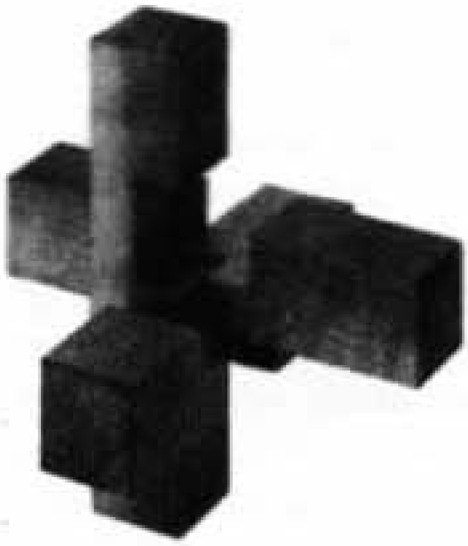

1. The Genesis of Japanese Joinery

Where Wood Has a Soul Because Japan was heavily forested, the architecture she developed contrasts sharply with that favored in many other areas of the world. In Europe and China, for example, where both stone and good clay for brickmaking were abundant, the mason's art developed and flourished. But the volcanic soil of Japan and other Pacific islands, which offered few materials to tempt a mason, yielded a seemingly endless variety of trees and other plants suited to a different type of construction. Thus, as European and Chinese masons were developing techniques for stacking stones and bricks atop one another, Japanese carpenters were experimenting with the post and lintel construction basic to wooden architecture.

While the most highly developed mason's art is to be found in Europe, Japan undoubtedly enjoys the most advanced techniques of wood construction. The seventh- and eighth-century structures at the Nara temples Hōryū-ji, Tōshōdai-ji, and Shin Yakushi-ji, for example, show the Japanese adaptation of mainland architectural forms introduced into Japan by that time. Even in these early structures we can see evidence of the advanced wood-construction techniques already used by the ancient Japanese.

It may seem paradoxical to state that Japan's highly developed joinery techniques resulted from her abundant timber; however, that abundance encouraged an almost exclusive concentration on wood construction. In order to continue that tradition once all the good timber had been felled, it was necessary to use the inferior timber that had been passed over earlier. The challenge presented in constructing a plumb and true building from the gnarled and knotted timber that remained undoubtedly led to the creation and development of both new techniques for joining wood and the tools with which to work the joints.

For a modern example of the problems of working with poor timber, we need look no farther than the wooden bathtub traditionally favored in Japan. Until twenty or thirty years ago, the bathtub maker split his boards out of a section of a tree because that yields more boards. But this method works well only with good, straight-grained timber. Since today's bathtub maker can usually get only timber of lesser quality, he has had to stop splitting off his boards and begin sawing to get usable boards from the knotty timber left to him.

Although the abundance of timber definitely contributed to the concentration on wood construction in Japan, other factors affected this choice of materials. One of these is the sheer destructive force of nature as seen in the numerous typhoons and earthquakes Japan experiences. Wood construction, because of its smaller mass, is better able to withstand earthquakes than is stone or brick construction. During an earthquake, the joints so necessary to wood construction function somewhat like shock absorbers, affording wooden buildings a certain amount of give, which is not possible with rigid stone or brick construction. Other factors favoring the choice of wood in Japan include the native timber's natural resistance to attack by bacteria, fungi, and insects, and the native termite's lack of vigor. Although termites have destroyed virtually all the older wooden buildings throughout the South Pacific, in Japan they have done very little damage.

Most native timber, such as pine, cedar, and Japanese cypress, is coniferous and grows well in temperate Japan. From earliest times, however, imported timber, variously called *karaki* (literally, "precious foreign wood") or *tōhemboku* (once meaning "precious unusual foreign wood"), was mostly of the broad-leaved variety, such as teak, red sandalwood, ebony, Indian ironwood, and lauan. In the Pacific, coniferous timber was peculiar to Japan, where the abundant rainfall and very warm growing season contributed to rapid summer growth and strong, beautifully grained timber. The Japanese climate was as admirably suited to the conifers as those tall, strong, easily worked straight-grained trees were to Japanese architecture.

Numerous Japanese leaders of the past have promoted and supported reforestation projects. The level of their activity and their success is demonstrated by the fact that much of the building timber used today, for example, the prized cedar from Akita Prefecture in northern Japan, was planted during the Edo period (1603–1868) by these far-sighted leaders. Although these reforestation projects may have been politically or economically inspired, I believe they were largely a result of the deep, almost religious reverence the Japanese have for trees. While most mountain residents know the names of only a few kinds of seaweed and most seaside residents know the names of only a few mountain wildflowers, everyone in Japan knows the word *kodama*, literally, "the spirit of a tree." I think it must have been an early faith in this *kodama*, this spirit of a tree, that caused the Japanese people to revere their trees, to care for them, and to actively promote reforestation. This same reverence no doubt accounts in part for the innumerable trees throughout Japan that are considered sacred.

