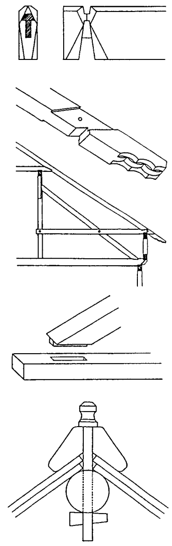

Wood and Wood Joints

Klaus Zwerger

Wood and Wood Joints

Building Traditions of Europe, Japan and China

With a Foreword by Valerio Olgiati

Third, Enlarged Edition

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Foreword

After searching for a copy of this book and in the knowledge that the English version was already out of print, we contacted the author and the publisher directly. Not only were we lucky enough to receive one of the last remaining copies but also learned that a new edition was in preparation. This is now available and we are delighted that this wonderful book can once again fascinate new readers.
Illustrated with beautiful photographs and meticulous drawings, the book details the long tradition and development of timber construction in Europe and Asia. Architects and carpenters cultivated a highly developed understanding of this material and the possibilities it offered. The path of forces and the specific properties of the material fundamentally determined the formal appearance of timber constructions and their details.
Timber construction has always related closely to the engineer's way of working and, compared with load-bearing construction, was very highly developed.
The culture of building with wood, its tradition, its regional and climatic particularities, its influences and developments are documented in impressive detail in this book.
In the last few centuries, building with wood has changed dramatically. Adhesives and steel components have changed the character of its construction. In contemporary architecture, wood is used for surface cladding or in construction in the form of resin-soaked materials such as chipboard or sandwich panels. Knowledge and skills of the kind described in this book are rarely seen today.
My own buildings from the past few years have been made primarily of concrete. With concrete one can build houses that are made almost entirely of a single material. Reinforced concrete can sustain tensile and compressive forces, can be used as a slab or a bar and can be assembled on site in phases; the manifestation of an idea to form a larger whole.
All this is possible with wood as well. It is just that we no longer know what this material is capable of and lack the skills to work it. And that is something we can change.

In this respect, this book is a welcome inspiration.

Valerio Olgiati
Flims, December 2010

Introduction to the Third Edition

Several years passed before an adequate reward for the groundwork I had put into this book came to pass. When it came, however, it was exceptional. In the year 2000, as part of a research project, I was given the opportunity to travel to China for the first time, more specifically to the region where the three Provinces Guizhou, Guangxi and Hunan meet in which the people of the Dong minority live. The impetus for the trip came from a series of photographs I had seen in a book in Tokyo. In the 1980s and 1990s this kind of leads had often led me on tracks that in many cases proved most worthwhile for my research for this book. But what I was able to experience in China moved me deeply. Every single village consisted almost exclusively of wooden houses. The sole "eyesore" was a single concrete block – one in almost every village –, resulting from the Chinese central government's intention to bring modern school education to the people of the minorities in the 1950s. It wasn't enough to ruin the image of paradise, at least from the viewpoint of the photographer. And the fact that it was only possible to reach the villages on foot added to the impression. Even the most inclement weather conditions – the monsoon had all but destroyed the roads – could do little to tarnish my enthusiasm. In a moment of fateful intuition, I realised I would have to act quickly to document these hidden treasures.

Now, some 15 years later, most of the Dong minority's settlement area has mutated into a tourist destination. The few means of access, once destroyed and renewed every year, have since multiplied and almost all the roads are now tarmacked. Motorways slice through stretches of land that until recently were unpopulated. The cost of abandoning the autochthonous culture in favour of an incomparably less frugal way of life is for many visitors hard to accept. To us it seems as if the people have been driven out of paradise. But the Dong have made their decision and very few would like to return to the ways of the past.

Similar developments took place throughout China during this period. The more remote, more exotic, more hard-to-reach the places are, the faster and more radical their transformation. Today, the situation for scholars and researchers in China is similar to that of my own in the 1980s as I began collecting and collating material for this book in Europe and Japan. A few individual buildings still remain that are certainly worth visiting and studying, however, here one important aspect is missing: only when one can observe and study a building as part of a larger group of comparable buildings, one's findings will be informed by the bigger picture and thus more meaningful. An individual building may present a special case, but without its context it lacks a connection to the environment that grew up with it. Reference cases in books are necessarily interpretative: the photographs, drawings, graphics and descriptions are a reflection of the respective author's perception of the building. Inevitably, every description falsifies the truth to some degree. Every reality is manipulated as a result.

A further aspect must also be taken into account: almost every building is modified over the course of its existence. No building is an "original" in the sense of "still as it was originally built". Ironically, the people who live in these buildings, who use them on a daily basis, are often least aware. While that may sound surprising, it is easily explained: when we look in the mirror every morning, we rarely register that we have grown older. In 2006, I visited some very remote villages in the region near the border with Tibet where the Yunnan and Sichuan areas meet. The people there live in log houses. Six years later I returned to the region. Many new houses had since been built, but a few of the old buildings still remained. Only once I stood inside did I see that in the meantime the roof structure had been changed and simplified. Here as elsewhere, the people were grateful that the government had made electricity and running water available to each courtyard, and that the old compacted earth floors could be replaced with cement screed. To this end, the old houses were taken down and rebuilt again afterwards. The residents are absolutely convinced that the buildings they live in are identical to how they were. Without photos, I would never have been able to convince them otherwise. And what purpose would it have served anyway? Maybe it was the presence of blatantly different neighbouring buildings that hindered them from noticing the smaller changes to their own homes. As a researcher of traditional roof constructions, however, one could have come to quite false conclusions, as there are no drawings of these kinds of buildings from the past. Today's young Chinese researchers, of which there are now hundreds in the field of vernacular architecture alone, can only record the structure of the building in its current state. Dendrochronological investigations are not yet commonplace in China. Then again, who's to say that the construction I recorded in 2006 was more than a few years old? When people cook indoors over an open fire, timber beams acquire a patina before a year is out ...

To come back to this book: it first came onto the market nearly two decades ago – and yet still continues to sell. What is it that constitutes its special fascination? As the author I can only speculate, but my own emotional connection to the topic stems from my own experience of working with wood. Anyone who sets out to test the limits of a material without taking guidance on how to work with it, has a long journey ahead of them. Every step of the way leaves a lasting impression. Well-founded knowledge is the product of experience, and is not quickly forgotten. Every new experience is measured against past experience, and assessed in relation to it. That results in standards that are subjective and that – as discussions with colleagues from academia and craftsmanship alike reveal – are continually changing or are being substantiated. Our experience grows with our ability to respect the work of others. And experience in turn hinders stagnation and promotes mental agility. By the same measure, our knowledge and understanding of historical timber buildings also changes incessantly, just as new developments are made in contemporary architecture.

Today, some 20 years after I wrote this book, I have a much clearer picture of the two primary motivations behind its genesis. As an enthusiastic woodworker, I am fascinated by the eloquent expressions of the carpenter's craft. A connection between two solid pieces of wood relates its function to the interested viewer, and in turn helps explain the construction and structural system of the building. Only rarely do decorative treatments – themselves fascinating artistic demonstrations of the carpenter's knowledge of his material and the tools he uses to work it – weaken or compromise the underlying function.

The second motivation was a vague sense of dissatisfaction with the literature at the time, despite much being available. One expects that scholarly authors will draw up classifications and ordering schemes. Their intention is to capture as many phenomena as possible and to classify them into a sensible underlying ordering system. In essence that is a process of pigeonholing. This inevitably leads to constrictive bracketing, to subjective valuations and the overlooking of details. No wall is large enough to accommodate all the pigeonholes required to depict reality.

In this book I look at many different cultures of timber construction. In Europe alone, historical timber architecture is anything but a monoculture. Many technical terms have arisen and been handed down over generations without due thought to their correctness. Sometime they characterise construction details that are entirely unknown in other parts of Europe, sometimes details that have an entirely different name elsewhere. The same principle also applies in reverse. Sometimes the same technical term has a different meaning in another building culture. The terms *Rofen* in mainland Europe and *rafter* in England, for example, while etymologically related, are semantically worlds apart. Both terms and their meanings are so firmly anchored in the respective literature that it would seem impossible to supplant one with the other. Nevertheless, in the English edition of this book, I have insisted on introducing the term *spar*. My view is that linguistic distinctions between entirely different constructions systems are important for understanding them properly, although I am aware that I am swimming against the current of the majority of available literature. This is just one example of many that illustrate how difficult it is to produce a correct and precise translation. The terms *Geschoßbau* and *Stockwerksbau* in the German language describe two entirely different construction systems – one with posts extending over multiple storeys, the other a storey-by-storey construction method – although the terms *Geschoß* and *Stockwerk* both mean floor or storey and are synonymous with one another. How should a translator deal with such problems? A proper explanation of the specific complexities of these two methods would require a chapter of its own.

