at the panel point. (The Kennedys simply offset the tie beams slightly.) Ohio builders often addressed this difficulty by placing the tie beams on the post tops and adding a separate plate to carry the rafters. In New England, Paddleford trusses also have the tie beams on the post tops, but they have no known historical connection to Ohio.

Flared Posts. Posts in most Burr trusses appear to be oriented straight up-and-down, perpendicular to the chords. Close examination shows that in many cases they incline slightly outward toward the ends of the bridge, a configuration connected with the camber of the truss. In other words, the panel length is slightly longer at the top than at the bottom. When this effect is greatly exaggerated, we say that the posts are flared (Fig. 8). Lewis Wernwag, builder of a 340-ft. clearspan bridge over the Schuylkill River at Philadelphia in 1812, used flared posts, and they are occasionally found in the Burr tradition also. Often, but not always, such Burr truss bridges were found in areas where Wernwag himself was also active, such as northern Delaware. The most exaggerated form occurs sporadically across southern Indiana and into Missouri, and it may represent Wernwag-influenced Burr truss builders migrating westward (though this assertion would be difficult to document). Burr himself did not use flared posts, nor did he mention them in his writing.

Arrangement of the Sandwich. By far the most common form of the Burr truss uses a single truss on each side of the roadway, with arches fastened to both sides of a truss. Rarely, the sandwich is reversed, putting a single arch between a pair of trusses. Such an arrangement was more typical of Lewis Wernwag, and most but not all Burr trusses framed this way occurred in areas where Wernwag's work would have been familiar. Two Burr trusses built within the past ten years also follow this layout, at Golden, British Columbia, and at Salem, North Carolina. This variant is not mentioned in Burr's 1817 patent.

Arch Variants. The Burr arch nearly always springs directly from the abutments below the truss seats. In a few examples, especially in northern Vermont, it is tied instead to the ends of the bottom chord. This may allow for lighter abutments, or perhaps some

Fig. 8. Flared posts. Huffman Mills Bridge, Perry-Spencer counties, Indiana (W. T. Washer, 1864). Note skewed joints at tops of posts and curious surface shape between brace joint and chord joint. Graffiti, common enough in covered bridges, have flourished here.

builders did not trust New England dry-laid stonework with the tremendous thrust of the arch ends. But if the arch is tied, the end framing is complicated, and this part of the bridge is much subject to decay from wind-driven rain unless a generous shelter panel is provided.

Lightly framed Burr trusses may have just a single arch, on the inside face of the truss, though this arrangement is not common. On the other hand, heavily framed bridges of long span sometimes use a doubled, concentric arch on both sides of the truss, for a total of four arch ribs per truss. Most of the above possibilities, including the tied-arch variant, were foreseen by Burr in his 1817 patent text. He specified that the arch should be added last during construction. Indeed, J. J. Daniels in Indiana did not bolt his arches to the truss until after the construction falsework was removed and the bridge had settled; his arches do not notch into the lower chords but are splayed around them. However, the Kennedys in the same state bolted their arches before removing the falsework. Their arches are notched into both the lower chords and the posts, but not into the braces, which are narrower.

Abutment Work and Shelter Panels. The Burr truss has so many regional variants in abutments that no one type is typical. The highly developed tradition of southeastern Pennsylvania used random mortared masonry not only for the abutments, but also for the wing walls that retain the road fill for the approaches. These wing walls extend above the road level, forming a sort of guard rail known as a parapet. The stream banks often slope gently in this region; the road rises gradually inside the ever-narrowing parapet until it enters the tunnel of the bridge. The result functions as a very pleasing kind of landscape architecture (Fig. 9 overleaf).

Burr trusses typically occupy very little space over their abutments. However, southeastern Pennsylvania builders extended the bridge housing out onto the parapet for somewhat over half a panel length after the end of the trusswork, to protect the truss seats from wind-driven rain. This is one variant of a shelter panel. Indiana builders did the same thing, usually with longer shelter panels, but their parapets did not extend out to encompass the road fill much past the ends of the bridge. In Vermont, an alternate practice was to end the housing at the end of the trusswork, but to extend the roof line with an overhung portal that slants outward towards the traveler.

The New Brunswick Burr Truss. So widespread was the Burr building tradition that it developed many idiosyncratic local forms found only in one or a few bridges. These cannot all be described here, but one major local adaptation deserves notice because there are so many existing examples. This is the New Brunswick Burr truss, in Canada.

Fig. 9. Southeastern Pennsylvania's builders fit their bridges beautifully into the landscape. Mercer's Bridge, Chester-Lancaster counties (J. Brinton Carter, 1880).

The New Brunswick Burr truss itself has two different variants, and both are so far from the mainstream that some writers have disputed the name, but these bridges have always been known locally as Burr trusses. Both forms date back to the 19th century, although their origin is obscure; both were built into the mid-20th century. They have radically flared posts, and the dimensions of posts and braces are generally proportioned to the load, which is rare in the Burr tradition. Panel lengths also decrease toward the ends of the bridge where loads are concentrated.

New Brunswick's "arched Burr truss" has an arch, but it is laminated instead of segmented as in the main tradition, and it rises up over the top chord in the middle of the span, a possibility Theodore Burr foresaw in his 1817 patent text (Fig. 10). It was rarely ever used elsewhere, perhaps because it interfered with the roof. The New Brunswick bridges with this feature seem all to have been non-covered. Where the arch rises above the top chord, the posts and braces also rise to meet it, but the framing here is so complicated that it defies quick description. At the ends, the arch is tied to the bottom chord instead of springing from the abutments.

New Brunswick's "strutted Burr truss" uses a set of straight timbers near the ends, sometimes known as arch braces, instead of a true arch (Fig. 11). Here indeed we go beyond pure Burr territory. The joint between arch brace and top chord varies from bridge to bridge. Strutted Burr trusses were built in both covered and non-covered varieties. In the non-covered kind, the centerpost extends above the top chord, where it can be used for sway bracing over the traveled roadway. Nowhere else in North America were Burr trusses built non-covered, because the joints are impossible to protect from the weather without roof and sides. New Brunswick's non-covered examples were treated chemically, but such treatments were not widely available before the 1880s.

The province still has three non-covered arched Burrs, three covered strutted Burrs and 11 non-covered strutted Burrs. Bridges of the last type were still being built into the 1960s, and one as recently as 1973. These are the last examples of an unbroken tradition stretching back to the early years of North American timber bridge building. They preserve a high degree of traditional joinery, and some engineers believed them to be stronger than the more modern Howe trusses that are still common in the province.

BURR'S LEGACY. Theodore Burr overextended himself financially and he died in poverty in 1822, but his bridge truss lives on, some two centuries after he developed it. The Burr truss was one of the three most widely used timber trusses for long-span bridges, along with the Town lattice (1820) and the Howe (1840). Many consider the Burr truss to be the most beautiful. So far as is known, it was not adapted to other uses such as roof framing, like the other two. But the competing designs were attempts to modernize. The Burr truss ensured that traditional timber bridge framing would still be done into the 20th century, and now beyond.

—Joseph D. Conwill

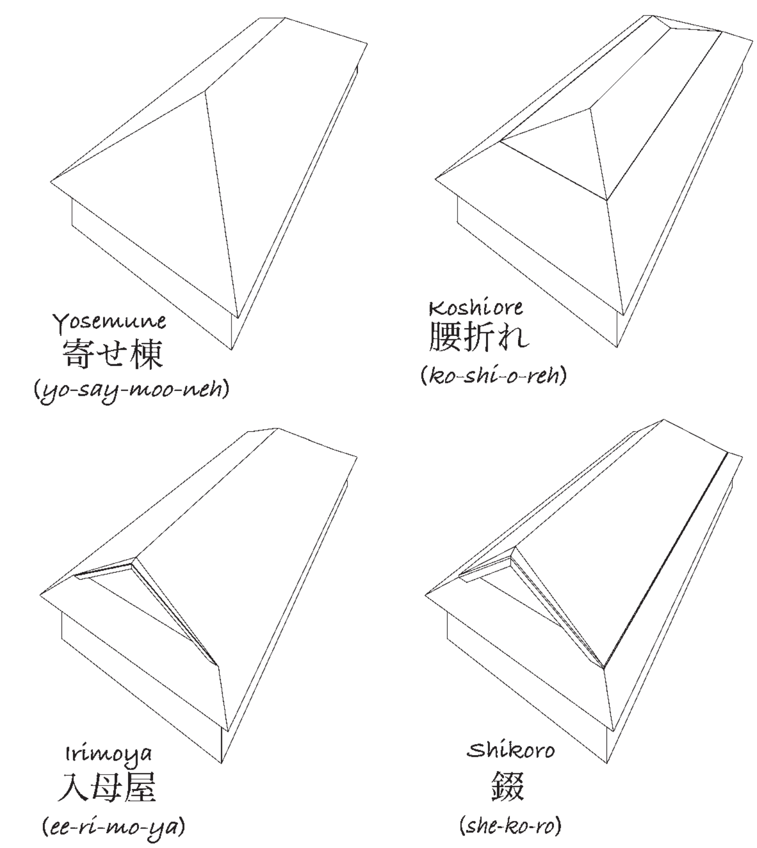
Joseph D. Conwill of Sandy River Plantation, Maine, is a photographer and the author of several books about covered bridges. He has visited every covered bridge in North America.

Fig. 10. New Brunswick arched Burr truss, at Cocagne (1941). Concrete approach railing mimicking the arch is an unusually fine touch and found on other bridges of this design from the Public Works Office.

Fig. 11. New Brunswick strutted Burr truss. McElwaine Bridge, at Temperance Vale (1955).

Japanese Compound Layout

I. Jō-go-kata (Hoppers)



All drawings Chris Hall

Fig. 1. Four examples of Japanese hip-roofed buildings.

THIS article is first in a series to explicate hip roof layout using the Japanese *kō-ko-gen-hō* (literally, the "rise-run-length method"). This system is basic for compound joinery of slopes of equal gradient that abut over a 90-degree corner (regular pitch, regular plan). For compound angle roof carpentry, this situation is perhaps the most common, and the *kō-ko-gen* method is one of the simplest I have come across for finding the appropriate cut angles. There are other methods for determining these angles in Japanese carpentry. One common method, *ki-no-mi-kaeshi-hō* ("body of the wood reversal method"), transfers the width of a face or edge to a slope line, and then squares across from that. This method appears in the English translation of the Yasuo Nakahara text, *Kenchiku-mokkō-zō-kōsaku-zushu* (Rikō-gakusha, 1967), incorporated into a larger work titled *The Complete Japanese Joinery* (Hartley and Marks, 1983), with which some readers may be familiar. Unfortunately, the more versatile *kō-ko-gen* method is barely touched upon in that text, a general survey of Japanese carpentry, so it has remained, as they say, shrouded in mystery. I hope to explain this wonderfully simple technique.