Lebanon was once famous for its cedars. Phoenician fleets were built of the cedars of Lebanon, as was at least part of Solomon's Temple, and a 140-foot ship, excavated in superb condition from a pyramid and reassembled, was built of Lebanon cedar some 4,500 years ago. Yet today the famed forest lands of Lebanon are barren; only a few trees, protected as national monuments, remain as testimony to the ancient riches. Perhaps reforestation was not practiced in Lebanon or perhaps effective forest management was not possible because of climatic conditions. Whatever the cause, the result is a great loss to Lebanon and to the world: the once rich Lebanese forests are now a sere wilderness. The Japanese, in particular, should be grateful for their still-green mountains and for the fact that their ancestors fostered one of the earliest successful reforestation programs in the world. Perhaps, then, the Japanese, as developers of highly advanced carpentry techniques and as pioneers of reforestation, have a special obligation not only to their own children, carpenters, and ecologists, but to future generations outside their archipelago.

In contrast with inorganic building materials and more recently developed high-molecular building materials, timber requires an almost animistic faith of the people who work it. I suspect that even noncarpenters cannot escape the inclination to ascribe divinity to the mystery of nature that creates beautifully grained wood. In Japan, various myths and legends immortalizing the divine nature of particular trees survive even today in stories recorded and handed down to us in literature and in picture scrolls. It is not because my understanding of theology is wanting that I cannot help believing in the divine nature of a tree when I see that through some mysterious inspiration it has been enhanced and transformed into artistic expression. When I look at a beautiful example of wood construction, I cannot help thinking that the beauty of the architecture derives not only from its design and construction techniques but also from the very soul of the wood itself. At the same time, fine wooden structures seem to speak with the hearts of the master carpenters who constructed them with obvious respect for the soul of their timber.

Wooden Structures It is often pointed out that wooden buildings are highly vulnerable to fire. Certainly this is true in large, congested cities; but in the days when Japan's cities were not so crowded that houses had to be built literally eaves-to-eaves, wooden structures were rarely destroyed by fire. In Japan today, a great many old wooden buildings survive in out-of-the-way places that were not plagued with the fires that commonly attended civil strife. Actually, the majority of fire damage suffered in Japan in the past resulted from the battle tactic of deliberately firing buildings; and it was not until quite recently, with the advent of arsonists and the increase of fires caused by gas and kerosene stoves and heaters, that our wooden structures began succumbing to fire in greater numbers.

But a comparison of fatality statistics is much more revealing: the number of deaths recorded for fires in buildings constructed of such noncombustible materials as concrete far exceeds the number recorded for fires in wooden buildings. Equally interesting is the fact that wooden buildings often survive a fire largely intact. For example, the oldest wooden structure in the world, the Golden Hall, built in 679 at the temple Hōryū-ji, near Nara, suffered a fire in 1949. Of the priceless murals on its walls, many were destroyed and others were badly damaged, but almost all its structural members survived undamaged. Today, after surprisingly small-scale repairs, this ancient wooden building is still in use and still open to the public.

In Japan, countless people have witnessed fires in ordinary wooden dwellings and noticed that the commonly used 10 cm. square posts (roughly 4" × 4") and 30 cm. square beams (about 12" × 12") generally remain in place, even if badly charred. Wood does not begin to burn until it reaches a temperature of about 300° C (575°F); but since wood is such a poor conductor of heat, even when the surface temperature reaches 300° C the heart of a substantial building member is little affected and will continue to support the load it was intended to support. Hence, we can say that in a fire, wood construction is actually safer than steel-frame construction, since steel is a very good conductor of heat, bending like soft taffy at 800° C (1472°F) and warping badly at lower temperatures. Steel stairways are hazardous during a fire, since at relatively low temperatures they quickly become too hot to step on and at higher temperatures they warp, losing their shape entirely at very high temperatures.

Although steel-frame construction appears safer at first because it is itself non-flammable, during a fire it is actually less trustworthy than wood-frame construction. For example, because steel is an efficient heat conductor, very hot steel stairs cannot easily be cooled enough with water to be usable in a fire; yet because wood is an inefficient heat conductor, wooden stairs can so easily be cooled that they can be used even with flames licking at them. Sturdy wooden stairs are fairly safe in the early stages of a fire, since the heart of the timbers is unaffected and it is necessary to cool only the burning surface, which does not retain heat as well as steel does. Hence, we should not cavalierly dismiss wood construction because the basic material is flammable.

Because wood is such a poor conductor of heat, it generally maintains an even temperature relative to the season and is warm to the touch even in midwinter. In very humid countries like Japan, stone buildings will sweat greatly on a muggy day; and marble-faced buildings sweat so much that they become very uncomfortable in moderate weather and almost unbearable in humid weather; but wood construction rarely sweats, since it can absorb the normal levels of surrounding humidity. This alone would persuade me that wood construction is most suitable in a humid country like Japan, even if I did not take traditional Japanese aesthetics into consideration. This is not to say that the ancestors of the present-day Japanese eschewed or had no skill at stone construction; on the contrary, at archaeological sites dating from about 3000 B.C. to the seventh century A.D. we find an abundance of stone construction, interspersed with pit dwellings and stone burial mounds, to remind us that wooden architecture is, in Japan, a relatively recent innovation. But we must keep in mind that once in use it quickly became the primary architectural medium.