A particular fascination of old photos of villages is the cohesive impression that they portray. On closer inspection, however, one sees that no two houses are truly the same. While the construction of houses within a region may originally have followed the same principle, they were continually adapted over the course of decades and centuries. Regional conditions, such as climate, topography and economic integration, resulted in numerous, often small-scale variations of a construction method. A further, and in my view especially important aspect is that to a far greater degree than today, traditionally trained carpenters had to take the material into account and with it the manpower (and not horsepower) that would be required. They had to apportion the energy of their labours sensibly across the entire day. The more primitive the tool, the harder it was to work against the will of the material. Buildings made entirely of crooked pieces of wood testify to the roundabout solutions that were sometimes necessary. Here it was down to the craftsmen, using the means available, to develop individual solutions, unfettered by standard or typified solutions. By comparison, the room for custom variation in modern-day construction sites is very limited.

Despite the cohesive impression of such settlements, we therefore find ourselves faced with the fascinating phenomenon of endless variations of historical timber constructions. Scholarly publications have responded on the one hand with elaborate classification systems and on the other with detailed studies of increasingly localised variations. In an attempt to find an alternative to this fruitless and unsatisfactory situation, I sought to identify the factors that influenced the formation of different exemplary variations.

But this approach also has its weaknesses. On the one hand, I refer back to existing classifications and on the other my organisational structure of chapters may be misinterpreted by some as a (rather vague, in this context probably too vague) attempt at classification. It was not my aim to introduce a new system of classification. On the contrary, my intention was to highlight the complexity of building, as exemplified in the detailing of wood joints. I single out some of the many reasons that give rise to a specific form and describe how they influence the formal articulation of a timber connection. The cumulative effect of several form-influencing causes on a connection changes its form, sometimes marginally, sometimes significantly, and at times fundamentally.

The more I see, the more complex building seems to appear. The more research conducted in the field of timber architecture, the more it calls previous findings into question. Despite the many rules, regulations and constraints that timber architecture is subject to, it still remains an individual form of cultural expression. The faster a population grows, the more land is consumed, the more people flood into the cities, the quicker the buildings studied in these pages will disappear – and with them knowledge of these buildings and the culture surrounding them. That also includes knowledge of their use as well as of their construction. We speak off-hand of traditional architecture as if it were something static. But carpenters of all times had to react flexibly to changing conditions. The tools of the different material ages (stone, bronze, iron and steel) brought about change as did the declining availability of easy-to-work materials. The consumption of wood did not decline with the increasing scarcity of good-quality wood. On the contrary, ever more people consumed ever greater quantities. And not just for building. When people are freezing, they are not choosy about the wood they burn, be it hundreds of years old or gathered brushwood. The production of salt in saline works required such quantities of wood that there was no time for someone to separate valuable wood for construction from less valuable wood for firing the ovens. Woodland that stood in the way of cultivating crops was burnt down, as was woodland that sheltered enemy soldiers in times of war. Contemporary methods have caused more lasting damage to the stocks of trees than ever.

It was therefore down to the carpenters to make the best of the material available to them. Better tools were a great help. Cutting a notch with a stone tool into a piece of wood requires one to work around any knots in the wood. But large trees with significant quantities of knot-free wood were too large to cut down with stone axes. As a consequence, carpenters had to select their material very carefully. The better the cutting tool, the easier it is to overcome irregularities in the cell structure of the material. That doesn't mean that carpenters no longer needed to worry about knots in the wood. A knot in a wooden column was not a problem, but it certainly was in a notched groove for a sliding door. Knowledge and careful consideration were therefore indispensable.

Working from this basis, the creators of traditional timber buildings were able to exercise the freedom they felt necessary. To properly understand their constructions, one must go out and talk to them. Here, time is of the essence: it is getting ever harder to find people with the requisite knowledge, as they are no longer able to live from their knowledge. The old carpenters, although sometimes (seemingly) at a loss to explain the reason for a construction detail in an old building, do in the end invariably come up with an explanation for how things were done in the past that in many cases is remarkably simple. Such reasons would never have been found through systematic research, comparison, classification and description, simply because they are the product of a practitioner's pragmatism. For example, the reasoning behind the use of wooden nails with a rectangular cross section in a half-timbered construction is relatively straightforward to surmise: the rectangular cross section prevents the building element from skewing. But as a researcher, how can one explain the fact that precisely one of these nails is in fact cylindrical? I will spare the reader my various chains of association and attempts at explanations, and instead refer straight to the carpenter who has the proper explanation: after assembling the timber frame, the carpenter needs a way to adjust the skew of the building element. Only timber nails that have a round cross section allow to do this. In research it is therefore necessary for scholars and craftsmen to work together more intensively to bring together the different logics of their respective ways of thinking.

Since this book was first published in 1997, innumerable publications have come out that deal with one or other related aspect more or less directly. Just as it gets more difficult to find something new and spectacular to research in the field, it is getting ever more difficult to publish something spectacularly new. As more and more of the main subject areas and outstanding examples are addressed, researchers are having to turn their attention to the smaller, less conspicuous subjects of research.
Ando Kunihiro (cf. for example *Sumai no dento gijutsu*, 1995), following in the footsteps of Kawashima Chuji (cf. *Horobiyuku minka*, 1973, 1976), has dedicated himself to documenting the historical architecture of rural farmers in Japan. There is now little left to research of the remaining large houses. Ando's analytical drawings and photographs have, so to speak, filled in the last remaining gaps. One of his most recent books (*Koya to kura – hosu, shimau, mamoru*, 2010) is the product of decades of research and collection. All over the world, barns and granaries have played a vital role in agricultural settlements. As essentially utilitarian buildings, little money was invested in their construction: their function was the primary concern. As such, most of them disappeared once they had outlived their purpose or their last remaining user or owner passed away. Where they still exist, then primarily as part of an ensemble of buildings at one or other open-air museum. This transplantation, however, compromises their value (more so than other kinds of historical buildings) because they cannot really be properly understood without the context that informed their existence.
The hard graft of documenting historical buildings can take other forms. A large number of the temples in China have now been studied in detail. Similarly, the building of durable roads into the most far-flung corners of the People's Republic over the past

decade means that few new discoveries remain to be made. Most exceptional new finds are now being made below ground. Nevertheless, numerous representative buildings have still not yet been analysed in detail. The book on the Palatial Hall at Baoguo si (*Ningbo Baoguo si dadian*, 2012) by Zhang Shiqing is a highlight in this respect.

Detailed studies can both call earlier research work into question as well as remedy previous errors. Academic research work is inseparable from the personality of the researcher. The way they go about conducting research and the conclusions they draw are informed just as much by the general research climate of the time as by their ability to differentiate between different aspects: one's own practical experience of working with a material changes one's perspective on such constructions, resulting in a study that is more than purely analytical. Knowledge of the working process of craftsmen, the ability to see and think the way a carpenter would, often makes it easier to understand a particular construction detail. At the same time, one also runs the risk of not looking closely enough: there are occasionally lateral thinkers among craftsmen. The innovative effort that goes into achieving an end product that corresponds to the formal requirements (that the carpenter is invariably obliged to observe) will go unnoticed in studies that are based purely on logical association and conclusion by analogy.

Liu Yan's dissertation *Woven Timber Bridges: A Special Form of the Bridge in Western and Eastern Cultures of Timber Construction* (2016) deals with a very specific type of bridge in China and sheds new light on many details of these structures, the craftsmanship of which is listed on the UNESCO Intangible Cultural Heritage List. In her research, she took what may seem an obvious, but nevertheless among researchers very uncommon step. Although she was able to learn much through intensive, well-prepared interviews with specialist carpenters, it was still not enough. She therefore joined a team working on building sites constructing these traditional bridges until she had gained sufficient knowledge to build one herself. As a by-product of her research, she was able to convincingly refute the recurring speculation that sketches by Leonardo of a very similar-looking bridge construction may have been inspired by Chinese precursors.