The scope of *kō-ko-gen* excludes non-90-degree corner intersections such as in octagonal, hexagonal, or other polygonal structural shapes (irregular-plan or *takaku-kei,* "many-sided form"), or 90-degree corners in which the abutting planes are of different pitches (regular plan, irregular pitch, *fu-re-zumi*), or the combination of these two situations. Other methods in the Japanese bag of tricks deal with these non-orthogonal problems.

Perhaps the key to grasping compound layout of any degree of complexity is understanding descriptive geometrical drawings. Upon first examining these drawings, many will feel bewildered by them. My advice is simply this: draw. Manually copy the drawing and you will begin to grasp the connections. Repeat this step again as necessary, and soon your ability to visualize the interrelationships between one part and another will improve. I cannot recommend strongly enough that the key to understanding is to make the drawings yourself if you do not grasp them right away.

The Japanese system for measurement, whether in metric or in the traditional *shaku-sun-bu* units (*shakkan-hō*), is a base-10 system. Thus, slopes are defined on the basis of unit rise to base of 10 units, such as 3.5:10, 5:10, and so forth. The Japanese framing square, or *sashigane*, is available in an inch-scale, base-12 version, but it is of limited use to explore Japanese roof work (unless you want to convert everything to base 12). Fortunately, in the past year, a *sashigane* in inch-scale, base-10, graduated in 10ths and 20ths, has become available for those carpenters wishing to do Japanese roof work in inch-scale. The great advantage of base-10 is the ability to go directly from calculator to framing square without having to convert decimals to fractions.

While the objective of this series is to explain the layout of the regular hip roof, we will take a somewhat circuitous path to get there. After an overview, we will look at infundibuliform constructions—hoppers, funnels, battered boxes and the like. In Japanese these shapes are referred to as *jō-go-kata* (funnel-shape) or *asa-gao-kata* (morning glory-shape) or *shihō-korobi* (four-way splay). These forms can be made by simply joining boards together. If inverted, the boards that form the hopper shape are identical in situation to the decking boards on a hipped roof, so there is an application beyond the hopper. When the hopper grows to a size that would need reinforcement—a hopper on a grain elevator for instance—the insides of that hopper might be lined with timbers shaped to fit flush to the abutting faces at the inside corners (and that means making the timber non-square in cross-section). If you consider this structure without the boards on it, and invert it, you have the form of the sawhorse, or splayed-post bell-tower, steeple, etc.—and, adjusted for pitch, the frame of a hip roof. The second article in this series will look at those forms in considerable detail. After that, the focus will move to hip rafter layout and the methods of determining the required cuts for the pieces in hip roofs.

IN Japanese architecture, hipped-roof buildings are found in several forms, some of which are shown in Fig. 1. (The pyramidal roof, with hips meeting at a central point, in Japan is termed a *hōgyo* or "square" roof and, because of its lack of any ridge, is excluded from the category.) In Japanese, the hip itself might also be termed a "descending ridge" and forms the line of abutment between adjacent roof planes. In a regular hip, each plane of roof meeting at the hip is sloped the same amount. The *shikoro* (the neck guard, or havelock, on an ancient battle helmet) roof differs from the *irimoya* ("enter the *moya*"; *moya* are purlins) roof in that the upper gable roof is more steeply sloped than the lower, hipped roof. The simplest is the *yosemune* ("approaching ridge") roof. In the case of the *koshiore* ("folded hips") roof, the upper roof is of slacker pitch than the lower.

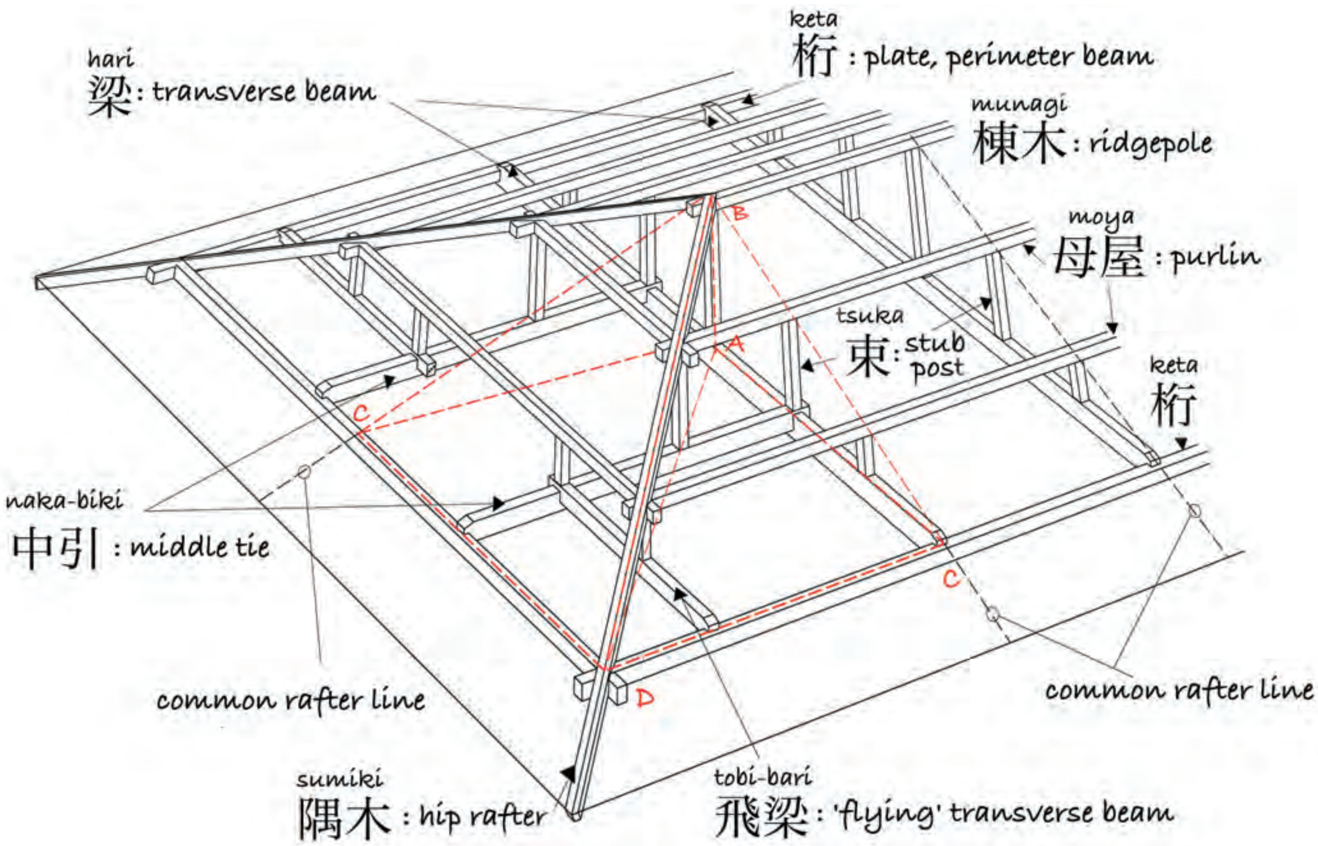


Fig. 2. Yosemune structural elements. Wall posts, braces, strapping and integrated hidden-decorative roof system omitted for clarity.

Fig. 2 shows a *yosemune* roof structure stripped down. It's common to have diagonal bracing *(hi-uchi-bari)* at the corners under the hip running horizontally from wall plate *(keta)* to wall plate. With the use of a dropped ceiling, diagonal struts may be fixed across the stub posts or *tsuka* to reinforce them. Also eliminated in this simplified view are details of the integrated hidden roof-decorative roof system**.** *Keta* and *moya* support the rafters *(taruki)*; the *moya* (purlins) are typically smaller in size than the *keta* and often square in section; the *keta* are typically rectangular, often 1:1.6 width to depth. Sometimes the *keta* is a log, in which case it is termed a *gagyo*. Where *keta* or *moya* cross beneath the hip rafter *(sumiki)*, they form complex lap joints. The interior spaces between *keta* in the building are spanned by transverse timbers, *hari,* which join to the *keta* with housed dovetails or lie across them in housed cog joints. *Hari* are very often bowed logs, though they may also be squared and straight timbers as illustrated. The bowed logs are the stoutest way of spanning the interior space in the traditional framing system known collectively as *wa-yō-gumi;* the practical span limit is 18 to 20 ft. For larger spans, trusses are employed (*sei-yō-gumi* framing), usually concealed by a drop ceiling.

Looking closely at Fig. 2, note the section of the roof delineated by the broken lines in red. This section, typically referred to in recent American discussions as the roof kernel, is displayed in schematic form in Fig. 3. Stripping away the structural elements and viewing simply their geometrical relationships is the first step to determining the angles at which these elements intersect.

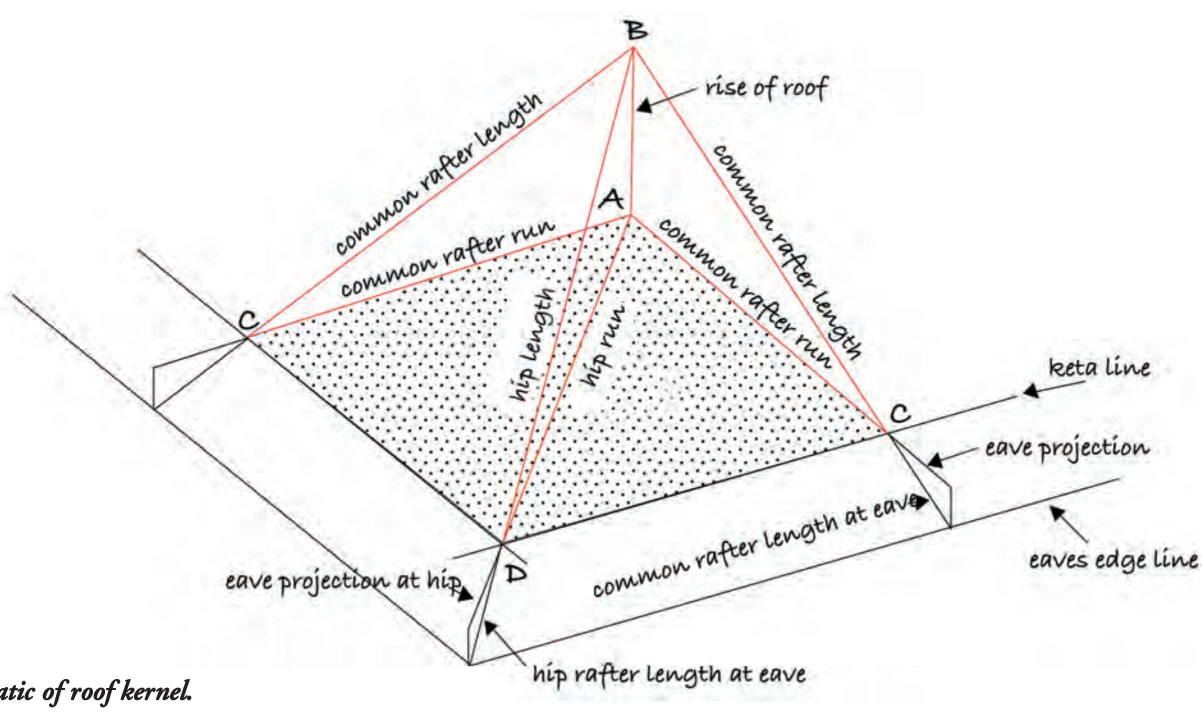


Fig. 3. Schematic of roof kernel.