***Kiwari:* Construction Proportions** It is generally held that the beauty not only of architecture but of all things, both man-made and natural, derives from their proportions. In architecture the ancient Greeks, in particular, experimented with proportions, eventually establishing the Doric, Ionic, and Corinthian orders, based on highly developed ideal standards of proportion. In Japan, too, people experimented with architectural proportions and developed a kind of order, an ideal standard of proportion. This order is known as *kiwari*, literally, "dividing wood," but meaning "determined construction proportions." *Kiwari* eventually gave rise to a formalized system of prescribed design techniques known as *kiwari jutsu*, or the art of determining construction proportions.

Although the word *kiwari* did not come into use until the early seventeenth century, near the beginning of the Edo period, at different times before the Edo period two separate words had been used to identify the concept of determined construction proportions. Thus, it would be proper for us to consider *kiwari* a very general term, not referring to a specific order or set of ideal proportions but encompassing the larger concept of proportional relations among the individual structural members of a building.

If we accept *kiwari jutsu* as a recognized discipline governing construction, we can discern clearly established relations among the proportions of structural members of buildings erected as early as the Nara period (646–794) and during Japan's middle ages, the late twelfth to late sixteenth century. In particular, we notice well-defined standards for posts, based on the thickness of structural posts and on interpost spans, and for roofs, with heavier roofs requiring thicker, more closely spaced posts.

If we consider the relation of interpost span and post size, in ancient architecture the uniform distance between posts appears rather narrow in relation to the massive size of the posts or pillars. But in time, technical advances, no doubt stimulated by the rising costs of materials, resulted in progressively less massive posts spaced farther apart. If we compare one of Nara's older temples, the Tōdai-ji, built in the first half of the eighth century, with one of Kyoto's more recent temples, the Chion-in, rebuilt in the 1630s, the earlier temple appears very massive and imposing, while the later temple leaves a lighter, more delicate impression.

Until almost the beginning of the Muromachi period (1336–1568) architectural proportions gave an impression of great strength and beauty. But the increasingly far-reaching effects of the incessant civil war of that period included both the destruction of a great many imposing older buildings and a shift from the earlier massive structures to equally pleasing styles that were easier and less expensive to construct, or reconstruct, as occasion demanded. Although the use of decorative sculpture, carving, coloring, lacquer, and metal fittings to ornament buildings was developed to a sumptuous degree during the Momoyama period (1568–1603) and the Edo period (1603–1868), at the same time, in the actual framework of buildings the proportions, or *kiwari*, of the various structural members are greatly reduced when compared with earlier buildings. Among various buildings intended for the tea ceremony and among buildings in the *shoin* style of architecture adopted by aristocrats, warriors, and priests toward the end of the Muromachi period, we do find many very beautiful structures; but theirs is indeed a rather delicate beauty when compared with buildings of earlier periods.

Many different *kiwari* systems, each with slightly varying standards of ideal proportions, were developed and handed down from generation to generation. The oldest extant system was developed before the Kamakura period (1185–1336) by the Abè family, traditional master shrine carpenters from Shiga Prefecture. Among the several extant *kiwari* manuals that were eventually compiled, perhaps the most famous is the five-volume *Shōmei*, prepared in 1608 by the Heinouchi family, who served the government as master builders and chief carpentry supervisors. It might at first appear that the various manuals were intended to preserve rigidly exacting standards of design, but in all honesty, we cannot be certain that any structure was ever built in strict accordance with the rules set forth in these manuals. Perhaps we should consider the surviving manuals as general reference works, architectural encyclopedias in which all the existing technology of Japanese architecture was assembled and presented in a systematic form, setting patterns for modern Japanese architecture.

The *kiwari* manuals anticipated such questions as what is a good height for a ceiling. When a ceiling is too low, it leaves us with a cramped, gloomy feeling; when it is too high, it seems loose, disconnected from the room. And will one ceiling height work for all rooms? To answer such questions, some kind of standard is needed. According to the established patterns, in a six-tatami-mat room (roughly 9.7 sq. m., or about 104.6 sq. ft.) the ideal ceiling height is 60 cm. (about 23 7/8") from the bottom edge of the lintel, and in an eight-tatami-mat room the ideal ceiling height is 80 cm.

(about 31 1/2") from the bottom edge of the lintel. Since the standard distance from the sill to the bottom edge of the lintel is 180 cm., we know that according to *kiwari* systems the ideal height for the ceiling of a six-mat room is 240 cm. above the sill, and for an eight-mat room 260 cm. above the sill.

Besides setting forth such standards for the modular composition of space, the *kiwari* manuals also gave detailed consideration to many structural elements, including the relationships among the size of the structural posts, the spacing of rafters, and even the proper dimensions of *shōji* (sliding panels made of translucent paper mounted on one side of a latticed wooden frame and used as either windows or doors). For example, if the structural posts of a building are 12 cm. square, then exposed beams should be 9.5 cm. square, and the frame members of *shōji* should be 3.4 cm. square.

Space I believe that one salient characteristic of Japanese art and culture is the emphasis on *ma*, a space or interval. In Nō plays, for example, a small hand drum is struck; the beat is followed by silence; then the drum is struck again; that beat is followed again by silence; and so on. This *ma*, the interval between the soundings of the drum, which is characteristic of Japanese music, is not related to the pause or rest found in Western music. In Japanese music, even when there is no sound, something vital remains.