Internationalisation in the field of research can be fruitful in many ways. Liu Yan, for example, used European technologies in her surveys of the bridges. This is even more apparent in the open-mindedness with which a researcher can approach a topic in a cultural context that is not their own. Alexandra Harrer, for example, examines a very specific localised kind of *dougong* (as discussed in this book) in her dissertation *Fan-shaped bracket sets and their application in religious timber architecture of Shanxi province* (2010).

My own research into the typology of cereal drying structures (*Die Getreideharfe in Europa und Ostasien*, 2011), another now obsolete architectural relict of past rural economies, is a product of my own fascination with the many different manifestations of this building type. This fascination went beyond a purely visual comparison: in the cereal drying structures as they only appeared in Europe and East Asia, one can trace many of the "classical" principles of the various developments in construction systems in Europe and East Asia.

A common aspect of all the studies mentioned here is that they examine the construction of wood joints. In some, this represents a fundamental aspect of the research work, in others one aspect among many. These works are written primarily for a very specific audience of interested professionals. Two other books with a much broader remit address a further aspect of great importance to my own work: the perspective that cultural history offers. The first of these, by the historian Alexander Demandt, is subtitled simply *A Cultural History* and takes a comprehensive journey through the cultural epochs of Eurasia, striving, in the author's own words, to "cover much in order to offer something for everyone" (Demandt 2014, p. 7). The title of the most recent revised and expanded edition of this book, *Der Baum* (The Tree), affords him the necessary breadth. And indeed, the pages are filled from beginning to end with such detail that concentrated reading is required to digest it properly. The author describes how trees have been firmly anchored in the minds of people of all cultures and ages (ibid., p. 14), and that their use as a raw material for building construction is but a tiny part of this culture, albeit one that has extended over thousands of years. This raw material is addressed directly in a book by Joachim Radkau, who describes the use of wood in building over the course of history. Entitled simply *Wood – A History* (Radkau, German edition 2007, English edition 2011), it aligns more closely with our own topic. Despite focusing on economic aspects for much of the book, the central section on Europe in particular offers an illuminating account of the relationship between wood as a raw material and the people who benefit from it, most notably the carpenters, or the laypeople acting as carpenters. As such, it is a good complement to this book.

The role of wood as a building material in Europe, as in parts of East Asia, declined rapidly following the Second World War. The desire to cast off the fatal ideologies of the 1930s and 1940s as quickly and demonstratively as possible must be seen as a contributing factor. As we now know, this renunciation was largely dictated by the victors and did not generally meet with great conviction. House building is culturally bound up with our forebears in much the same way as customs are. My own observations over many years of cultural transformation in the regions of the Chinese minorities have shown me just how much building is a part of cultural life. People do not simply shed the customs of their ancestors; new customs must arise in their place. As such, it was a desire to consign received practices to the past that heralded a shift away from traditional building techniques after the Second World War.
The Second World War had also revealed to a dramatic extent the greatest disadvantage of building with wood. Throughout the ages, rival armies have burned down the houses of their enemies in times of war. The arrival of newer materials such as steel and concrete promised to change all that. More durable than wood, partially prefabricable, strong enough to withstand earthquakes and above all resistant to fire, steel and concrete quickly advanced to become the predominant building materials. As more organised criticism began to be voiced in the 1970s and 1980s, the respective industries were quick to dispel concerns with "green" campaigns of their own promoting concrete's credentials as a natural material. Whether the criticisms that arose were a product of the emerging ecology movement, or the re-awakening of the timber construction industry is hard to tell. Either way, the euphoric reception of steel and concrete has since ebbed somewhat over the past few

decades. Ultimately, the test of time is a far better measure than promises, projections and artificially induced expectations. This does not mean to say that we shouldn't continue to strive to make new discoveries, improvements and adaptations to meet changing conditions and requirements. Only that we should assess innovations more carefully with respect to their impact during production and after the end of their useful life; that we should look more closely at who supports research, development and production and to what end; and that we should consider in advance who will be faced with the disposal of which components and in which timeframes.

In the meantime, wood has again acquired renewed importance as a building material. Many steps were needed before the use of wood began to gain traction. More economical methods of processing and finishing along with intensive research into resolving the perceived disadvantages of the material led to the introduction of composite wood materials. They rapidly gained popularity, not least because they were game-changing: suddenly wood became a much more economical raw material, for a certain time. The advances made in the development of composite wood materials are significant and earn our utmost respect. The advantages sound too good to be true: no more limits on the dimensions of wood products, a material that doesn't split or warp, no more problems with wood grain orientation, the elimination of knots and improved density and strength properties. Machines now produce wood-based materials just how we want them to be. The material no longer has a will of its own like when we employ it straight-cut and must accept that it twists and warps over the course of time. Machines shred the wood, select the required qualities and compress the raw mass plus bonding agents into the desired length, cross-section or form. Additives or additional components improve its material qualities still further.

The products are artificial materials that are based on wood as the raw material. These wooden artificial materials or artificial woods have extended the range of possible buildings beyond our imagination. In absolute terms, the primary component is wood, and they are therefore, in contrast to many other modern building materials, comprised for the most part of renewable, regenerative resources. In virtually all our productive endeavours, we treat nature only as a resource. Ambition and economic efficiency are the most productive drivers of invention and new developments. Numerous companies compete with each other for a share of the market, paying scientific institutions to stay one step ahead of their competitors. But, somewhere along the line, this gruelling, but nevertheless well-oiled competition has (suddenly?) got grit in its gears.

We regularly read or hear about the "lungs of the planet" without giving much thought to it. But when we damage part of our lung, and have to remove part of it, our ability to breathe is impaired. An artificial lung is an emergency stopgap, not a full-scale replacement. (Comparisons tend to be midleading, a problem I am all too familiar with. For this reason, I speak of juxtaposition in this book, not about comparing). When we talk about the sustainability or the carbon-neutral qualities of wood, we should avoid clandestinely applying this, by linguistic association, to artificial materials. Wood and wood-based composite materials are not the same thing. What about the calculation of the energy costs for machine-processing the wood, for the production of adhesives, for their application, for the manufacture of the composite and the incorporation of optimising additives? And what about the costs of its disposal, and ideally of its separation into its original constituents? By that I don't mean who pays for the incineration plants, which today are regarded as state of the art "clean" disposal facilities. I mean who is accountable for the carbon dioxide emissions that this produces? And for the road building without which it would not be possible to transport the "endlessly long" wooden elements from the production plant to their place of use?

Trees were once planted for future generations. Has anyone ever drawn up a list of the cultures around the world where it was customary to plant a tree to celebrate the birth of a child? That is much more than just a custom; it is responsible action. The planting of large swathes of fast-growing monocultures ready for harvesting after just a few years makes at best only a temporary contribution to oxygen generation. It certainly doesn't help resolve the problem of our consumption behaviour and its short-term economic interests. It displaces the diversity of species that are a prerequisite for healthy forests. Monocultures likewise have a lasting impact on the fertility of soils. In livestock breeding, we are beginning to call into question the large-scale use of feed additives and medicines. When will we start to question the use of fertilisers and pesticides in forestry management?

I follow new developments, especially of old techniques, with great interest: for example, the roof structure of the new golfing clubhouse in Yeoju, South Korea (cf. Jeska, *Emergent Timber Technologies*, 2015, p.69). There they have used traditional lap joints, not for nostalgic reasons, but because these represent the most effective solution for the specific task at hand. Double-curved structures had already been constructed by use of *Klingschrot* some hundred years ago. Seen as a process of development, the renewed use of traditional technologies, developed and continually improved over hundreds of years, raises the hope that other traditional details could also become the focus of more intensive study and renewed application. The problems that arise with steel connectors in timber construction in the event of a fire have been raised often enough. But developments are rarely linear and are more frequently arrived at by roundabout means. Because they are visible, lap joints must be fashioned with great precision. The manual fabrication of joints by hand cannot compare with the precision of joints milled by machines, at least when it needs to be similarly cost-effective. And there are numerous examples around the world of how the cumulative effect of inaccuracies in hand-made joints within a building can lead to its deformation (the reasons for which are described in detail in this book).