Fig. 4 takes the roof kernel and shows two different versions, one in which the rise is less than the run, at top, and the other in which the rise is greater than the run. The legs of the common triangles are given the Japanese nomenclature *kō, ko,* and *gen*, with the hip rafter labeled *sumi-gen*. The modern Sino-Japanese characters for the three legs of the triangle are themselves simplifications of older characters. *Kō* refers to the short leg of the triangle, and means "hook." *Ko* refers to the long leg and means "thigh." *Gen*, the hypotenuse, means "bowstring." (The etymology of the Greek word *hypotenuse* is "under stretch," so the Japanese term is similar in original meaning.)

Notice that the labeling of the high- and low-pitch triangles reverses. In Western framing, slopes are always given in relation to their unit run of 12, thus we have 6:12, 12:12, 24:12, and so on. In the Japanese system, if the slope is greater than 10:10 the practice is to reverse the orientation of *kō* and *ko*. That is, the shortest leg is denoted by *kō* in either case.

Why make the switch in labeling the run and rise? The reason is to make convenient use of the *sashigane* for layout. It's configured like the Western framing square, with a short arm and a long arm (in American terms, tongue and body respectively). These proportions usually go along with the orientation of the roof, and the horizontal run is taken as 10 units on the long arm of the square. In a low-pitched roof, with a run of 10, the rise most often will be 8 units or less, and there is no problem using the *sashigane*. In a steeply-sloped instance, however, if we take the run of 10 as the horizontal on the long arm, there isn't enough left on the short arm for the rise. For instance, given a slope of 10:2, if we take the horizontal as 10 units, then we end up with an impractical vertical of 50 units. In steeply-sloped constructions, then, it's more convenient to take the rise on the long arm of the *sashigane,* again as 10 units, and let the horizontal part, the run, be taken on the short arm.

THE first relationship to consider is the angle formed in the plane of the main roof where it meets the adjacent roof atop the hip. If we place a board in that plane, as in Fig. 5, we can see that this first angle we seek forms the face cut on that board. The board represented is a typical component in the Japanese roof lying at the eaves atop the rafters. According to the application, it would be called variously *kaya-oi, yodo* or *ura-gō.* The board drawn on the lower part of Fig. 5 would be more typical of a hopper, with its generally steep walls, and we will hence concentrate on that kernel. Once the common slope has been decided, the next step is to determine the face cut angle for the board, indicated on the drawing by the arc line. Once we have determined the face cut angle, in the *kō-ko-gen* method we will also have the information we need to do the edge cut angle as well, whether it be for a mitered or an unmitered joint. Note that in neither case do we need to look at the actual hip slope itself, or to figure out the cut angles from that perspective. All the cuts can be readily ascertained from simply looking at the common rafter triangle, A-B-C, and how it relates to the triangle that develops from it, B-C-D (Fig. 6).

Looking at Fig. 6, we will first find our numbers using the Pythagorean method, and then I'll explain how to use the *kō-ko-gen* method to find the same results. The slope is to have a *kō* of 3.5 (length A-C) and a *ko* of 10 (A-B). The first task then is to determine the measurements of B-C, the hypotenuse or *gen*. Following the Pythagorean method, the *gen* measures 10.59481. Now that we know the length of B-C, we can look at triangle B-C-D, illustrated in the lower part of the drawing. Note that A-C is equal to C-D. The triangle B-C-D gives us the face cut angle we are looking for, indicated by the red arc, and we can see that this angle is given by a triangle with a rise of 10.59481 and a run of 3.5. Since it is not convenient to use the *sashigane* with a run measure of 10.59481, we convert this measure to 10 by the simple expedient of dividing both run and rise measures by 1.059481, which yields a run of approximately 3.3035. (In other words, 3.5 ÷ 10.59841 = 3.3035 ÷ 10.) The cut angle is then determined by taking 10 on the long arm of the *sashigane* and 3.3035 on the short arm. Fig. 7 shows the B-C-D triangle overlaid on the face of the board and how the square is applied to give the cut angle.

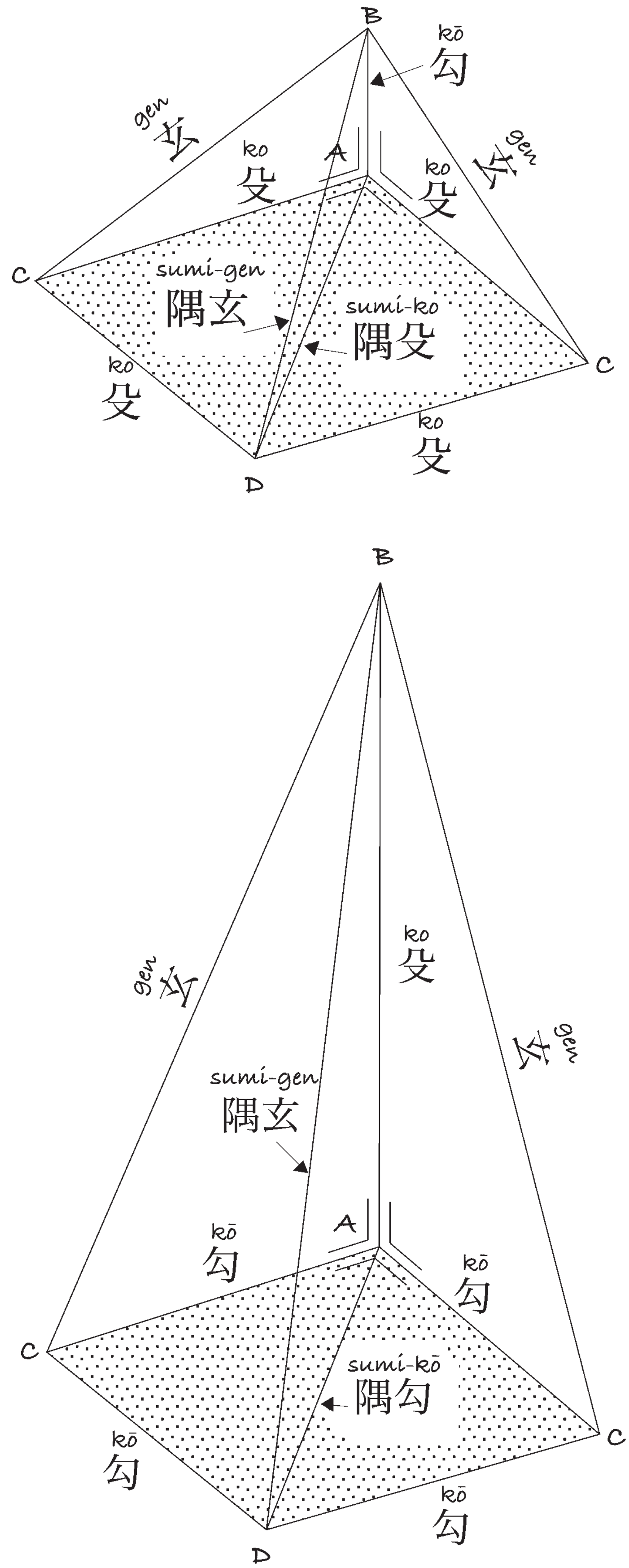


Fig. 4. Low-pitched and high-pitched roof kernels.

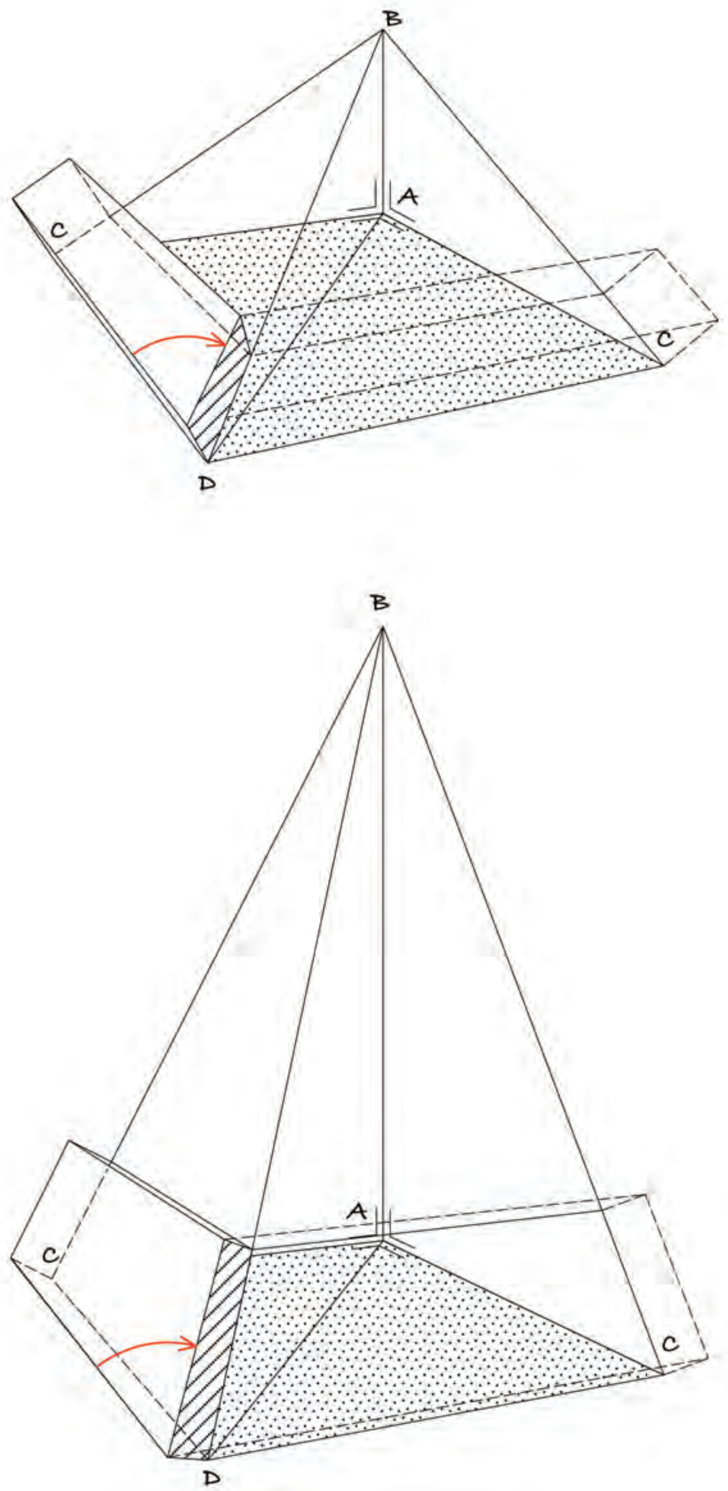


Fig. 5. Boards applied to low- and high-pitched hips.