To the Japanese, *ma* is not just an empty space, where nothing exists: it is the space or interval necessary to give shape to the whole. One of the more vulgar derogatory terms in Japanese is *manuke*. In use, its meaning is something on the order of "grossly stupid," but its literal meaning is simply space (*ma*) that is missing (*nuke*). That *manuke* is considered such a strong insult that it can lead to blows is, I think, a good indication of just how important the presence of space, or *ma*, is in Japan.

In construction, *ma* referred simply to the space between structural posts. Among the many architectural terms derived from this word are *magusa*, or lintel, which initially meant the material (*kusa* or *gusa*) that was put into a *ma*; and *mado*, or window, which was basically a door (*to* or *do*) that was put into a *ma*. Originally the *ma* was not a unit of measurement; but the Sino-Japanese ideogram that can be pronounced *ma* was also used to indicate the actual measured distance between posts, and in that usage it is pronounced *ken*.

The *ken* is the fundamental measurement of modular construction in Japan, but this basic unit has been a variable one. At first one *ken* was equal to one *jō*, or three meters. Then the *ken* came to be measured in terms of the *shaku*, about thirty centimeters, roughly equivalent to the English foot. At that time, in the mid-sixteenth century, one *ken* equaled seven *shaku*, or about 2.12 meters. Later the *ken* equaled 6.6 *shaku*, or about 1.99 meters. The *ken* shrank further to 6.3 *shaku*, about 1.9 meters; then to 6 *shaku*, or about 1.82 meters. Quite recently, however, the *ken* has shrunk to exactly 1.8 meters. It seems distinctly odd that while the height of the average Japanese has been increasing steadily over the centuries, the measured length of the *ma* has been decreasing just as steadily, reducing the overall size of buildings. But I suppose that the *ma* became the established standard module for structures without regard for what the actual measured length of a *ma* was at any given time.

Although the *ken* has been a changing measurement, its relation to the *ma* has remained constant. In modular construction a *ma* is invariably one *ken* long, while a supplemental measurement of half a *ken* is used to permit flexibility in construction. Since the *ma* refers not only to width but to height, it is actually a square space, one *ken* by one *ken*, measured from centerline to centerline. A square *ma* of floor space, called a *tsubo*, is equal to two tatami mats.

Determined construction proportions, *kiwari*, were based on a modular coordination that was intimately related to everyday life. This relationship is seen not only in the sizes of tatami mats, but even in furniture. For example, in the old days the standard dresser was 3.1 *shaku* wide (about 93.94 cm.), 1.4 *shaku* deep (about 42.42 cm.), and 1.7 *shaku* high (about 51.5 cm.). It occupied about 1/4 tatami of floor space, and though quite heavy when full, was still small enough that it could be quickly removed from a building, in the event of a fire, for example. When the *ken* equaled 6.3 *shaku*, about 1.9 meters, two of these dressers easily fitted side by side into a one-*ken ma*, or one fitted comfortably in a half-*ken ma*.

In recent years, wood construction has been displaced more and more by ferroconcrete construction; yet since the measured length of the *ma* has not changed, new problems arise. Because of the materials used, the walls of a ferroconcrete building must be at least 20 cm. thick; hence its *ma* measured from centerline to centerline results in a room very much smaller than a comparable room in a wooden building with 12 cm. square posts. In Japan this further reduced ferroconcrete *ma* is called "*danchi*-size," *danchi* being a nickname for the public housing complexes that marked the beginning of concentrated efforts in ferroconcrete construction. But the term "*danchi*-size" is only a deceit, an attempt to give this reduced *ma* an air of legitimacy by giving it a name. For example, in a house using Kyoto-size tatami (6.3 *shaku* by 3.15 *shaku*), a room of four and a half tatami mats has a floor area of 9.6 square meters, while a *danchi*-size four-and-a-half-mat room has an area of only 6.2 square meters. In fact the Kyoto-size four-and-a-half-mat room is actually larger than a *danchi*-size six-mat room, which has an area of about 8.2 square meters.

Carpenter's *Dōgu*, or Instruments When we think of wooden architecture, we usually think of post and lintel construction, with all the members meeting at right angles. But there are many buildings in which the emphasis is on a diagonal element, or curved surfaces, or a parabolic roof. There is a growing interest in seeking solutions to the problems of constructing such buildings, and we saw many unusual buildings constructed in Osaka on the site of EXPO '70.

In wooden architecture, however, the majority of construction employs straight lines, primarily because of the characteristics of wood and the nature of its growth. There are obvious exceptions, such as wooden ships with their curved, sloping hulls, gracefully curved furniture formed from a single piece of wood, and unusually shaped kitchen utensils. But in such cases, the shipwrights, furniture makers, and other craftsmen have had to develop techniques for forcing wood to assume and retain an unnatural shape.