Perhaps even more impressive is the attempt by Steffen Reichert and Achim Menges from the Institute for Computational Design at the University of Stuttgart Faculty of Architecture to create responsive surface structures that emulate the reactive, reversible mechanism of a pine cone in response to ambient humidity levels. In this book I describe the sealing principle of wooden wells, barrels or the chests of Japanese merchants for storing important papers which exploits wood's ability to respond to the moisture saturation of the surrounding space, a quality that most modern wood-based composite materials no longer exhibit. In times past, woodworkers also faced this problem, and came up with corresponding solutions. The greatest difference between then and now is that overcoming these problems required extensive experience. Today, no-one wants to be dependent on experienced, well-trained and therefore costly skilled workers. What kind of investment is more sustainable: investment in machines, or in people? The project cited above is an example of the kind of research in which I see the greatest potential for wood and wood joints in the future development of building construction. Here wood is not being processed using energy-intensive means into something new, robbing it in the process of its key characteristics, but rather these qualities serve as inspiration for creative explorations that undoubtedly have the potential to be incorporated into future building construction. Other disciplines are far less averse to emulating natural phenomena.

Whether one sees architecture as an art or a science – how about "and" rather than "or" – the dissatisfaction with traditional architectural training and the conviction that architecture can be created not just by academically certified architects has produced some quite revolutionary results since the end of the war. Some of the protagonists of this movement have since been lauded as the forerunners of contemporary timber construction and are now, in an ironic twist of history, or perhaps as a logical conclusion, part of the academic establishment. Their development of a new formal language was and is an expression of the desire to liberate themselves from the perceived constraints of traditional timber architecture.

Developments in the field of building physics have given rise to standards that can no longer be reversed. Contemporary timber construction methods are in a position to fulfil both high expectations as well as current requirements with respect to insulation, sound protection and airtightness. All of these developments have conditioned and fostered one another. Intensive research into the fire performance of wood has tipped the scales away from the traumatic memories of the Second World War and back towards the use of wood for building. The ability to more accurately predict the rate at which wood burns makes it possible to anticipate precisely how long a burning timber building will be structurally stable, and therefore how much time rescue services have to evacuate a building before parts become unstable. The Pritzker Prize winner of 2014 clad steel beams in wood to protect the steel core of an office building against fire (cf. Ban, Mc Quaid 2003, pp. 92–97): Shigeru Ban once again found an innovative way to put new findings into practice. While wood is extremely susceptible to contact with water, it can still serve as an effective means of shielding against water. Perhaps Ban was thinking of the centuries-old dichotomy between wood and water in Japan and transposed this into a dichotomy between wood and fire.

As more and more of the rational arguments against buildings made of wood cease to apply, their emotional qualities will once again rise to the fore in our eyes as users: their warmth, the sense of comfort and security they convey. The texture of wood is something that its main competitors, concrete and steel, lack. Whether wood cladding is used simply as decoration or as a means of "greenwashing" is neither here nor there. In either case, the visual appearance of wood obviously acts as a stimulus that triggers a positive reaction in the viewer. That is a remarkable phenomenon given the complexity of the process of perception of materials.

Just as I was writing this introduction, I had the good fortune to welcome a visitor who on arriving told me enthusiastically that she had recently obtained a copy of this book. Without my asking, she went on to answer the question posed at the outset of this introduction about what constitutes the fascination of this book: reading the book, she said, had made her curious about the material, its qualities and what one can make with it. I should add that she has nothing to do with wood, or with architecture: she is a musician, with a musician's sensitivity. During a few days off in North Germany, she had had the opportunity to take a walk around an old town with half-timbered buildings. Looking at the houses, she recalled one story after the other from what she had read.

It is the inhomogeneity of the material that makes it so attractive; its irregularity, its authenticity. That's another difficult term that all too often borders on sentimentality. But the buildings shown in this book were not built for sentimental reasons. They respond to a need. The respect for the material comes through its practical use. In the description of the many and diverse activities that ultimately culminate in a usable building, nature is not resurrected and times past are not glorified. Our actions are simply a response to natural conditions and circumstances. We cooperate with nature. We live with and alongside nature, as it does with us. But in this partnership, there is no doubt which is more yielding, and which is unquestionably the stronger of the two.

Wood is one of the few materials that can be totally and completely returned to the natural life cycle after use. An awareness of the need for building materials to be recyclable is growing as a prerequisite for taking a more honest approach to calculating the cost of building. Throughout the history of building, it has been common practice to repurpose timber construction elements for new uses. The new wood-composite materials have yet to demonstrate this capacity. But the best and most sustainable solution of all is still the ability to continue using a building for as long as possible, providing its use causes no harm. And indeed, the adaptation and retrofitting of old buildings is becoming increasingly attractive, and not just for purely sentimental reasons. Houses that have stood for hundreds of years exude a sense of assurance that they will continue to serve their purpose in future. To date, the framework constructions of houses made of wood by skilled craftsmen have lasted longer than any other. So it would seem that joints fashioned out of wood alone have contributed significantly to the durability and longevity of the built environment.

The properties of wood

"By applying appropriate tools and techniques to a good piece of timber, a woodworker's imagination is limited only by the nature of his material – a material that often seems to have a life of its own."[1]

Every material is distinguished by characteristics peculiar to itself. Knowledge of these is a necessary prerequisite for processing the material appropriately. Wood lets us know quite definitely and unpleasantly when it is not being treated correctly, whether due to negligence or lack of knowledge. But wood also obstructs us when we try to unravel its mechanical, physical and chemical properties. Many modern textbooks attempt to present the material in a way which justifies this theoretical approach to its use. Twisted fibres, bows and colour discrepancies are only referred to, if at all, as abnormalities to be cut out; beauty, as a non-technical term, is an unknown word. All the properties of wood are interlinked. They interact with each other or are dependent on each other in such a way that this textbook-type of classification is quite simply inadequate if we wish to explain the connection between the characteristics of wood and the culture of woodworking.

The loading capacities of timber in tension (Fig. 1) and compression (Figs 2 & 3), in bending (Fig. 4) and shear, i. e. the mechanical properties, need to be considered directly and visually, as apprentices once did on their long way to becoming masters. The practical reappraisal of what had been seen in active work and daily routine was in any case only achieved competently by very few. The size of the cross-section is of fundamental significance for the loading capacity. The oversized members often encountered in older elements, possibly not unaffected by considerations of proportion, i. e. partly determined by aesthetics, undeniably contributed to the preservation of the material. Other authors dispute such oversizing and prove "that the timber constructions investigated from the period between 1000 and 1800 are often loaded to the limit of their capacity."[2]

According to David Gilly in 1797: "For example, the machine master Reuss from Dresden cut the heavy truss posts in the town's opera house to suit the machinery in such a way that a narrow opening was created through both truss posts. He was very well aware that the truss posts would remain capable of taking any load likely to be put on them."[3] Examples of oversizing are the (sometimes) original columns of Norway's stave churches,[4] Switzerland's wooden bridges, which are capable of carrying today's heavy road traffic,[5] or Japanese temples and shrines. The fire in the Horyu-ji in 1949 can be regarded as an example of just what stresses wood can withstand even after 1200 years. The colossal dimensions of the columns, each 1.5 m in diameter, are certainly to thank for the fact that sufficient undamaged timber remained to guarantee the survival of a large part of the structure intact.[6] In total contrast to this are the sometimes "stupidity prescribed standardized sizes for all posts which would have been heavier in places if the construction had been logically worked out."[7]

1 The joints of the diagonal bracing members on this bridge between Appenzell and Schlatt in Switzerland are so tightly restrained that settlement at the corner in the left foreground has caused the wood to split.

2 In technical terms the loading capacity parallel to the grain is greatest. However, in a structure, as compressive forces increase so does the susceptibility to buckling. – Cowshed on a farm in Zaunhof, Tyrol, Austria.

