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Wood Utilization

Old knowledge for a sustainable future

Kessel Publishing House
www.forestrybooks.com
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Cover design and repro: Werbeagentur Rypka GmbH |
A-8143 Dobl/Graz | www.rypka.at

Cover pictures: Front cover, small picture in the middle, back cover, picture on the far left: Andrea Weber; all other pictures: University of Natural Resources and Applied Life Sciences, Vienna, Institute of Wood Technology and Renewable Resources.

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Kessel Publishing House
Eifelweg 37
53424 Remagen
Germany
ISBN: 978-3-910611-36-8
www.forestrsybooks.com
www.forstbuch.de

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Layout: Ecotext-Verlag, G. Schneeweiß-Arnoldstein, 1010 Vienna, Austria

Content

Acknowledgement

We would like to take this opportunity to thank all the sponsors of the various projects who have contributed to the production of this book:

University Anniversary Foundation of the City of Vienna 1002/2004 'Prehistoric wood and forest utilization in Hallstatt' (2004-2006); University Anniversary Foundation of the City of Vienna 1595/2006 'Prehistoric Wood and Forest Utilisation in Hallstatt: Continuation – Dating of wooden artefacts from the Hallstatt period' (2006-2007); Upper Austrian Provincial Government, Provincial Directorate of Culture 'Dendrochronological investigations of the oldest staircase in the world' (2006-2007); FWF TRP 21-B16: 'Historical Wood Utilisation in Austria' (2010-2013); Popular Culture Lower Austria: Forest and Wood Utilisation in Lower Austria (2010-2011); Sparkling Science SPA04-188 'Forest – Timber – Raw material' (2012-2014); Sparkling Science SPA05-123 'Wald-Holz-Viertel' (2014-2017); Sparkling Science SPA05-013 'Timber' (2014-2017); Sparkling Science SPA06-021 'Woodcraft revisited' (2017-2019); World Wood Day Grant 2020 – 'Reconstruction of forest management activities in prehistoric Hallstatt, Austria' (2020-2021).

The research in the prehistoric mine of Hallstatt is supported by the cooperation of the Natural History Museum Vienna with Salinen Austria AG and Salzwelten GmbH. The Sparkling Science project SPA04-182 'Wood for Salt' and the projects supported by the ESS programme of the Austrian Academy of Sciences and the FaceAlps and Hallimpact projects have provided important information on the use of wood in prehistoric times. This book is the unchanged version of the German edition from 2021. The literature has not been updated.

We are grateful to Joe Thompson for helping us to compile a glossary, which formed the basis of the English translation.

Preface

Modern wood research has made it possible to develop high-performance, cost-effective, predictable and lightweight wood-based materials. These are significantly expanding the range of applications for solid wood. This is an important contribution to making our economy and society more sustainable.

However, in addition to modern technology, there is still valuable knowledge about the use and properties of wood that has been passed down from generation to generation over many centuries, even millennia. However, a considerable amount of this knowledge and skill has already been forgotten. A folklorist in Bohemia pointed this out as early as 1917.

In the past, wood was an important part of everyday life. It accompanied people as firewood, building timber or work timber. People knew how to use wood profitably. Other industries such as glassblowing, salt production and mining would have been inconceivable without wood.

In times when wood was scarce, there was a great need to optimise the use of wood. This meant minimising losses during processing, using wood according to its properties and using all parts of the trunk.

All this knowledge is still very important for modern use. There is therefore a great need to rediscover knowledge and skills.

By analysing museum objects and archaeological finds, as well as studying old literature, it is possible to rediscover (pre-)historical rules of craftsmanship regarding the timing of felling, the choice of wood species and the use of wood.

In this book we mainly present our own research results from the last 25 years. This work has all taken place in Austria. We therefore present the results for 'Central Europe'. Our own findings are supplemented by reports from other authors. The aim has been to present the results in a scientific manner, but in a way that is understandable to all interested parties. For this reason, all further sources have been cited (see bibliography). Terms that may not be commonly known are briefly described in a glossary. The scientific names of wood species have not been given in the text. However, these are listed in the glossary to clarify any ambiguities.

In order to better convey the content, numerous images and graphics have been added for better visualisation. The captions provide additional information to the main text. We would like to take this opportunity to thank many institutions and individuals for their support, especially for providing images.

The book is intended to provide a glimpse into the past, to broaden the knowledge of interested parties, woodworkers and hobbyists from a broad perspective, but also to inspire modern, new applications. Let's use this knowledge for a sustainable future with our favourite material – wood!

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A shingle roof ('Schieferschindel') with staggered shingles. The ventilated space between the shingles allows for the use of spruce wood. Image: Austrian open-air museum Stübing/ UMJ; Photo: BOKU

Introduction

Photo: BOKU, Katzensteiner

The forest – origin of wood, habitat, recreational area.

Without trees and their wood, life as we know it would not be possible. Photosynthesis removes carbon dioxide (CO_2) from the atmosphere and converts it into organic matter such as leaves, fruit or wood. In the process, the air is enriched with oxygen, making it possible for humans and animals to breathe. As the climate crisis intensifies, the ability of plants to sequester CO_2 is coming under increasing focus, with wood being the material of choice.