In addition to the wide variety of timber available, which makes it possible to select wood with the properties best suited to the intended use, technical advances in processing timber have resulted in a new variety of building materials. Strong, relatively lightweight plywood can be molded in a variety of shapes while retaining its strength; and particle boards, made of wood flakes bound together with synthetic resins, also lend themselves to new shapes. Because of such new materials and the tools with which to mold them, it has become possible to move away from the traditional straight-line construction in wood and experiment with many new forms and shapes. While the use of large sheets of plywood has resulted in an enormous saving of time and energy in putting down subflooring, for example, the wide range of electric woodworking tools now available has not only saved time and energy for carpenters but also altered woodworking techniques.

Although modern technology has given us new materials and new tools, Japanese carpenters still use a very special, respectful term for their instruments, even their electric tools. No Japanese carpenter refers to his instruments as mere "tools," but instead calls them *dōgu*, which really has no equivalent in another language but means roughly the "instruments of the Way [of Carpentry]." *Dōgu* is a very old word and perhaps it has not disappeared because even though materials and tools have changed and improved, carpentry methods and the "Way of Carpentry" have remained basically unchanged for hundreds of years. A certain pride in being an accomplished professional carpenter may also contribute to the reluctance to demote those instruments to tools.

Originally, a *dōgu* shop was one dealing in implements and equipment for the tea ceremony. The various implements used in the tea ceremony—*sadō*, or the Way of Tea—were called *dōgu*, or "instruments of the Way [of Tea]." Carpenter's tools also came to be called *dōgu* because for carpenters there is a Carpentry *Dō*, or Way of Carpentry; and carpenters, too, considered their implements *dōgu*, or instruments of their Way. Although many artisans use implements unique to their crafts, these implements are always called tools, never *dōgu*. To a Japanese carpenter, his *dōgu* have a significance far removed from that of the mere tools that other craftsmen might use. Nowadays, however, the carpenter's *dōgu* are not so highly respected and valued as they once were, perhaps because the most highly skilled traditional carpenters are now quite aged and so many younger carpenters lack the spirit and devotion that are the bedrock of fine workmanship. In the old days, for example, if an apprentice stepped over a saw, it was only natural for his master to strike him soundly for showing such disrespect for his *dōgu*. The apprentice would accept his punishment without complaint, knowing how gravely he had erred. Perhaps we could even say that formerly the carpenter's *dōgu* were invested with a degree of divinity.

According to a Chinese myth, a family named Fūshī devised the compass, square, level, and plumb line, collectively known as *kinorijunjō* in Japanese. Many consider this to mark the origin of true carpentry instruments, or *dōgu*. It is easy to imagine that the first *dōgu* employed to work wood were axes of various sizes, since the first step in working wood must be the woodcutter's. It is clear that the ax is among the oldest of man's tools, since it is found throughout the world in the oldest strata of man's debris. Because ancient Japanese axes are almost identical to contemporaneous axes found in China and Korea, it is surmised that the early ax came to Japan via the continent. And today's skilled carpenters can still do the most exacting work with only an ax.

We believe that the chisel and hammer or mallet were the first tools to follow the ax. It was not until the iron age that these stone implements were joined by the saw. In collections at the Hōryū-ji and in the Shōsō-in, the eighth-century repository of the Tōdai-ji, a few ancient saws are preserved, all with blades much thicker than those of modern saws. By measuring the width of kerfs, or saw cuts, found on ancient timbers during one rebuilding of seventh-century Hōryū-ji structures we have been able to determine that the saws used in the original construction had blades about 5 mm. thick (about 3/16"). The blades of saws found in third- to seventh-century mounds are quite thick, although most of the saws are so badly corroded that we cannot determine either their original size or their original thickness.

One board commonly used in Japan was known as a four-*bu* board, since it was supposed to be four *bu* thick (about 12.12 mm., roughly 1/2"); however, measurement was considered accurate if the board was 2.3 *bu* thick (about 6.97 mm.). This acceptable difference of about 5 mm. is the result of subtracting the allowance for the kerf when cutting the board; but even today, with improved sawyer techniques that make it possible to produce boards of absolutely true measure, this 5 mm. allowance for the kerf is still accepted. In America, too, we see a similar allowance for the kerf: a 2 × 4, for example, should be 2 inches by 4 inches, but in fact the generally accepted measurements are short about 3/16", the thickness of the kerf. We can therefore assume that for quite a long time about 5 mm. has been accepted as the standard thickness of a saw blade in both the Orient and the West. It is possible that the properties of ancient iron required thick saw blades. We cannot, of course, know the thinking of the creator of an early saw; but if we suppose that he considered each tooth of a saw as a separate cutting edge, like a minute adze or chisel, then it is probable that a saw was regarded as a blade with a series of little chisels set in a row along one edge. Such a perception would undoubtedly affect manufacturing methods and could account for the great thickness of early saws.

When the Hōryū-ji and Tōdai-ji were built, in the seventh and eighth centuries, the main carpenter's *dōgu*, or instrument, was an iron adze. Carpenters in those days did all their work, from roughing out to planing, with only an adze; even mortises were made with just an adze and chisel. With such primitive tools, however, the amount of lumber actually usable for construction was only about one-tenth of the timber that had been felled in the forest: the remaining ninety percent simply disappeared in the dressing and finishing. Even temples built as late as the Kamakura period (1185–1336), with their fine, delicate elements, were constructed with only the adze, saw, and similar tools, since the plane had not yet been introduced. Planes did not appear in Japan until around the beginning of the Edo period (1603–1868), and it has been suggested that they were introduced from China.