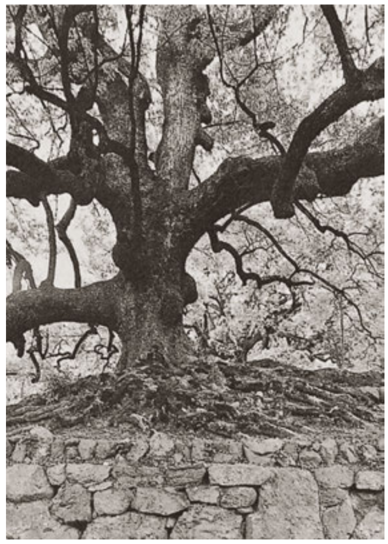
4 The pliability of wood can be exploited in very simple ways. – Zuberec, Slovakia.

3 As a rule, horizontal timbers subjected to compressive loads cannot buckle; instead they are crushed. Therefore, the growth rings of rift-sawn wood are placed opposing the compression whenever possible. – Sill of a timber-framed building in Oslo, Norway.

5 The corner column of this barn in Zaunhof, Tyrol, Austria, is made from two older columns. This can be recognized from the lap-joint housings and nail holes of former bracing members.

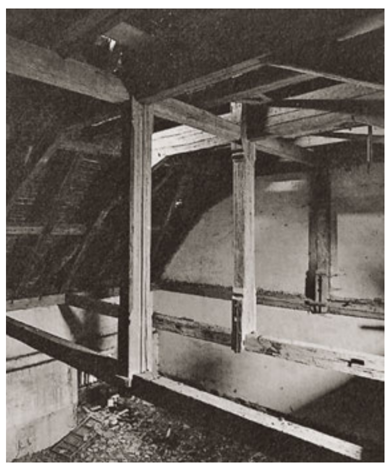
And yet wood itself is relatively light, as the one time normal transportation of houses and churches indicates quite clearly. The village of Kiscsány in Hungary supplies a rather curious example of this. When in 1764 the local church threatened to sink into the marshy ground, strong wooden axles were laid beneath the sill beams of the building and then fitted with wheels. Oxen, helped by the whole community, then proceeded to pull the church 1,500 m to safety.[8] Even today, we take advantage of this fact which once shaped the term "goods and chattels". In Switzerland old storehouses are, literally, led to a new lease of life as holiday homes![9] In Japan too, there is some evidence to suggest that shrines were built as movable objects. Even today there are customs which require shrines to be carried around on certain festive occasions.[10]
When still usable wood was no longer needed to fulfil its original function, there were sufficient reasons to recycle it. (Fig. 5) It saved its user a great deal of work and, above all, had already proved its worth. Numerous instances of reused timber have been found even in buildings which, even when subjected to closer scrutiny, did not appear to make use of such savings. During repair work, non-original members, carefully removed from other places, have been discovered again and again in the so-called "hidden roofs" (see p. 193ff.) of Japanese temples.[11] Spectacular examples of this procedure are provided by a barn in Jordans, Buckinghamshire, England, built from the wood of the *Mayflower*,[12] or the use of beams and spars from St Mary's Church in Munich, Germany, to make violins.[13]
"Out of all the natural materials wood has the most balanced characteristics and can be relatively easily worked."[14] This is probably one of the reasons why timber has been used for building even in Iceland, which has no trees.
Humans were at least at one time convinced that each tree had a soul. In Japan the view is held even today that such a soul can also be bestowed on pieces of wood. On the surface this soul materializes in the beauty of the wood. The close bond with the material is revealed not least in the fact that it remains almost totally untreated.[15] Only if you walk barefoot or in socks across a wooden floor will you appreciate its texture, learn the difference between a few wide planks and many narrow ones. They are chosen for the beauty of their grain, and that depends

to a large extent on the conversion of a trunk. The deep admiration, indeed almost religious worship which trees are assigned in Japan is expressed in one word: *kodama*, the spirit of the tree.[16]
If we look for positive characteristics in wood, then one of the first that comes to mind is its warmth. And this can be actually depicted. The average wall thickness of the houses in Goms, a valley some 1,500 m up in the Swiss mountains, is only 140 to 150 mm.[17] However, this definition would not correspond to our modern concept of warmth; a constant room temperature according to our tastes would very quickly kill off traditional timber construction.
Looking at a tree we might be able to glean how the forces of nature act on it and within it. (Fig. 6) The older the tree, the more it might have to tell us – what chaos it has had to face, how it overcame this, how it regained its balance again and again, defying the force of gravity. It demonstrates a diversity of forms which we only have to copy in order to employ them properly. It is not so very long since we knew how to use the tree as nature gave it to us. For those for whom the tree was too short to span the required width, they had to accept intermediate posts, those "tyrants of the floor layout". (Figs 7 & 8) It was only the development of the truss post (see p. 186 ff.) which allowed unsupported spans to be gradually increased. (Fig. 9)
The bond between the woodworker and the wood itself had already begun back in the forest. The location and appearance of a tree were decisive criteria for its later use. The master builder himself selected it. The farmer, in the capacity of master builder, observed the forest, whether it was his or not, and so knew about just a few more details which could be significant



6 Camphor tree in front of the Shoren-in in Kyoto, Japan.

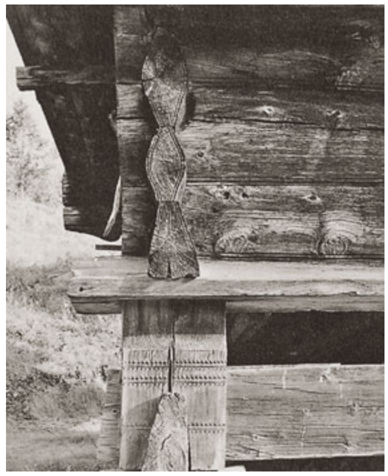
8 The roof in the Senyo-kaku in Miyajima, Hiroshima, Japan, is supported by columns arranged on a grid.



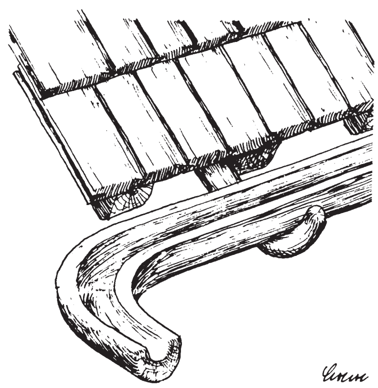
9 Two-part truss posts carry the tie beams in Schloß Thürntal, NE Austria.

7 Granary beam supported on columns.
– Primmersdorf, NE Austria.

for its use. *Schindelbaum* (literally "shingle tree" – a tree whose timber was particularly apt for shingles; it has nothing to do with shingle tree, *Doona zeylanica*) is just one of many names which owe their existence to such knowledge.
The individual character of all nature's products does not only lead to the individual appearance of every house in a village. It is also found in the uniqueness of every single tree, every post and every beam. It is the Norwegians who express this best. In a very discreet way the two-dimensionality of the perfectly sealed wall is broken down in the horizontal direction by way of grooves in its individual members, the wall thus separated into its components so that their uniqueness may be appreciated. (Fig. 10)
Knot-free, straight wood only grows in dense, regular forests. A style of building which will probably never be revived, revealed in many listed timber structures, demonstrates most conspicuously, particularly in the use of wood as nature provides it, how extreme economic constraints and the standard of living we demand have impoverished our use of form. For example, many timber-framed buildings are in fact characterized by bowed timbers. The original economic requirement to also make use of timber which was not straight enjoyed such a wide acceptance that in later times bowed timber was produced artificially.[18] People were so familiar with the mainly irregular elements of the tree – in fact, an irregularity governed by natural laws – that certain shapes seemed predestined for certain applications. (Figs 11 & 12)
In Japan this tradition has not been so thoroughly wiped out as it has been in western Europe and a large part of eastern Europe. Influenced by the Sukiya philosophy, which found expression in the tea-house style,[19] the Japanese have developed a very special feeling for timbers which have grown unusually. (Fig. 13) Indeed, they look for growth abnormalities. (Fig. 14) Just like in the West, demand outstrips supply. The result is industrially produced growth abnormalities. Examples of this are the *Kitayama sugi*, a cedar, the growth of which is influenced artificially, and the *Sugi kashira*, another cedar, which has pieces



10 Very light grooves decorate not only the ends of the logs, they emphasize the individual wall elements of this *loft* in Åmotsdal, Telemark, Norway.