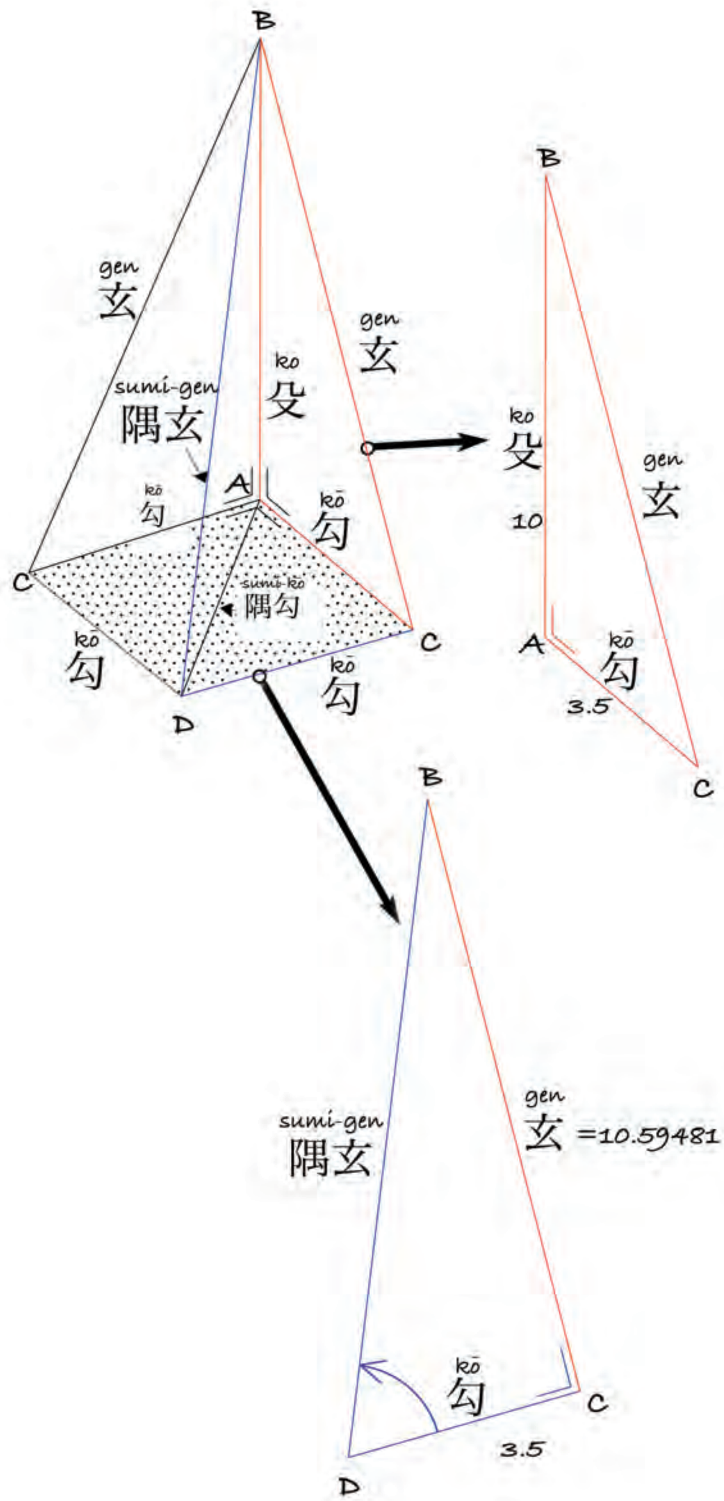


Fig. 6. Relationship of common triangle to hip triangle.

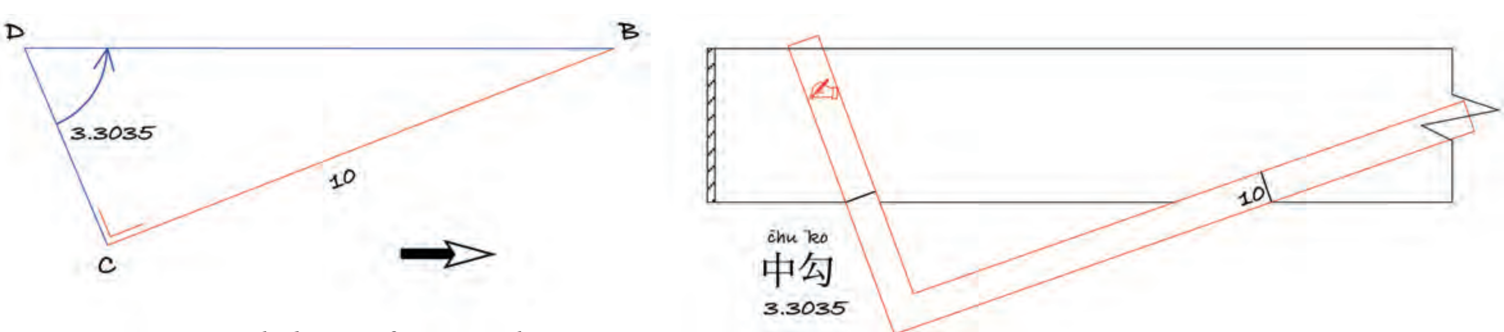


Fig. 7. Square applied to give face cut angle.

Now let's look at the question using our *kō-ko-gen* method. We can consider it two ways, one without math. Pictured in Fig. 8 is the common rafter triangle of 3.5:10. The value for the length of *gen* has been filled in, determined by the Pythagorean theorem, or directly by laying the *sashigane* against a straightedge at slope. Divide this main triangle to form the next largest right triangle within it by drawing the line labeled *chū-kō* ("middle rise"). You can calculate its length step by step, using the Pythagorean theorem and the similar triangles of the division, or you can take a shortcut, as shown: take the run, divide it by the length (hypotenuse) and multiply that by the rise. The answer (drum roll, please): 3.3035. Therefore, the *chū-kō* measure, taken with a run of 10, gives the cutting angle we sought in Fig. 6 (previous page), but in one triangle calculation instead of two.

There is a direct, adequately precise method to determine the *chū-kō* measure shown in Fig. 8. Drop a line to the horizontal from the apex of the square (taking care to use the outside corner of the square). Measure this and, if your other steps were done reasonably accurately, you will find the distance is around 3.3 (Fig. 9).

We have found the slope for the face cut line in the case of the hopper-pitched triangle using *chū-kō*. But what about the edge cut angles for mitered or unmitered joints? Fig. 10 expands a bit upon the initial division of the triangle done in *kō-ko-gen-hō*. The division line meets the hypotenuse, or *gen* line, dividing it into two parts. The long part is the *chō-gen* ("long gen") and the short part is termed the *tan-gen* ("short gen"). Now, we can surmise that the miter cut angle, since it is somewhere in the vicinity of 45 degrees, involves taking 10 on the long arm of the square and some quantity close to that on the other arm. That length is *chō-gen*. For an unmitered joint, it is apparent that the cut angle is slight, somewhere close to 90 degrees, so we need 10 on the long arm and a small quantity on the short. That length is *tan-gen*. To determine the lengths of these subsections of *gen*, use the handy formulas given, and check if you like using the Pythagorean theorem and the method of similar triangles.

We see that squaring the run and dividing it by the length gives *chō-gen*. Okay: 10 x10 = 100, and 100 ÷10.59481 = 9.43858. Our miter cut is given by *chō-gen*, which means we take 10 on the long arm of the square and 9.44 on the short arm, marking the cut line along the short arm (Fig. 11, left side). What about the *tan-gen* measure? Well, it's given by squaring the rise and dividing it by the length: 3.5 x 3.5 = 12.25, and 12.25 ÷ 10.59481 = 1.15623. For the unmitered joint layout, then, use the *tan-gen* slope: 10 on the long arm, 1.16 on the short, and mark the cut line along the short arm (Fig. 11, right side upper).

One can also determine the *chō-gen* and *tan-gen* measures by the method used in Fig. 9: where the plumb line intersects the horizontal, it divides the two subsections of *gen*, each of which may be measured with the square.

Some of you may be wondering why the edge cut is *chō-gen* or *tan-gen*. It's one thing to accept that such is the case and to see that using mathematics it's provable as the correct answer, but many want to know why something *is* what it is. To that end, Fig. 12 illustrates the derivation of *tan-gen* for our unmitered hopper. In the upper part of the figure we see an elevation view of our hopper boards where they abut at one corner. On the left is board *A*, of which we see the end grain, on slope, and on the right is board *B*, of which we see the face, on slope. In the elevation view, I have marked out our common rafter triangle, *kō, ko,* and *gen,* taking *ko* to be equal to the thickness of the board. Next I have taken the points on the top surface (the edge) of the right-hand board *B*, marking the inside corner and the outside corner, and projected them down to a view normal to the board edge. Again, in this view the thickness of the board is equal to *ko,* and the inside and outside arrises are marked. The point from the upper elevation view

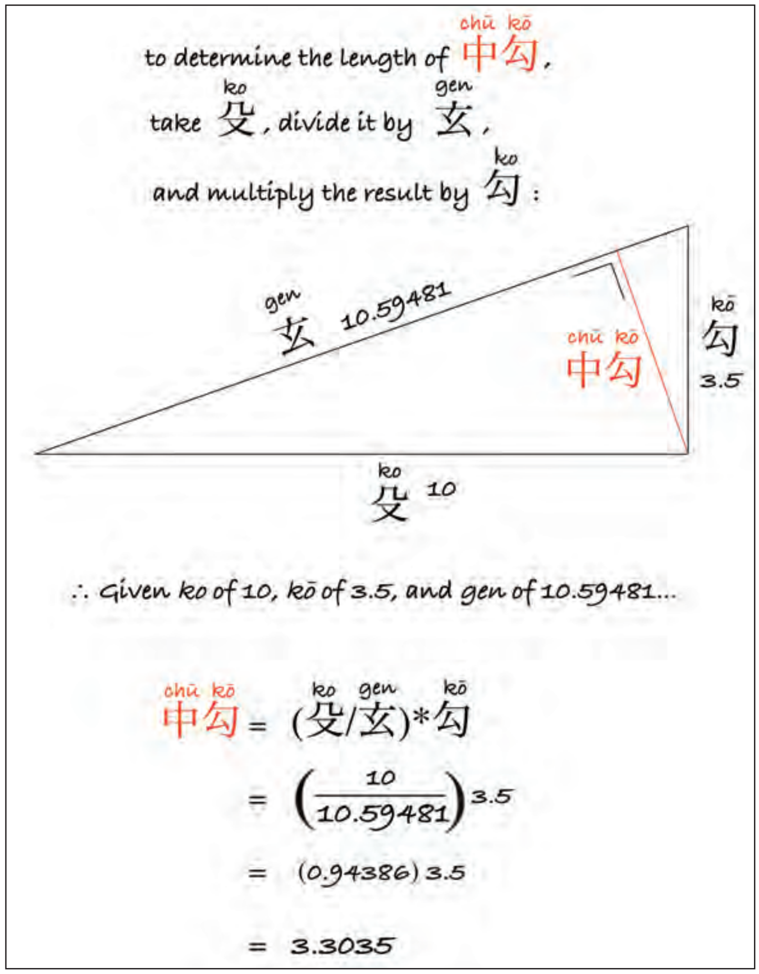


Fig. 8. Analysis using kō-ko-gen-hō.