Wood is the body of trees and shrubs enclosed by the cambium (the growth layer beneath the bark) of the trunk, roots and branches (Schafflützel 1974). Wood is formed by photosynthesis. This requires sunlight. To get more sunlight, trees grow upwards – the tallest trees in the world, growing in California and Oregon, are over 100 meters tall (the coast redwood 'Hyperion' is 115.6 meters tall – Sillet et al. 2010). Other species in North America live to be almost 5000 years old (Bristlecone pine, 4850 years old, recorded in the 1950s; Brown 1996).

Photo: BOKU

The bristlecone pines of Nevada and California are the oldest trees in the world, at around 5000 years old.

Austrian open-air museum Stübing/UMJ Photo: BOKU

A harrow used to cultivate the soil after slash-and-burn cultivation (shown in the background). This tool was made entirely of wood.

In our latitudes, the situation is somewhat different: Trees do not reach a height of 50 meters and rarely live more than 1000 years.

Wood has been with us since prehistoric times (Heinzinger 1988). Human development would have been different without the ability to make fire. By burning branches or small logs, the duration of the fire could be controlled. Fire provided light and warmth, protection from wild animals and enabled the preparation of easily digestible food. The burning of wood also made it possible to produce the first ceramics. However, wood as a continuous source of fire was not the only wood-related achievement that allowed us humans to evolve.

The development of the first tools, starting with throwing spears, stone axes, bronze axes and iron axes, gave us the first advanced civilisations. Moreover, agriculture in its early stages and far beyond would have been very difficult to realise without wooden tools (Gieser 1992).

Since time immemorial, mankind's dexterity has developed through working with wood. 'Ötzi', the mummy found in 1991 CE on the Hauslabjoch at an altitude of over 3200 meters, used 17 different wood species for the equipment he carried with him (Spindler 2000).

Wood was also important in the construction of the first dwellings. The first pile dwellings (wooden buildings on piles in rivers, lakes or swamps) were built around 5000 BCE (Hafner et al. 2016). Log buildings, which have been found in the Alpine region for many centuries, are still evidence of the long tradition of timber construction (Klöckner 1982), and the development of timber construction in Austria has known no bounds since then.

The development of many trades would have been different if, until about 100 years ago, every craftsman, regardless of guild, had not known how to make and repair his own wooden tools (Radkau 2007, Grießmair 2012).

The gearing of a flour mill (Feistritz near Birkfeld) with the crown wheel. This changes the direction of rotation from horizontal to vertical to drive the millstone.

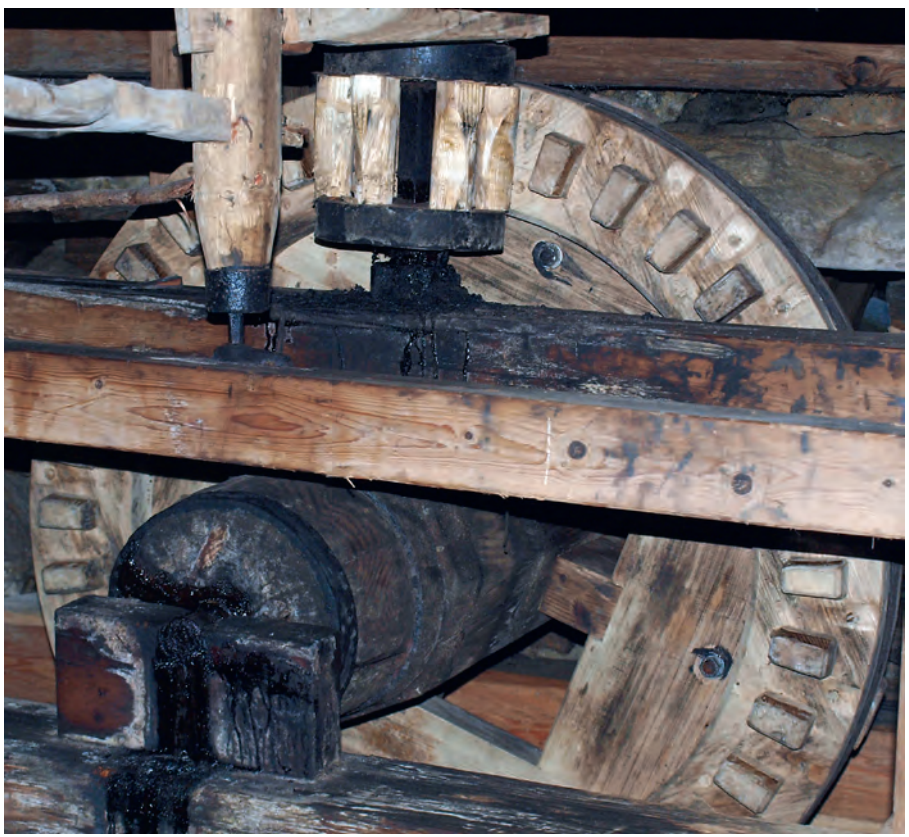


Image: Austrian open-air museum Stübing/UMJ; Photo: BOKU

Hardly any tool could do without a wooden handle, every spindle on the water-powered mills that drove the first machines, every shaft, every axle on the carts, every small part on the agricultural equipment was made of wood (Werneck

Photo: BOKU

An example of modern timber construction – a seminar building at the University of Natural Resources and Life Sciences, Vienna.