11 The form of this natural curve is exploited to discharge water from the gutter. (source: Loewe, 1969, p. 132)

12 These bowed timbers enable a design clear of the ground in the virtually always damp Salzkammergut region. – Gössl, Steiermark, Austria.

13 Beams in Sakuta House, Chiba, Japan, in the Nihon minka en.

14 The owner of this *minka* in Shirakawa-mura, Gifu, Japan, does not conceal his enthusiasm for unusually shaped pieces of timber.

of hard plastic placed around its trunk which, for at least one year, force the tree to produce an extremely erratic surface.
Today, it is rare for the location of a tree to be taken into account when deciding its future usability. But it is precisely this aspect that can either bring about a rude awakening or a purposeful application. Single, exposed trees must constantly resist the actions of wind and weather. The result is that their heartwood is displaced northwards, giving rise to unequal densities on the north and south sides. Upon drying, the softer southern side shrinks more than the harder northern side. Acknowledgement of this property and knowledge of the wood allow the carpenter to exploit this characteristic. Used horizontally, the carpenter will place the timber north side uppermost, thereby building in the tree "pretensioned". Vertical applications of this irregularity are also possible.[20]
Spruce is not simply spruce! Trees which grow in a dense group are subjected to less favourable growing conditions and, hence, produce denser timber. This is normally regarded as more valuable.[21] Especially well liked are northern timbers because both the duration and severity of the winter forces a particularly slow rate of growth. Another highly valued property in woodworking is that coniferous trees growing under such extreme conditions form fewer branches, or at least no large branches.[22]
However, growing in a dense, regular forest in no way guarantees uniform material. It is not without reason that Japanese carpenters are reported to say you should not buy a piece of wood but rather the whole mountain![23] The master carpenter Nishioka Tsunekazu, who died only recently, is said to have proceeded with the rebuilding of the Yakushi-ji – a temple in Nara originally built in an age when the town was a political and cultural centre (710–94) – in such a way that the wood was used according to where it was felled, i. e. timber from southern slopes on the south side …[24] To Europeans, such a consistent approach to the material may appear, at best, exaggerated. However, it is known "that for longhouses [residence and stable positioned adjacent each other under one ridge] in the Tegernsee valley in Germany, single, slow-growing trunks from northward-facing slopes … were specifically selected."[25]
A property which can often be seen from the outside is the orientation of the fibres: straight or twisted. Timber with a twist to the right is generally considered to be usable. However, you are urgently warned against so-called "with-the-sun" or "after-the-sun" timber (wood which grows in the direction of the rising sun – midday – setting sun, i. e. like a left-hand screw thread).[26]
The effect is supposed to be exactly the opposite for wood destined for shingling. The shinglemaker preferred left-hand timber because, apparently, it could be split more easily.[27] Everywhere you go these days, you notice how this property of wood is not taken into consideration. (Fig. 15) Nevertheless, examples of old timber architecture can also provide evidence of past negligence. (Fig. 16)
On the other hand, the careful observer gets the impression that the study of considerate or prudent handling of the material is virtually only possible using old examples. If coincidence can be ruled out as a design factor and an outdated "ornate artistry" seems hardly credible, then we must ask ourselves

15 Even sophisticated timber joints would not have been able to prevent this timber from twisting. – Wooden bridge in Umhausen, Tyrol, Austria.

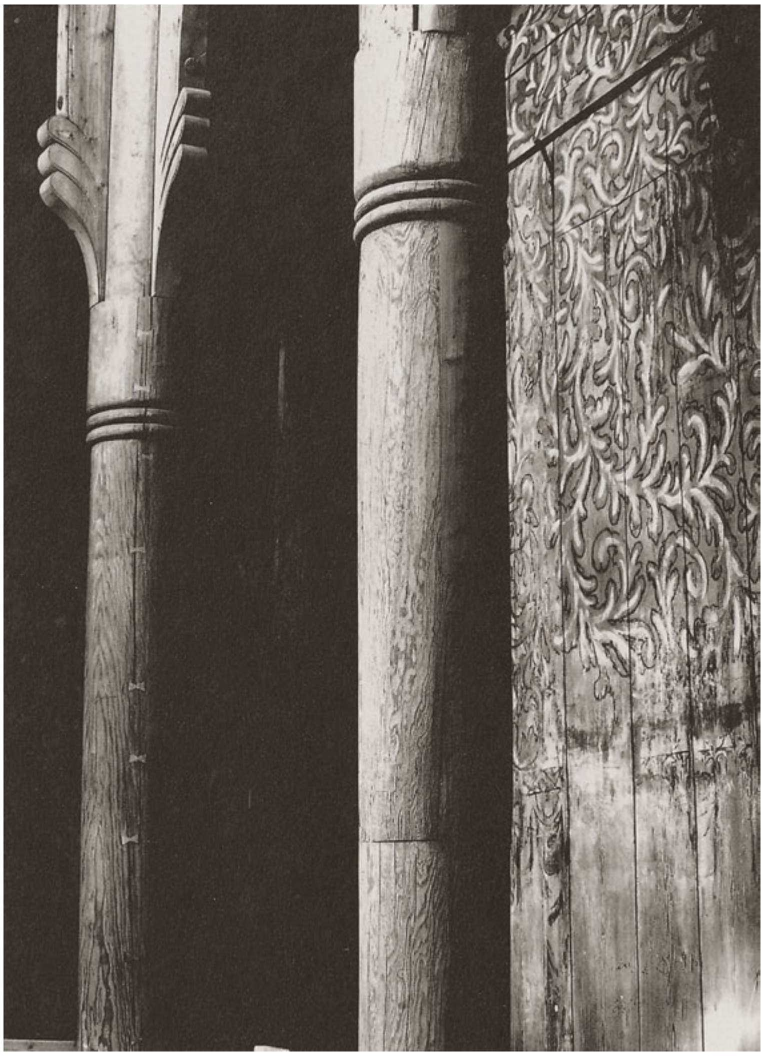
16 The thrust of the corner column of this bell tower in Malé Ozorovce, Slovakia, exacerbates the rotational movement of the twisted-fibre sill beam. As the halved-and-tabled joint prevents it from deflecting, it has to split.

17 **On this bracket complex in the Yakushi-ji eastern pagoda, Nara, Japan, the direction of the wood is altered from block to block in order to compensate for possible twisting as far as possible.**

whether such old examples, like the Japanese temples, might not be an occasion to reflect on the best of pre-industrial craftsmanship. (Fig. 17) Those who cut their wood themselves are fully aware of its qualities and can put this knowledge to best use in selecting planks or posts for certain tasks. Those who do not cut their own timber, but at least look at it, can gather some information about its characteristics from the pieces lying before them. However, those who rely totally on today's customary working procedures must work hard to develop a "timber" matching their ideas.

Diverse methods have been ventured in order to counter the reduction in value of the total quantity of felled timber during the drying process. One really successful method was girdling. It is said that this is how the selected pines for the stave church in Heddal, Norway, were polled when they had reached the necessary height. A small piece of bark was removed from the base of the tree. Further upward growth was thus hindered and afterwards the tree only grew very much more slowly. It became extremely hard and produced close growth rings. At the same time, the pine impregnated itself with its own resin. The tree was then felled only 20 to 30 years later; and prior to being worked it was still allowed to dry for many years.[28] (Fig. 18)

We can be relatively sure that it was not just the girdling which produced the desired success. A multitude of sayings conveying the knowledge of skilled woodworkers are evidence of how



18 The new columns of the stave church in Heddal, Telemark, Norway, erected during its reconstruction in 1952, can be recognized by the up to 20-mm-wide crevices, next to which the fine cracks of the old columns remain almost invisible.

important the "right" time to fell was considered to be. The famous Schaffhausen bridge (1755–57) built by Grubenmann had to be renovated only 28 years after its completion "because timber felled at an inopportune moment" had been used.[29] In any case, in establishing the correct time to fell, economic considerations were just as important then as they are now. In earlier times no building work took place during the winter months, so workers were available for low wages. In the mountains in winter, felled trees could be relatively easily brought down into the valleys. In winter wood is more resistant to fungal attack – and timber infected by blue stain fungus would have been no easier to sell in the past than it is today. Furthermore, wood has been built in "green" for a long time and of course should not become infected by fungus in the built condition either. And finally, freshly felled timber is much easier to chop or work with an axe than dry timber.[30]