We should also give some thought to the basic measurements used in construction. In some ancient Japanese structures we find evidence of the use of a measure known as the Koguryŏ *shaku*. Since it is believed that the Koguryŏ *shaku* was used as a measurement in constructing numerous massive burial mounds surviving from the third to seventh century, it seems likely that it came to Japan from the Korean kingdom of Koguryŏ, becoming established as a standard measure in very ancient times. Among extant ancient carpenter's rules, one in the Shōsō-in is considered a national treasure. A similar rule that may have once belonged to the Nachi Shrine in Kishū, south of Osaka, has disappeared. It is believed that in addition to these few carpenter's rules we now know, many other standard measures were in use. But when we compare the ancient *shaku* used in different areas or structures, there is remarkably little variation among them. For example, the *shaku* used in 1124 in constructing the Konjiki-dō, or Golden Hall, of Chūson-ji in Iwate Prefecture, in far northern Honshu, equals 1.065

shaku (about 32.27 cm.) in modern measurements. The difference of 1.97 cm. between this and the modern *shaku* is probably an error arising simply from the rather primitive techniques of those days. Since the *shaku* used in construction in the then-pioneer countryside of northern Honshu was this accurate, we can assume that even at that early time a fairly standard *shaku* was in use, differing very little from one part of Japan to another.

The Roof Truss The one element common to all structures we call buildings is the roof, and I believe it is the most important structural element. We often speak of the "shape of a house" and in Japan that shape always includes, in our mind's eye, a triangular gable. The "shape of a house" calls to mind the same image in the West: neither Japanese nor Westerners are likely to visualize the flat-topped, boxy structures we find more and more in modern construction. Even the doghouses we build have pitched roofs. Hence, the shape of a roof is obviously an important element in the basic designs that determine the shape of a house, and in Japan, where rainfall is abundant, roofs with a steep pitch are a necessity. It could be said that *kigumi*, or wood construction, is basically the construction of roofs and posts, encompassing the composition of the roof truss and framework.

As Japan's forests became exhausted, the increasing scarcity of good timber needed for truss construction undoubtedly had a direct bearing on the development of the numerous techniques not only for splicing short timbers but for connecting structural members. In the West, joints fall into one of two general classes: a joint is either a butt joint or a lap joint. In Japan, too, joints fall into one of two classes: a joint is either a *tsugite* (splicing joint) or a *shiguchi* (connecting joint). In the West joints are classified according to the manner in which the pieces of wood are joined, but in Japan joints are classified according to their function. Thus a half lap joint used to join two pieces of wood end to end (Fig. 11) is classified in Japan as a *tsugite*, or splicing joint, and a cross lap joint used to join two members at a right angle (Fig. 55) is classed as a *shiguchi*, or connecting joint, while in the West both are classed simply as lap joints. Apart from serving to splice or connect timbers, *tsugite* and *shiguchi* should contribute to both the strength and the beauty of a structure. And in truss construction in Japan both strength and beauty are major considerations.

The most important architectural element in Japan is the rafter, both from a structural viewpoint, since the rafters must support heavy tiled roofs, and from an aesthetic viewpoint, since exposed-rafter construction has long been favored. It is no wonder, then, that from very early times Japanese carpenters have been preoccupied with rafters. In ancient times, although rafter distribution and density were closely related to the placement of roof tiles on a building, they had no relation to other parts of the structure, such as interior walls. It seems, however, that rafter distribution and density gradually came to be more related to other parts of a building and eventually to have a definite bearing on construction plans.

During the Kamakura period (1185–1336), when carpenters built a house they took its rafters as their standard, basing all other plans on that standard. Carpenters first determined the distribution of rafters and the interrafter spacing and on the basis of these decisions worked out all other details, from the placement and dimensions of individual rooms to the length of the overhang of the eaves. Later, with the development of fan-rib or radial raftering (Fig. 7), construction planning started to become more precise, probably because more complex and exacting techniques are required in constructing fan-rib raftering. In time, fan-rib raftering became the basis of structural planning: carpenters first decided where to place the hip rafters, then determined the placement and density of the radiating common and jack rafters, and on the basis of this work completed the plans for a building. During this period, the rules of *kiwari*—or determined construction proportions—that applied to eaves construction advanced greatly, finally becoming codified.

Although *kiwari*, or *kiwari jutsu*, is basically the study of structural proportions, from the foundation of a building to its ridgepole, special emphasis is laid on the construction of the roof truss and rafters. Among the important structural proportions of a building, such as the roof, framework, and windows, the most important for traditional Japanese carpenters is the roof, because it not only determines the shape of a building but is also the distinctive feature that makes Japanese architecture look Japanese.

When Westerners draw pictures of Oriental architecture they usually draw buildings with sweeping roofs that resemble an inverted V that has been sat upon. It is quite true that a great number of Oriental buildings have such roofs, but in Japan the straight pitched roof predominates. Although one does find a number of sweeping roofs in Japan, one also finds a number of roofs with a pronounced camber. Both these roofs are difficult to construct. For example, to create the trailing curves of a sweeping roof we must rely on the plasticity of heartwood, but if we use only sound, straight timbers it is very difficult to create these shapes with wood alone. These sweeping roofs with their trailing curves, which were originally introduced from China and are still called "Chinese style" roofs, created many problems for Japanese carpenters, who tried to reduce the degree of warp in rafters, ridgepoles, and so on, while still fashioning an elegantly curved roof.