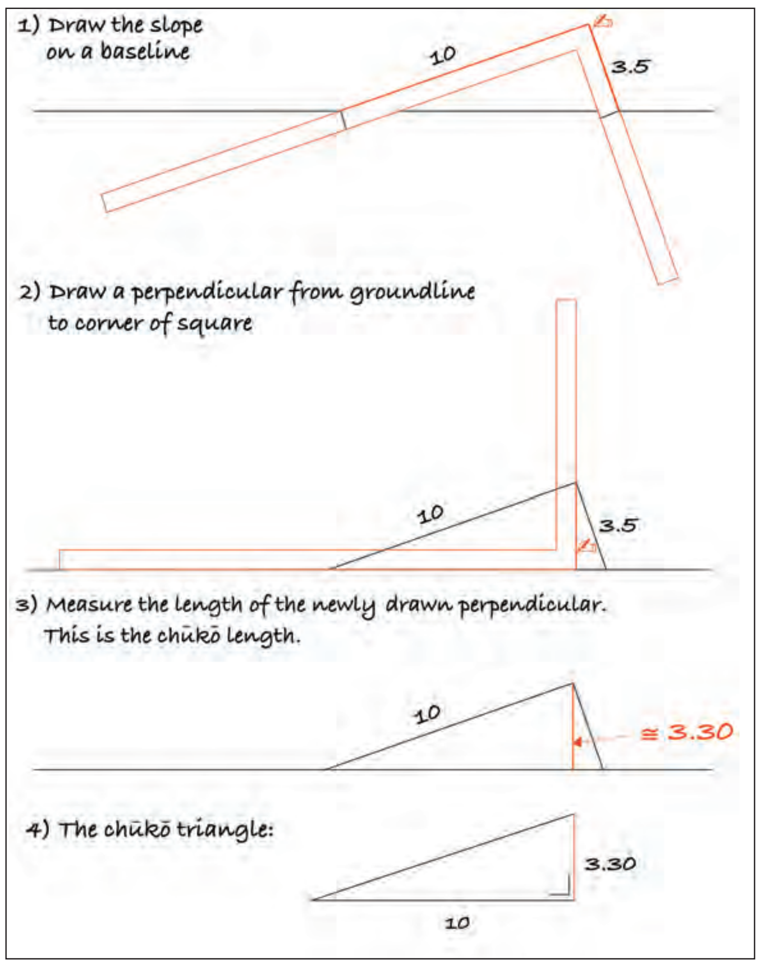


Fig. 9. Determining chū-kō using the sashigane.

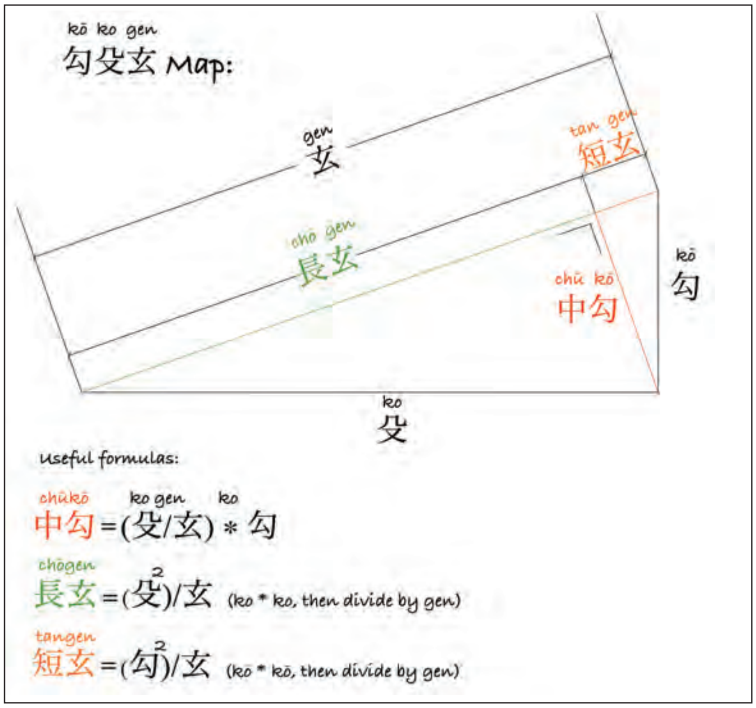


Fig. 10. Kō-ko-gen map showing division of gen by chū-kō.

giving the inside corner is marked on the normal view where it intersects the inside arris of the board, and the same is done for our outside corner point, the line for which intersects the outside arris. It is readily apparent that the distance between these two projected lines is equal to our *tan-gen* measure and, since the thickness of our board is equal to *ko,* then the unmitered-joint angle is given by a triangle that's *tan-gen* on the short arm of the square and *ko* on the long arm. This slope (*kō-bai*) is called *tan-gen kō-bai*. Curious and motivated readers may wish to use a similar drawing method to see why the *chō-gen kō-bai* is used for mitered hoppers.

Jō-go-kata boxes can be turned upside-down with narrow end uppermost, an ideal shape for bench or toolbox, or many other useful items. There's always a career to be considered as a maker of planter boxes. —CHRIS HALL

Chris Hall, a Canadian currently residing in Massachusetts, is a designer and builder of Japanese structures and furniture. He teaches workshops in Japanese carpentry.

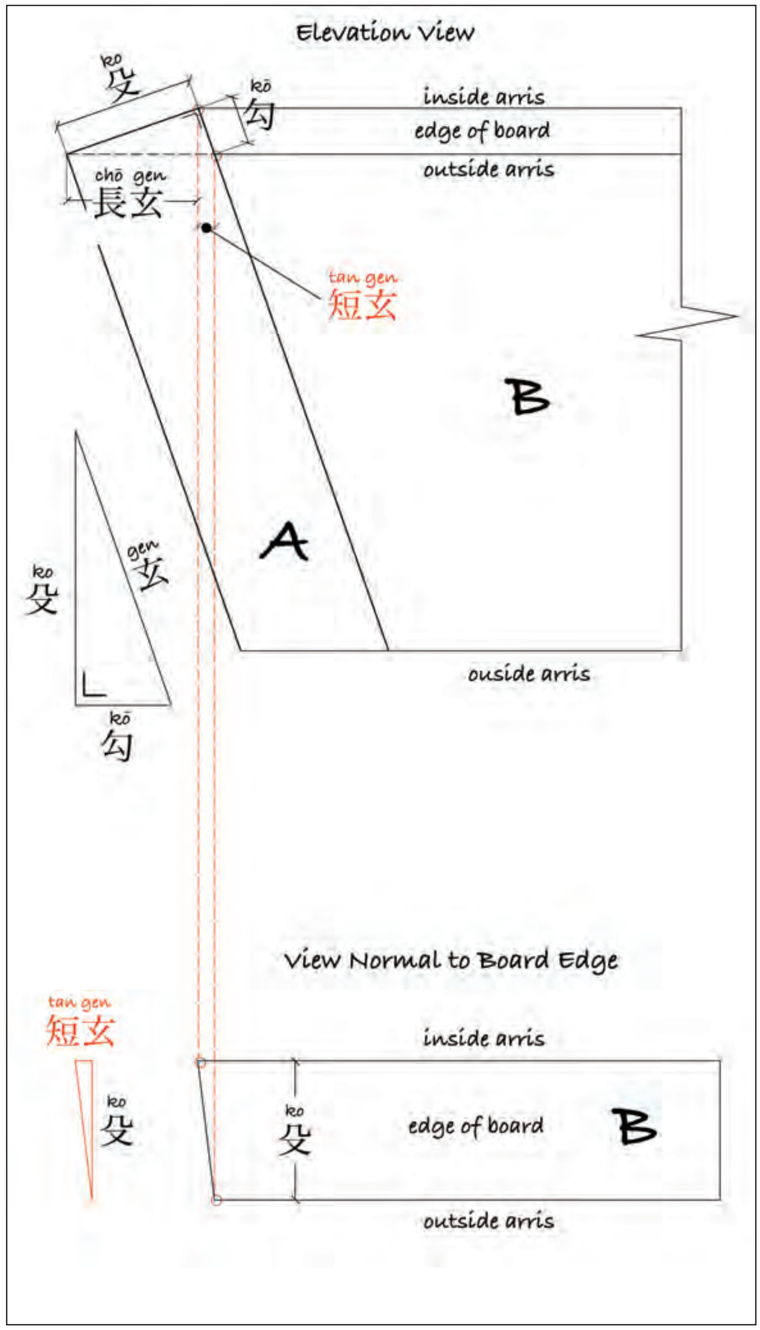


Fig. 12. The tan-gen.