Many of the maxims which became forgotten during the industrial revolution – e. g. "Timber felled on Christmas Day will hold your house come what may!" – have been unearthed again in recent decades. A reactionary movement questioned all commercial practices which contradicted the old rules. Today, the discussion is superfluous as to whether those who swear by the old custom of felling timber in winter are right just because this was based on centuries of experience. Researchers have come to the conclusion that the differences be-

19 The different cross-sections of root end and crown end must be taken into account if you wish to remain level! – Longhouse from Murau, Steiermark, Austria, Stübing Open-air Museum.

tween timber felled in summer and timber felled in winter are evened out after one year of air-dry storage.[31]
Trees grow in a pyramid shape; therefore, root end and crown end have different diameters. (Fig. 19) Once again it is the considerate Norwegians who have expressed this aspect most aesthetically. The tree "reaching for the sky" has been wonderfully imitated in the stave churches of Norway. With your head tipped right back you could almost believe you were looking up at a treetop in the forest. (Fig. 20)
Furthermore, root end and crown end exhibit different strengths.[32] In Japan there are separate names for the different possible variations for joining root end and crown end.[33] Besides the aesthetic aspect, the well-founded practical argument appears to be perfectly clear when we try to copy one or other of the highly complex joints.

20 As they rise, the tapering of the staves or columns in Torpo, Hallingdal, Norway, is emphasized most effectively by the carved shape of a head at the top.

There is another property which characterizes the structure of a tree; heartwood and sapwood possess very different properties due to their distinct, different functions within the tree. The variety of colouring sometimes found is a visible difference. However, others are more important for the use of wood as a building material. The main problem with sapwood is its susceptibility to fungal attack. (Fig. 21) The simplest solution would be to cut away the sapwood. However, many log buildings bear witness to the fact that this is not strictly necessary. Again it is the Norwegians who have found an ingenious solution to utilizing the properties of the material to best effect. The underside of the log is provided with a V-shaped groove; due to the weight of the logs placed on top, the softer sapwood of the log underneath in each case is pressed into the groove above, thereby sealing the joint. Apart from that, this method presents a very effective method of preventing the logs from rotating out of position.

The effect of the drying process on the heartwood side of the halved tree is similar to that on the north side of the whole tree (or south side and sapwood side respectively). The denser heartwood loses less volume through drying than the sapwood. As it is favoured during its growth, the wood from the southern side of a tree undergoes a more severe change to its shape after felling than the northern side. In solid wood the sapwood tends to split. (Fig. 22) The carpenter Tanaka Fumio had to replace the columns of a temple twice because they had split, although they had been air-dried for 20 years (artificial drying is not yet technically feasible for such large cross-sections).[34]

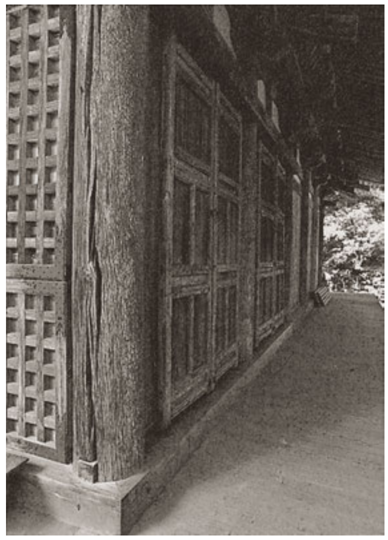
An essentially more pragmatic procedure is used in the reconstruction of the Ise-jingu, the most important Shinto shrine, which is carried out every 20 years. Here, as in many other structures built from solid wood, a groove is cut in the timbers down to the heartwood as a precautionary measure; this is done at a point not normally exposed so that cracks in exposed parts are avoided.[35]

Japan once allowed itself the luxury of fabricating the columns for temples, gateways, etc. from half-round timbers in order to minimize the risk of splitting. This raises the problem of where to obtain such enormous trees when restoration work is undertaken nowadays. And even with half-round timbers, the wood splits away from the pith on the heartwood side. (Figs 23 & 24) Only "the old masters understood how to handle the wood in such a way that even worked half-round timbers, in which the face of a cut passed through the pith, remained free from larger cracks."[36] (Fig. 25)

Timber should be dried before it is worked. But whether timber should be dried with its bark on or off is not irrelevant. This mainly depends on the species of wood, but the differentiation goes even further. Larch wood intended for use as shingles is allowed to dry with its bark left on. For air-drying, the recommendations vary between two and three years.[37] These days, artificial drying is the norm, and it is generally accepted that only timber in which the moisture content has been reduced to a certain figure should be used for building work. This was not always the case. Right up until late Gothic times wood was worked green.[38] It is not known when it became customary to dry building timber before working it.[39]

Every farmer knew how to sensibly exploit the properties of green timber. "The fabrication of wooden hay and crop forks depends on the combination of green and dried ash wood. The sharp-edged, dried nails are driven through the round holes of the still flexible prongs of the fork; the prongs shrink during drying and pull the whole assembly together so that it can no longer be separated."[40] It is precisely this principle that is employed in joints made with wooden nails (cf. p. 122 ff.).

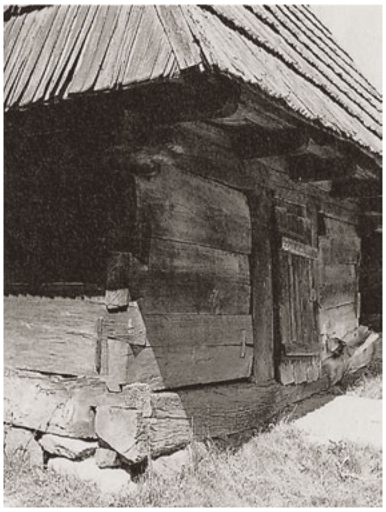
21 There is not a single log on this barn in Solvorn, Sogn, Norway, which is not severely damaged.



22 Due to the stress, the sapwood has had to give way in this corner column of the Muro-ji hondo at Muro mura, Nara, Japan.

23 The ridge covering on the stave church in Heddal, Telemark, Norway, will not fulfil its function for very long.

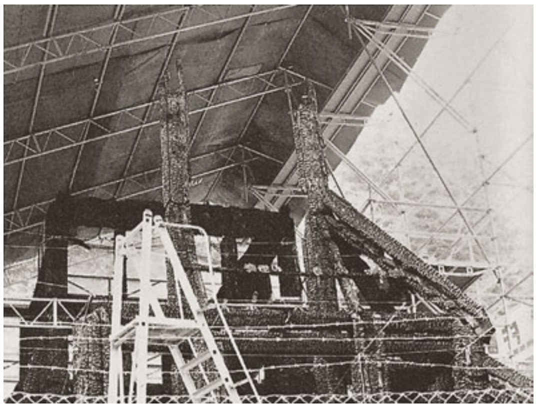
In Japan, in contrast to Europe, timber is normally stored and dried vertically (with the crown end downwards). This must be advantageous, at least until the fibre saturation point has been reached, because this method is also recommended in Europe for colour-sensitive woods, e. g. maple.
Timber is not dried so that it burns better! And despite this, mankind has painfully been forced to realize again and again that wooden buildings are combustible. Bruno Taut was advised by the Japanese to shout "Fire!" on discovering a burglar – only that would ensure getting help from others![41] In times of war, this property of wood has been exploited so consistently that hardly a conversation on timber structures passes without this "negative" characteristic surfacing. Besides the species of wood and the nature of the surface, the ratio of surface area to volume is the decisive factor for behaviour in fire. However, the oversizing of members, normal in the past, together with modern methods of fire-fighting, cannot prevent the further decimation of monuments to cultural achievements. (Fig. 26)



24 The butterfly spline is intended to prevent the log splitting away further from the pith. The concern of the owner was probably mainly aimed at the door post which in the end has also deformed in sympathy. – Sighetu Marmaţiei/ Maramureş, Romania.