In order to construct a pitched roof one needs not only horizontal members, such as ridgepoles and tie beams, but also vertical members, such as king posts, and diagonal members, such as rafters and struts. Joining the various members of a complicated roof truss, which can be challenging to a carpenter, requires the use of some very complicated *tsugite* and *shiguchi*.

In constructing a roof truss, carpenters must take special care with joints where members come together from three directions, such as at the corners of the eaves of the Japanese-style hipped-and-gabled roof. Curved gable roofs were originally created by carrying a very long rafter down from the ridgepole over numerous purlins and the wall plates, ending in flaring eaves. But in hipped-and-gabled roofs, the hip rafter joins not the ridgepole but a secondary ridgepole that descends, just above the principal rafters, from the ridgepole. From this joint, the hip rafter sweeps out in a graceful curve. Although it should be impossible to build this kind of roof without welded joints at the connecting and supporting points, it was accomplished through the ingenious use of flying rafters to support the eaves, and it still seems almost magical. It should be pointed out, however, that these curving eaves were also used to disguise the natural deflection that normally occurred at the eaves.

In Japanese architecture there are numerous ways of constructing rafters to hold the sheathing and support the roof; and there are numerous ways of connecting the rafters to other parts of the roof truss, such as ridgepoles, purlins, wall plates, and collar beams. A wide variety of splicing joints (*tsugite*) and connecting joints (*shiguchi*) was needed to create members of the necessary length, to join the various members of the truss, to achieve differing degrees of roof pitch, and to create curving eaves.

Some ancient buildings, for example, the eighth-century Main Hall of the temple Shin Yakushi-ji in Nara (Fig. 4), were built in a handsomely crafted bare-rafter style. Later treatment of gables and open attics included visible rafters, but the earlier bare-rafter style, which had displayed beautiful construction to great effect, had by then degenerated into a primarily decorative, formal exposed-rafter idiom of little distinction. Later, when closed ceilings were introduced, the defined space of the attic could no longer be seen. But these changes were accompanied by technical progress that made it possible, for example, to use various kinds of halved joints in attic construction to create deeper eaves.

The rafters visible in the formal exposed-rafter style were in fact a variety of flying rafter, as distinguished from the base rafters that actually support the sheathing and roof. Although it appeared that the true pitch of the roof could be seen from inside the attic, in reality the visible flying rafters used in the formal exposed-rafter style had a slightly smaller pitch than the base rafters. Because of an optical illusion, seen from outside, the roof appears to have a rather ordinary pitch, but seen from inside, the exposed rafters give the impression of a steep pitch. One type of gently arched exposed-rafter construction made with very little pitch was called the "boat bottom ceiling" because of its resemblance to the hull of a fishing boat. When carpenters had fully developed the formal exposed-rafter style, it was possible to employ a greater variety of splicing and connecting joints in the base rafters and truss, which were hidden behind the visible flying rafters. Here again technical advances were made in splicing and connecting joints.

Since the closed ceiling was unknown in the oldest architecture in Japan, the exposed interior of the open attic of a building was carefully and beautifully constructed. In recent times, far less care in construction has resulted in trusses that are both inaccurately made and vulnerable to damage, which may explain why so many modern buildings have leaky roofs.

In Japan, ceilings were originally called "dust catchers" and were intended simply to keep dust and debris from falling into a room from the exposed underside of the finished roof. In the beginning, *tengai*, loose, latticed canopies, were suspended from the truss to serve as "dust catchers." Eventually these evolved into more solid units attached to the framework of a room. Much later, such complex variations as coffered ceilings, coved ceilings, and coved-and-coffered ceilings were developed. With these ceiling variations also came advances in the splicing and connecting joints needed to construct them.

The so-called Japanese roof truss, or *kyōro-gumi*, shown on page 96, consists of a sometimes elaborate series of posts set on crossbeams, with the purlins, which support the rafters and roof, set on top of the posts. The Japanese roof truss may be unique in its use of whole, barked logs as tie beams, but they are preferred chiefly because that is the most economical way to obtain stout tie beams. During the Nara period (646–794), the *gasshō* truss style, shown in Figure 4, was quite commonly used. The *gasshō* style, however, is not considered a true Japanese truss and is almost identical to Western trusses.

Framework and Floor Framing Erecting a framework basically consists of putting sills on a foundation, standing posts on the sills, and laying beams on the posts. To this basic skeleton are added window frames, door frames, and so on. Then the framing for the fittings that will define the interior spaces is added. In Japan, the fittings that close off or divide space include not only solid walls but also *shōji* and *fusuma* (sliding partitions made of opaque paper mounted on both sides of a wooden frame and used primarily as room dividers). To strengthen the framing added to the basic skeleton, a variety of diagonal bracing, cross bracing, and so forth is added. Thus the framework includes not only the basic structural skeleton but all the members added to it either to define interior space or to strengthen the structure. And the most important points in the framework are the splicing and connecting joints used in the sills, posts, and beams.