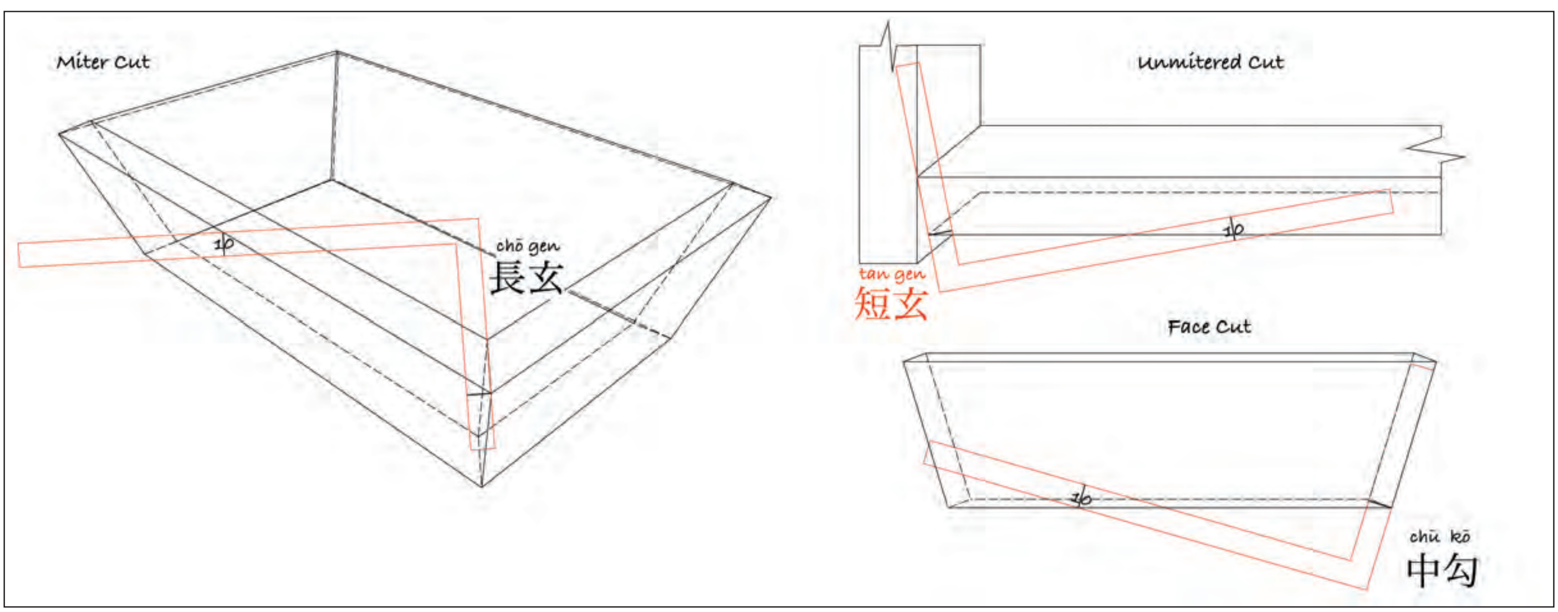


Fig. 11. The mitered hopper.

TIMBER FRAMING FOR BEGINNERS

X. Introduction to Scribing 3

All photos Will Beemer

Fig. 1. Log-builder's scribe technique used here at a crossing of two round timbers is equally applicable to lengthwise joints and combinations of square and round timber. Cavity is severely undercut in upper member to clear all possible projections of lower member at the joint and produce a seamless appearance.

ROUND timber offers no straight plane between arrises as does square-edged material, so myriad points need to be transferred rather than just the extremities. To make the transfer, we can borrow a technique from log builders who use bubble scribers to transfer the profile of a log to the one above that will rest on it snugly when hollowed out carefully to the scribed line.

Bubble scribers are dividers fitted with a bullseye (cross) level at or near the hinge point, and marking pens at the ends of one or both legs. If two logs or timbers are set out level and one stacked over the other, their intersection can be marked by riding the divider legs along the surfaces to be mated while keeping the bubble centered on the bullseye of the level. By keeping the bubble centered, one pen is always kept plumb over the other, just as if they formed the two ends of a plumb bob and string. This technique is best used for joining round to square or round to round timbers (Fig. 1).

Line the timbers as before (see previous article in TF 77), with the lines either representing the centerlines of the mating timbers or one side of joinery. When the timbers are assembled, the snapped lines should meet. If a timber is very wild and moves in and out of plane along its length, the line should be most nearly centered at the ends. It's also better both structurally and aesthetically if the grain at the ends is as nearly parallel as possible to the chalk line to optimize the lay of any joinery cut at the ends. Set out one timber over the other to be joined and level them both lengthwise and crosswise according to the struck lines on their ends. V-notched blocks 12 to 16 in. long can help steady the round timbers; log dogs and wedges can keep them from rolling (Fig. 2). Alternatively, you can also screw a horizontal board to the end grain of the round timber, aligning it to the horizontal level line on the end and making it deep enough to offset the centerlines the appropriate amount (Fig. 3).

Set your bubble scribers to the distance between the two centerlines. Since most such scribers are limited to 16 in. or so of spread, this will determine the amount of separation between the timbers you are allowed. The greater the distance, the greater the chance for error. If the distance is too great for the scribers to reach comfortably, you can "double-cut" the joint (see the previous article) by first cutting the mortise, then the tenon with extra length to the shoulders. Insert the tenon into the mortise and then scribe the shoulder and recut.

Once the distance is set on the scribers, they must be calibrated to make sure the two pens are plumb over one another at that setting. We use two small boards (1x2) screwed together at a right angle and mounted perfectly plumb on a wall or post. Stick the

Fig. 2. Logs of whatever size can be kept from rolling by cradling in V-blocks (right end above) or fastening to cleats if small enough (left end), then clamped or dogged in place.

Fig. 3. Strategy for holding log level. With appropriate depth, stick can provide correct offset for scribing.

pens into the corner of the two boards and adjust the bubble levels (if needed) to read plumb. Rotate the pens and check to see if the reading is the same. If not, one of the pens needs to be adjusted in or out in its mount. Turn the scriber over and check the readings again with the pens in opposite positions. In all cases, no matter what the orientation of the pens, they should read plumb in the calibration jig. This should be done each time the spread of the pens is changed for different layouts (Fig. 4).

Certain bubble scribers are better than others for different applications. Those with straight pens positioned to reach facing surfaces have limited ability to reach over the top of a timber or into tight corners, since there you need a scriber with an arm articulated enough to ride on a surface that may be oriented away from the face it is to meet. More elaborate scribers, such as those developed by Big Timberworks in Montana and Timmerhus in Colorado, are best suited for reaching over onto the top of square or round timbers to complete the scribe layout on all surfaces. These tools have two bubble levels, so they can work when flipped over. (You should make sure both levels are calibrated before scribing.)

Old-timers didn't have these $300 scribers, but could crudely accomplish the same thing with a good eye and a small forked branch with pencils taped on the ends, made more sophisticated by drilling a hole in the lower branch and hanging a plumb bob string from the upper branch through the hole. They probably did a lot of double-cutting, roughing out the joint and then partially assembling it to get it close enough for a more accurate final scribing with the shoulders near each other (Fig. 5).

Our scribers transfer points plumb over one another, and those points define a unique line to the center of the earth. You might be tempted to try scribing level points, say with timbers that are *in situ*, which would be possible by turning the scribers on their side so the points are level with each other and remounting the bubble level so it reads plumb at 90 degrees to the level arms. But you'd also need some way to account for your "in or out" (lateral) position, since the centered bubble now signals a plane not a line. I once saw a set of homemade scribers that included not just a bubble level but also a magnetic compass to establish the bearing angle the pens should have to each other. Ingenious, but not as practical as using gravity to transfer marks.

Fig. 4. Calibrating the bubble scribers. The pens must be plumb.

Fig. 5. Homemade scriber can be improvised with forked stick, pencils and bubble level.

Once the scribers are calibrated, they are brought back to the timbers and the profiles transferred from one timber to another. The technique of keeping both pens riding on the timber surfaces while watching the bubble level takes some practice (or three eyes). One hand should ride on the hinge of the scribers to control both arms, and the other can hold the pen of one arm (usually the top one) on the surface of one timber. It's easier that way to feel if the other pen is in contact with the lower timber while watching the bubble most of the time. Orient the scribers so the pens drag slightly across the timber rather than push into the fiber. This will minimize wear on the pens and keep them from snagging. Mortises and tenons can be laid out by marking their boundaries with the scribers, then using a gauge or framing square to set out their thickness above and below the centerline.

Many scribers come with ink pencils (available from drafting or surveyors supply stores), which facilitate marking on wet timber. They also may have felt-tipped pens, which tend to wear down fairly rapidly. We use Fisher plotter pens, which have pressurized roller-ball tips that stand up better over time.

JOINING round to square timber looks best if the tenoned timber is round and smaller in diameter than the square mortised timber it is meeting, since you don't have to chamfer flats in the round timber to make a pleasing intersection as it meets the square. If the larger, mortised member is also round (round meeting round), you have some choices. You can, for instance, cope the shoulders of the tenoned member to wrap around the surface of the round, mortised member. But this shape is difficult to cut and results in fragile feather edges at the ends of the cope. Another option is to scribe a housing at the mortise to the profile of the tenoned member, which can then bear its shoulder on a flat table deep enough in the housing so the entire member end is enclosed. The result of this technique looks much better than a coped edge, given that one can scribe the housing very accurately. The flat table inside provides a better and more predictable bearing surface as well (Fig. 6).

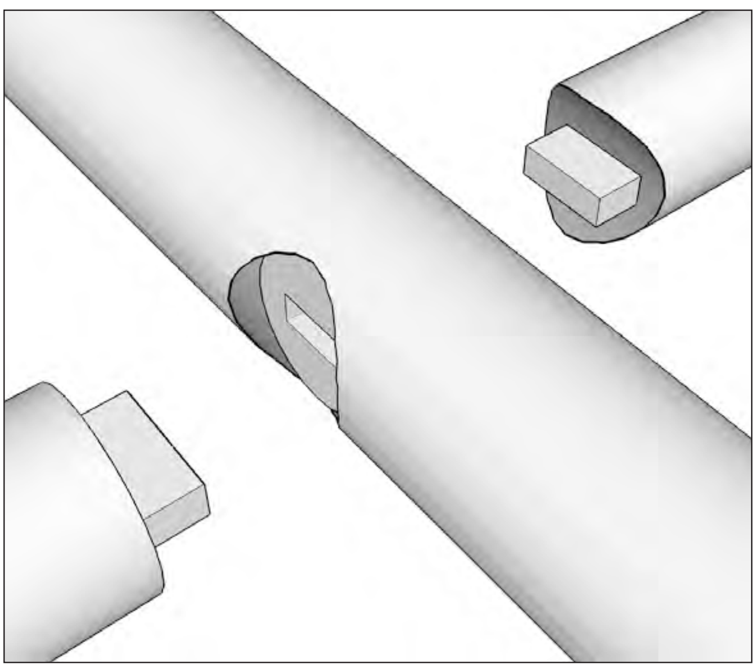
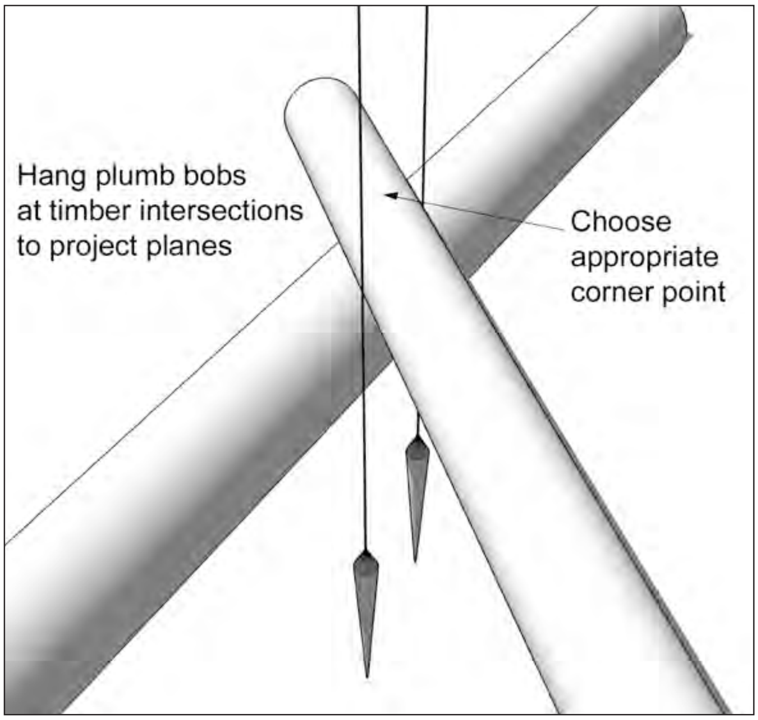


Fig. 6. Scribed housing (left) vs. coped shoulders in round-to-round mortise and tenon work. Scribed housing offers advantages.