25 Even in planks, the nature of the cracks reveals how wood dries. – Entrance area of the Zuisen-ji hondo in Inami machi, Toyama, Japan.

26 The stave church in Fantoft near Bergen, Hordaland, Norway, was destroyed by fire in 1992.



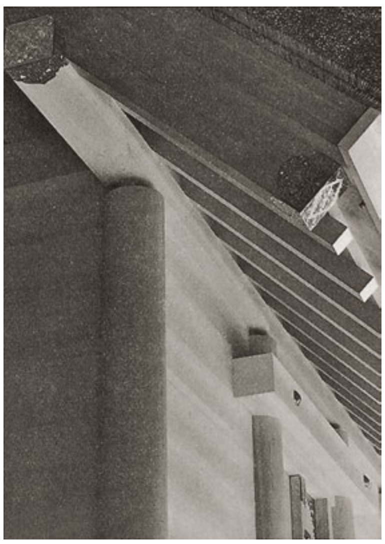
Mankind has known for thousands of years how to use the positive effects of fire on wood. Even today, posts which are to be buried are charred beforehand; likewise in Japan, wooden claddings to protect them from termite attack.
Even more pronounced is the ambivalence of wood and water. When timber is felled, its vital supply lines are destroyed. Its structure means constant loss of water from this moment onwards until equilibrium with the surrounding air humidity is attained. Linked with this is a decrease in the volume of the timber. The cell structure of the sapwood, which releases more water, undergoes a more severe change than that of the heartwood cells lying nearer the pith. The shrinkage of the timber in the radial direction is also different from that in the vertical.
In log buildings this property is particularly significant. Despite a two-year drying period, the log wall was left for at least one summer, in order to ensure that it had settled properly, before installing doors and windows.[42] (Fig. 27) However, the openings in the log wall were not the only problem. The logs settle within the wall more than at the joints, i. e. settlement

27 This window in the church in Ruská Bystrá, Slovakia, is mitred dispensing with the need for a cladding protruding from the line of the wall.

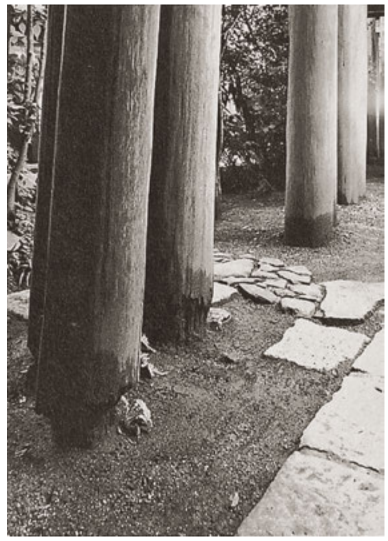
gaps must be incorporated. These weaken the assembly at the most awkward position. In Russia log cabins were built from green wood and then subjected to the drying action of the air for a certain period to allow the rings of logs to settle. The cabin was then dismantled and fitted together again, this time packing the gaps with moss.[43] Norwegian carpenters became so experienced that they were able to combine stave and log-cabin forms – an enviable achievement when the different rates of shrinkage of vertical and horizontal timbers is considered.[44]

As a result of many centuries of observation, mankind has succeeded in acquiring the knowledge of the regularity of this property. Only now was our builder in the position to install door and window frames at the same time as the wall itself. The precautions taken for this purpose can of course be extrapolated to encompass the entire building. (Fig. 28) The central column of many Japanese pagodas does not rest on the ground but instead is carried by the surrounding construction.[45] In his reconstruction of the second pagoda of the Yakushi-ji, Nishioka Tsunekazu resorted to the older system in which the central column is in contact with the ground. In order to prevent the column from damaging the supporting structure as it slowly settles over the years, the master carpenter had to calculate very accurately how high the column had to be wedged up during its erection.[46]

28 Directly after the erection of this building from the Ise-jingu complex, Mie, Japan, the settlement gap for the head beam can still be clearly seen. The perfectly sealed walls will settle over the years, taking the header beam with them.



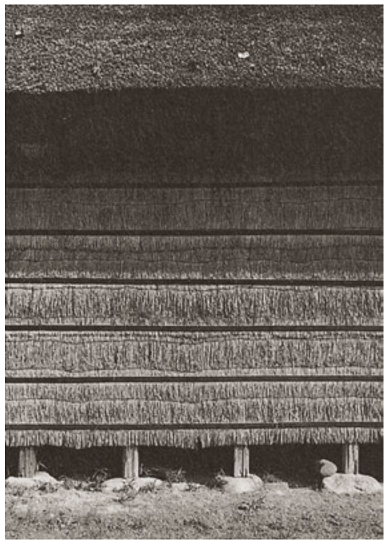
Wood does not just release water into its surroundings, it absorbs moisture from the atmosphere too. The climate fluctuations in Japan mean that the Japanese are far more acutely aware of this fact than the Europeans. For a long time it has been believed that the reason why the treasures in the Shoso-in (Todai-ji, Nara) have remained intact to this day is because of their storage in a log building erected in the 8th century, particularly as measurements of the atmospheric humidity inside the building have revealed that it remains practically constant throughout the whole year.[47]
This property of wood presents the woodworker with enormous problems which must be considered in advance. On the other hand, it is precisely this property which leads the architect Seike Kiyoshi to favour wood above all other materials.[48] Many other Japanese architects live in timber houses even though they do not use wood in any of their designs. Even Jules Fletcher, England's ambassador to Russia in the second half of the 17th century, came to the conclusion that wooden buildings were far more appropriate for the Russians than those made from stone or brick because inside it was much warmer and drier.[49]
Humidity, splashing water and driving rain can destroy wood under certain conditions. If wood becomes wet, then it must be ensured that it can dry out again as rapidly as possible, like after felling. Only in water, or rather under exclusion of air, are many species of wood immune to attack by fungi and insects. In 1877 in Austria, the corner of a log construction from the 6th century BC was uncovered by a landslide; it revealed just how durable timber is under ideal conditions. In rafting, which greatly eases the transportation of large quantities of timber, this fact has been put to good use.
Buried timbers or those erected directly on the ground are obviously at the mercy of decay. (Fig. 29) Nevertheless, the posts of the Ise-jingu were buried again after its reconstruction, probably to emphasize the nurturing of tradition. The soil excavated to form the holes for the posts was mixed with gypsum, this mixture being subsequently used to ram down the posts. (Fig. 30) Although it might seem unconventional to use, of all things, gypsum, which attracts water,[50] there are other interesting, not easily understood examples of timber protection which must be the outcome of many years of experience. In Romania timbers were laid across oak sill beams. Weaker boards were then laid over these and perpendicular to them. To prevent these boards from rotting, the space in between was packed with lichen and sand – not left empty, for example, in order to let air circulate.[51]
A solution to the problem was achieved by erecting the columns on padstones. (Fig. 31) In the case of huge columns with sometimes incredible diameters the problem was complicated by the fact that the base of the column had to be very carefully matched to the stone underneath if the long-familiar stability was to be maintained. (Fig. 32) As dressed stones became more common for these foundations, builders at the same time had to ensure that the column base was well ventilated, for water collected on the flat stone and was then absorbed by the end grain of the column.[52] (Fig. 33)
At most risk is end grain, every face of a cut revealed when a piece of wood is divided perpendicular to the direction of growth.



29 Wood suffers most damage at the air-ground transition, as shown by these *torii* in the Zeniarai benten in Kamakura, Kanagawa, Japan.

30 The columns of the Ise-jingu are somewhat protected from the moisture of the soil by means of copper sheathing.

32 The forest of columns under the Horyu-ji daihozoden, Nara, Japan.



31 Every single column of this *Kabuki* stage from Sodoshima, Kagawa, Japan, is placed on a padstone. – Shikoku minzoku haku butsukan Open-air Museum

33 The bases of the columns of the To-ji kodo, Kyoto, Japan, all have ventilation slots.

34 The rafters of this barn in Galgenuel, Vorarlberg, Austria, demonstrate quite clearly wood's weakest point.

35 The projecting ends of logs were often cladded for protection. – Farmhouse in Gaschurn, Vorarlberg, Austria.

36 On the To-ji kondo, Kyoto, Japan, the sill, rail and header are all covered in such a way that no end grain remains exposed to the weather.