Although a few horizontal structural members in Japanese architecture, such as exterior door lintels, are almost identical to their Western counterparts, there are a great many that are unique to Japan. There is, for example, a class of small beams called *nageshi* that are used at the top and bottom of the partial walls above *fusuma* or *shōji*. Originally, *nageshi* were functional structural members, but in modern times they have become almost purely ornamental. Now that *nageshi* have lost their true function, they are no longer dotted with the decorative nail covers devised to conceal the heads of the spikes that had been driven through the *nageshi* to reinforce joints. Also unique are the grooved lintels and sills that form the tracks that *fusuma* and *shōji* slide in. The grooves in the lintels, which are about six times as deep as the ones in the sills, were originally made by nailing strips of wood to the structural lintel; but now that routing tools are available these grooves are normally routed out of the lintel.

According to various myths and legends and the ancient historical chronicle *Kojiki* (Record of Ancient Matters; 712), in Japan, to "raise a post" means to begin the construction of a building. Perhaps the first posts were simply embedded in the ground. In prehistoric pit dwellings we do find post holes, often spaced fairly regularly, and it seems likely that the inhabitants of those dwellings added beams, braces, and rafters, lashing the members together with rope or vines. Dwellings of very similar construction are still to be found today on islands in the South Pacific.

Another way to build a house is by stacking up logs, which in a sense resembles building a house by stacking up bricks or stones. This is an ancient construction method in Japan, where it is called the *azekura* style (which is usually translated as the "log-cabin style") and has been used primarily in the construction of storehouses (Fig. 1). Because an *aze* is a ridge between rice fields and a *kura* is a storehouse, we presume that the *azekura* must be in some way related to a granary. Although we do not know when or whence the *azekura* style was introduced into Japan, where the primary construction technique was post and lintel, we should bear in mind that it, too, is included in what we call Japanese architecture.

The topmost part of the framework of a building is given a separate name: the roof truss. When the framing of the truss is finished, the framework of the house is considered completed; and in Japan, as in some Western countries, a celebration is observed at this stage of construction. The Japanese style of floor framing, similar to the construction shown in Figure 2, does not exist in China or in the West, where solid, closed foundations, joists, and subflooring are used. Altogether, Japanese *kiwari* consisted of floor framing, framework, and roof truss.

In ancient times commoners' houses in Japan generally had only hard-packed earthen floors, although they always had a wooden-floored sleeping area and often had a wooden floor in at least part of the main living area. The old Sino-Japanese ideogram now used in Japan to mean both "floor" and the Japanese-style "bed" originally meant only "bed." Because when this ideogram came to Japan from China a "bed" was simply a wooden-floored place to sleep, it is easy to understand how the meaning could have been broadened from just "bed" to include "floor," as well. There may also be an implication here that a wooden floor seemed artificial when compared with an earthen floor, much as a modern bed must seem artificial in comparison with a wooden floor.

Wood floors consist basically of sills, sleepers, joists, and floor boarding. In Japan, where humidity is high almost the entire year, good ventilation beneath the floor is essential to preserve the wood. Thus, it was very natural that a high, open foundation came to be preferred in Japanese construction.

Very often, the floors of Japanese-style houses are extended beyond the exterior walls as verandas. If we argue that the interior of a house has a floor and the exterior does not, then the veranda of a Japanese house must be considered as part of the interior. But if we argue that exterior doors or walls form a dividing line between the interior and the exterior, then the veranda must be considered as part of the exterior. In actual practice, however, the veranda is a sort of junction zone where the interior, or architectural, spaces and the exterior spaces of nature meet. Hence, the Japanese veranda is neither strictly interior nor strictly exterior, but is a bit of both.

Because the veranda is exposed to view, carpenters put a great deal of thought and care into the design and construction of its balusters and rails (Fig. 8). Their efforts did not end there, but extended to the design and construction of both the deep eaves that protect the veranda from the elements and the exposed rafters on the underside of the eaves (Fig. 5). Since veranda and eaves construction gave carpenters an opportunity to demonstrate their skills, the rules of *kiwari* that applied to the distribution of eaves rafters were among the most carefully guarded secrets handed down from one generation of carpenters to the next.

To be a slave to fashion is not in very good taste, but to be totally unfashionable is not in very good taste either. *Kiwari* has had its fashions, but as a criterion of beauty, it developed rather slowly. Throughout the long history of Japanese architecture, good ideas and poor ideas, ideas that worked and those that did not, were constantly reevaluated, contributing to the evolution and refinement of *kiwari*.

Determining the physical appearance of a house can be included among the *kiwari* techniques. If we think of design as a method of determining the most beautiful proportions, then in construction we could think of *kiwari* as a technique for building a module of beauty. In general, we cannot judge the truth, goodness, or beauty of a structure. But since it is possible to build a perfectly adequate or "correct" structure by adhering to the rules of *kiwari*, even though slavish imitation is not desirable, beauty can be created by following the rules of *kiwari*. Hence, just as laws are often revised to meet the needs of changing times, the rules of *kiwari*, as a fashion, may also change.