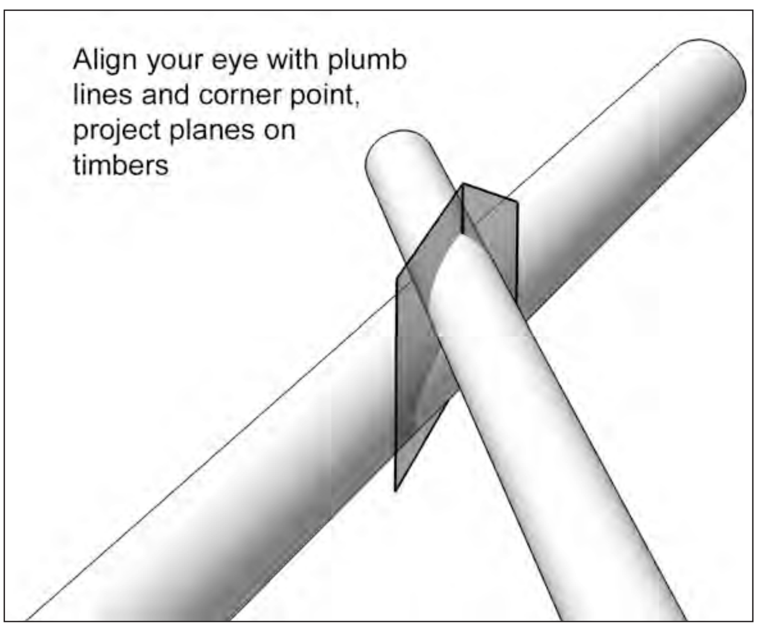
A third option is to use "mitered" joinery, especially attractive with round meeting round, making it appear as if the timbers are growing out of one another. Instead of scribers, you can use a jig, laser level or your eye to transfer the lines for the joinery. It's important to have no flat surfaces exposed to view, accomplished by carefully choosing the size of the round pieces. Logs oval in cross-section or with a lot of bumps are difficult to miter, so pick smooth round ones. Ideally, the diameter of the tenoned member (or the one whose end joins into the midspan of the other) should be about three-quarters of the diameter of the other member, or about 2 in. narrower. The idea is to lay out the miter at a point where the chord length of one member equals the diameter of the other. Mitered joinery is very strong with its large flat-on-flat bearing surfaces, which are also easier to cut than the other two shapes (Figs 7-8).

Figs. 7-8. Round-to-round mitred joint offers excellent bearing and neat appearance. Diameter of tenoned member will equal chord length of mortised member at joint. Example below has been artfully reshaped.

To lay out the miter, level your timbers over one another and align their centerlines to the proper dimensions or the floor layout (if there is one). Then support a plumb bob hanging through the intersection to be mitered. Hang it from a prop or support that doesn't interfere with your scribing; you'll need both hands free and the ability to move around the joint to sight a plumb plane through the string. The prop can be a 2x4 attached at the floor (or embedded in the ground) and the back of the timbers, or a tripod. (A crane would work, too, but it's a bit pricey.) Bring the string in with the prop until it's just touching the two pieces to be scribed, and secure the prop temporarily (Figs. 9-10).



Figs. 9-10. Projecting planes of intersection of round-to-round mitered joint. Plumb bobs are generally used one at a time in confined spaces.



On a windy day, a plumb bob may want to drift a lot. One trick is to suspend the bob in a bucket of water to block the wind and dampen the motion. Just be careful not to jostle the bucket while scribing.

Once a plumb bob is hung, any point not on that string will define a plane with the string (three points define a plane). The key to making mitered scribing look good is to find the best point on the timber to begin the layout of the flats of the miter. Visualize where the string will hang on the other side of the joint, and the way the two flats would intersect when drawn through each string position. If the corner of the miter were too far into the lower (larger) timber, large visible flats would result on the lower piece. If the corner is not deep enough, the large flats will appear on the upper timber.

The best way to make the miter aesthetically pleasing, and minimize the amount of exposed flats, is to pick the miter's corner points on the tenoned timber that will result in the same chord length in the timber below.

Take a caliper and measure the width of the upper log where you think the corner will work best. This is the chord length, the straight line measurement between two ends of an arc. Use that caliper setting to see if the chord length is the same on the lower log at a point directly plumb beneath the miter corner of the log above (Fig. 11).

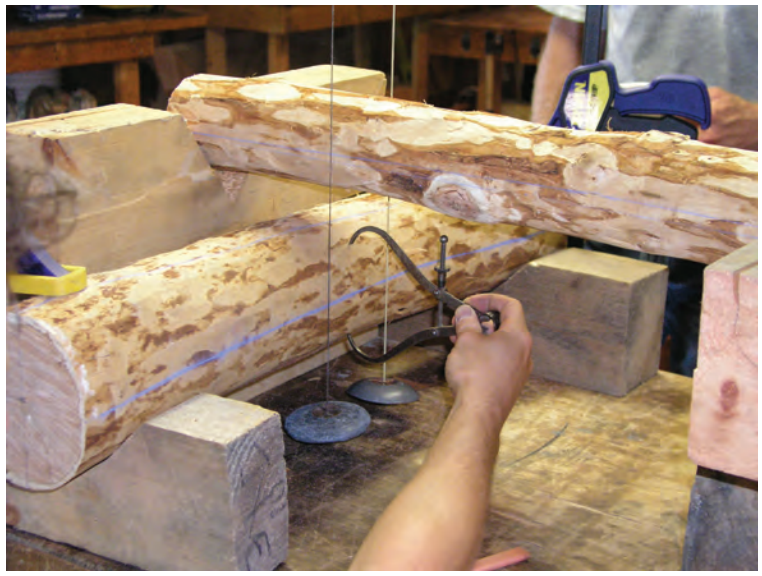


Fig. 11. Checking the chosen length between tenon shoulder points against the location on the member to be mortised.

You can also use the scribers to make this comparison, and the bubble level will make it easier to judge plumb. With calipers, you need to eyeball the point below for plumb. Still, if you're reasonably close (within a half-inch), it should work out.

When choosing the corner point and angles of the flats, you should be aware which surfaces are loadbearing. Ideally, they should be perpendicular to the axis of the stress, but you'll have to weigh that against what looks best. The two flats look best when they are approximately the same size. You don't want a flat that is so shallow an angle that the piece wants to slide out under load, nor so deep that the other flat needs to be exceptionally long to meet it at the corner. There may be some structural considerations that could compromise the aesthetics, such as the size of the mortise and tenon or bearing area requirements. There are cases where the diameter of the tenoned timber can't or shouldn't be used, such as if that results in too deep a miter in the larger piece. In the case of a brace coming in at a low angle, or a strut to a kingpost, the V may be purposely off center in the smaller piece to obtain or improve bearing. In these cases, flats do result but can be faired out (Fig. 12 overleaf).

Once you've chosen the corner point on the top timber, mark it and sight through the string to that point (Figs. 9-10). Now, keeping your head steady, one eye closed, and the mark you made in line with the string, make a series of marks as far as possible around the timber in the same plane as the string and the first mark. Avoid

Fig. 12. Kingpost with two mitered struts, an instance when expected loading indicates unequal bearing shoulders and thus asymmetry in the miter.

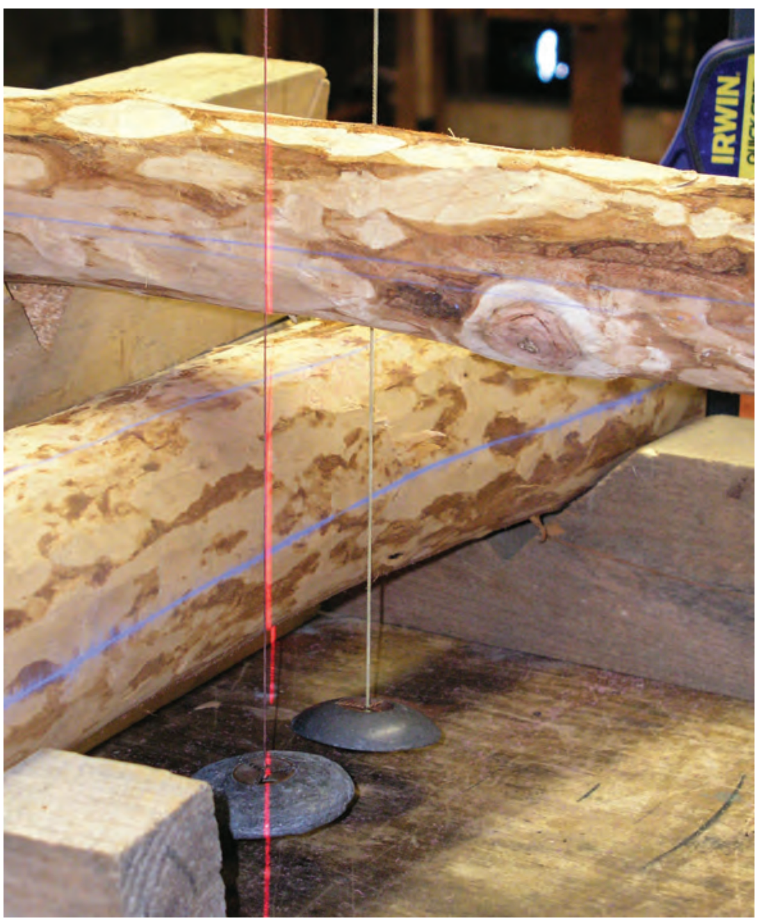


Fig. 13. A laser level can project a beam of light to aid in marking a projected plane on intersecting timbers.

touching the string. Drop the pencil down to the lower timber, keeping the same plane lined up, and make more marks to represent the intersection. Soon you will not be able to see around to the other side of the timbers, but you can use one of your last marks as a new alignment point. Shift your position to see the unmarked side of the timbers, and line up the string (still in its same position) to one of your later marks. Pick one far away from the string to increase accuracy. Continue marking around both timbers as far as you can, making your marks about an inch apart. You'll reach a point on the opposite side of the timber from the string where it will be impossible to line your pencil up with the string because the timber is in the way. In this case you may have to move the string to the near side and line it up with an existing mark, but usually you have enough marks at this point to define the plane around the timber. If joinery is only coming into one side of the timber, you may not need marks on the opposite side anyway.

New technology can also be a big help. A laser level such as the PLS2 from Pacific Laser Systems can be aligned to your floor drawing (if you have one) and project a continuous plumb beam of light across both timbers at the intersection. Mark the projected line with a pencil, being very careful not to look into the laser beam. With a floor drawing that shows the corner point (determined by the chord length method described above) and the true diameters of the log pieces, it's possible to mark the joinery with the laser level one piece at a time, without the need to set one timber out over the other (Fig. 13).

Once the first plane for the miter has been established, it's time to mark the second plane, which is determined by where the corner of the miter will be. Move the plumb bob, string and prop around to the other side of the intersection, secure it where it just touches both timbers, and sight through the string to the corner mark on the top timber. Mark this side of the joint on both top and bottom timbers as you did before. Connect the dots to establish the cut lines. This can be done carefully by eye, or use a flexible ruler or a piece of metal banding, which should be able to touch three points at once to guarantee that the curve is fair.

In all of the exercises above, the timbers are leveled both across their faces (or ends) and along their length, and may be aligned to a floor drawing if practical. Different techniques are appropriate for different circumstances, and the well-trained timber framer will have them all in his or her bag of tricks. One must carefully consider the aesthetics of mixing round and square timber in a frame, and round or crooked timber causes some obvious issues if it is on the outside wall or roof where sheathing needs to be applied. Understanding the concept of reference planes, and the use of the eye as the most valuable tool in one's kit, will add much versatility and variety to the types of timber you can use in your frames.

—Will Beemer

This article concludes a three-part series on scribing. Previous articles in TF 77 and 76 have covered plumb-bob scribing of square timbers. For more information on mitered joinery for round timbers, see Log Building News 17 (*February 1995) as well as* Log Building Construction Manual, *both by Robert Chambers and available through the International Log Builders Association, 800-532-2900, www.logassociation.org.*

A Timber Frame Addition

All photos Frazier Associates

Fig. 1. March of buildings continues with completion of addition. Original log structure at front, two 19th-century additions next, compound 21st-century timber frame last, terminating in masonry chimney at far right, the end of the conference room.

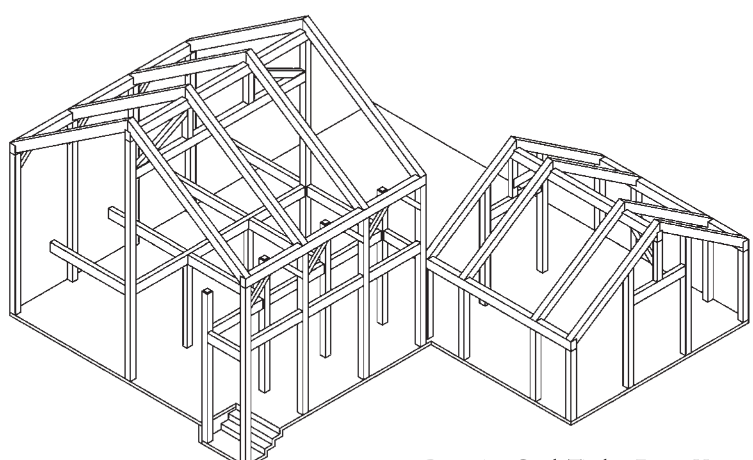
NESTLED in the Shenandoah Valley, the historic community of Staunton, Virginia (population 24,000), has an architectural advantage over most other small towns in the region because it escaped damage during the Civil War and retains an extensive stock of 19th-century buildings. The National Trust for Historic Preservation has recognized Staunton twice. One of the city's oldest surviving structures is the Trotter Tavern, built in 1802. During the last 200 years, Trotter Tavern has served as residence, tavern, stagecoach stop, school and office. The rectangular log structure is covered with lapped weatherboard and sits on a stone and brick foundation. The building fronts on a busy street in a National Register historic district, surrounded by residential-scale uses.

In 1988, our architectural firm rehabilitated Trotter Tavern to house its offices, faithfully adhering to the Secretary of the Interior's *Standards for Historic Preservation Projects* (1976, 1983). Approximately 3,500 sq. ft. of office space was spread out over two levels plus the garret, with its additional two offices tucked under dormers. While quarters were tight, the staff managed to squeeze companionably into the historic building for more than ten years. Eventually, however, as the firm continued to grow, it became clear that the building would require a major addition to accommodate increases in staff and technology. The challenge was to create an appropriate design for our historically inclined architectural practice, to create an exceptional and functional contemporary workspace, yet walk a fine line so that the firm could still secure design review approval within the historic downtown.

In 2002, two centuries after the original building was constructed, the firm began brainstorming ideas for the addition. Philosophically, the designers agreed that the addition should acknowledge the history of the site, meet local historic design guidelines and achieve compatibility in form and material without being a copy of the original. It was critical that the new addition provide for increased flexibility, by opening up space to encourage collaboration and communication across project teams. In its existing space, the firm had very limited opportunity to group project teams given the small spaces and limited configuration of the historic building.

A timber frame structure quickly emerged as the ideal solution because it would be compatible with the original log structure, plus it would be visually exciting and allow for expansive spaces. Conceptually, the idea of a "barn" or an "outbuilding" at the rear of the original residence and tavern seemed appropriate. Trotter Tavern had already been growing backward with multiple single space additions (in 1823 and 1854), and it seemed obvious that the building would continue to march backward into the steep lot.

The architects drew their inspiration for the expansion from the site's immediate qualities. The vernacular, rambling precedent set by the existing structure already had great charm and visual appeal. Continuing the building's natural evolution away from the street,



Dreaming Creek Timber Frame Homes

Fig. 2. Intermediate space exposed by articulated frame is occupied by composite structure with light-framed and load-bearing panel walls and timber roof trusses. New work adds about 3100 sq. ft.

Fig. 3. Fitting the white oak rafters. Support is at ledge in plate and combines with support at underslung ridge to eliminate rafter thrust.

the architects broke down the mass of the project (3,085 sq. ft., almost double the existing building) to appear relatively less massive in size and scale.

Once the design was close to completion, we contacted Dreaming Creek Timber Frame Homes in Powhatan, who used our floor plans to draw up corresponding timber frame plans. The oak timber was harvested in Virginia and processed at the company's sawmill and workshop. We requested a distressed finish for the timber to blend more appealingly with the chinked log work in the oldest sections of the building.

The frame of the addition was raised in three days. Structural insulated panels, recommended by Dreaming Creek for their energy efficiency, were fastened to the outside of the frame and the building was under roof and walls within two weeks. Fred Neurohr, Dreaming Creek's project manager, recalls that one of their biggest challenges was not the framing, but rather figuring out how to get a crane into the site, hemmed in by Staunton's historic district. Local contractor Ted Jordan continued the buildout and interior detailing of the space.

Now complete, the addition is a harmonious blend of old and new. The exterior fits snugly into its historic context and is modulated so it doesn't appear to be a monolith behind the 1802 log structure. The addition respects the historic integrity of the existing building and responds to the residential scale of its historic district. The addition's simple lines are a nod to the enduring appeal of appropriately sized domestic architecture.

The interior of the new timber frame addition (which one encounters only after moving through the historic reception area) is unexpectedly open, filled with light and exposed construction elements and a modern interpretation of the original building's detailing, the exposed timbers lending character, texture and unity with the original log structure.

The expansive interior enabled by the timber framing allowed the firm to achieve its spatial goals for project team flexibility. Workstations on both levels are congregated by project type, but separated by 4-ft.-high beaded-board partitions to allow some privacy. A wall of south-facing windows floods the space with light and warmth, while operable windows and wide-open spaces allow for natural ventilation. The beams over the second floor of the addition were left open to the roof. The volume of the second floor space offers drama yet is still an informal and pleasant work environment.

Fig. 4. Wood from a walnut tree removed from the site is used as detailing in the floor of the open-roofed conference room.

The two-story light well fosters communication between the two floors of architecture teams. Stairs were relegated to the back of the space so that building circulation wouldn't interfere with the atrium-like walkway to the conference room. Interior detailing takes its cues from the original building's beaded boards, reeded mantels and recessed panels. Eighteenth-century colors inspired the paint scheme.

The iron details were designed by Kathy Frazier, a principal of our firm, and fabricated by a local craftsman, William Ferguson. The gentle curve of the handrails and the balusters recalls the 18th-century hardware found in the original building. The black iron motif is reinforced by the tie rods, and further echoed in the hanging mechanism of the light fixtures.

While the firm chose to go with a timber frame addition for its aesthetic appeal, there were also great gains in energy performance by choosing this building method. A double-height wall of windows faces south, enhancing the building's natural compatibility with passive solar heating. During the warmer months, operable windows are opened to allow fresh air to circulate freely through the space. Energy consumption is low relative to other new conventional buildings of the addition's size.

Fig. 5. Two-story light well has double-height south-facing windows. Curved iron balusters were forged by local blacksmith.

While there has been some movement in the structure since it was completed in 2004, we find the aging, twisting and cracking of the wood all contribute to the material's inherent beauty. The firm's clients, who progress through the original building before being guided into the conference room at the terminus of the new addition, almost always glide to a stop in the exact same spot, about ten feet into the addition. They admire the character of the wood, the craftsmanship of the framers, and the addition's sense of connection to the original building. The architects who work in the space enjoy the visibility of the construction process, the appropriateness of the materials, and the wide-open spaces and corresponding spirit of collaboration that timber framing makes possible.

—Kathy Moore

Kathy Moore is an associate at Frazier Associates, a busy architectural firm in Staunton, Virginia, specializing in new work in historic styles, historic conservation and preservation, landscape architecture and community revitalization.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Doug Miles

Rendezvous at Château du Mesnil Geoffroy in Ermenouville, Normandy, in September. Studs have been removed from ca.-1700 service buildings under repair. New sills are being hewn and will be mortised and then maneuvered in with studs attached. Above, organizer François Calame codes the studs. ***Report page 2.***