1956). Rural life was always strongly linked to the use of wood and without farmers, the nobility and landlords would probably not have survived either.

Bohemian folklorist Josef Blau wrote in 1917 CE: "*The old ways of doing business and working, the skills, knowledge, experience and conditions that have been handed down for a long time, and with them much of the necessary linguistic and cultural heritage, are moving higher and higher into the forests and mountains*" (Blau 1917).

Sometimes it seems as if we are going backwards in the use of wood. Much knowledge of the historical use of wood has already been lost, and many species that were once taken for granted are no longer used. One reason for this is the industrial processing of wood – the aim is to standardise the raw material and make it predictable, thus homogenising wood, which is heterogeneous in its origin. It was only through standards, standardised product ranges and properties that widespread use by building engineers and architects became possible. The development of modern wood-based materials has made it possible to multiply the dimensions of timber construction and to make materials lighter, with better insulating properties and good sound insulation. Today, many wood-based materials are significantly cheaper than solid wood and can be used to make inexpensive furniture or building materials.

Why should we use wood?

In the past, the main reasons for using wood were its availability and ease of processing. However, the advantages of wood as a building material were soon recognised, such as its insulating properties. Timber buildings were much warmer in winter than stone buildings.

So why should we use wood today?

Sustainability

The expectations and demands placed on Austria's forests are immense and often divergent. As a renewable raw material and source of energy for expanding markets, it should provide sufficient wood. The forest should protect our valleys from avalanches, rockfalls, mudflows and other natural hazards. It is a refuge for biodiversity, which should be able to develop as freely as possible. It should store carbon to help protect the climate.

Photo: BOKU, Katzensteiner

Even in the past it was important to use wood sustainably (in this case firewood, in the background in the forest and on the donkey). The February page of a calendar: 1412 Brothers of Limburg.

An example of sustainable forestry in Austria. (far left)

The forest should provide clean drinking water and serve as a popular recreational area and core element of the landscape whose beauty attracts millions of tourists to Austria every year (Anonymus 2018). It should provide all this 'sustainably', i.e. simultaneously, everywhere and forever. The United Nations General Assembly, with its 193 member states, has committed itself to the following approach:
"*Sustainable forest management, as a dynamic and evolving concept, aims to maintain and enhance the economic, social and environmental values of all types of forests for the benefit of present and future generations.*" (Anonymous 2018).

Between the bark and the wood is the cambium. This is where the wood and bark are formed.

Image: HTL Mödling, Foto: Weber

The growth of Austria's forests has remained almost constant for decades at around 30 million cubic meters per year. Even though felling has increased over the long term (about 26 million cubic meters per year), less wood is consumed each year than grows back – in other words, the renewable raw material wood is used in a sustainable way in Austria. Almost half of Austria is covered by forest. With more than 4 million hectares of forest, Austria has a forest cover of 47.9%. This makes Austria one of the most densely forested countries in Europe. Expressed in solid cubic meters, this corresponds to about 1135 million solid cubic meters of wood or about 3.4 billion trees. In addition, the forest area is growing by around 3400 hectares every year – that is the equivalent of more than 4500 football pitches (Anonymus 2018, Jörg 2015).

Analysis of pollen from the last millennia preserved in a bog near the prehistoric mines of Hallstatt suggests that miners and foresters were already using their forests sustainably and not overexploiting them over 3000 years ago (Festi et al. 2021).

CO_2 storage

Photosynthesis removes CO_2 from the atmosphere and converts it into sugar, which is used to form wood. The carbon from approximately 1 tonne of CO_2 is stored in 1 m^3 of wood. Wood is 50% carbon (C). Assuming an average of 500 kg per cubic meter (dry weight) of wood, this means that 1 m^3 of wood contains 250 kg of carbon. If this carbon in the wood is then converted back into CO_2 by burning or rotting, i.e. oxidised, approximately 3.6 kg of carbon dioxide is produced from 0.9 kg of carbon. This means: 250 kg C/m^3 of wood x 3.667 kg CO_2 equals 916 kg CO_2 per 1 m^3 of wood (Jörg 2015).

Austria's forests store about 985 million tonnes of carbon. Of this, 41% is stored in biomass and 59% in the soil (Schreck and Lackner 2016).

So how do forests contribute to a positive carbon balance? Sustainable forest management is a key factor.

A detached house in timber construction. (right)

Photo: BOKU

Photo: BOKU, Katzensteiner

Sustainable forestry and wood use are important factors in reducing CO_2 emissions.

By using long-lasting wood products, the carbon stored in them is not released back into the atmosphere during this time, while at the same time the use of wood creates space for young trees that can absorb CO_2 again (Schreck and Lackner 2016). Assuming a wood requirement of around 40 cubic meters for a single-family house, a new house is built in Austria every 40 seconds (Jörg 2015).

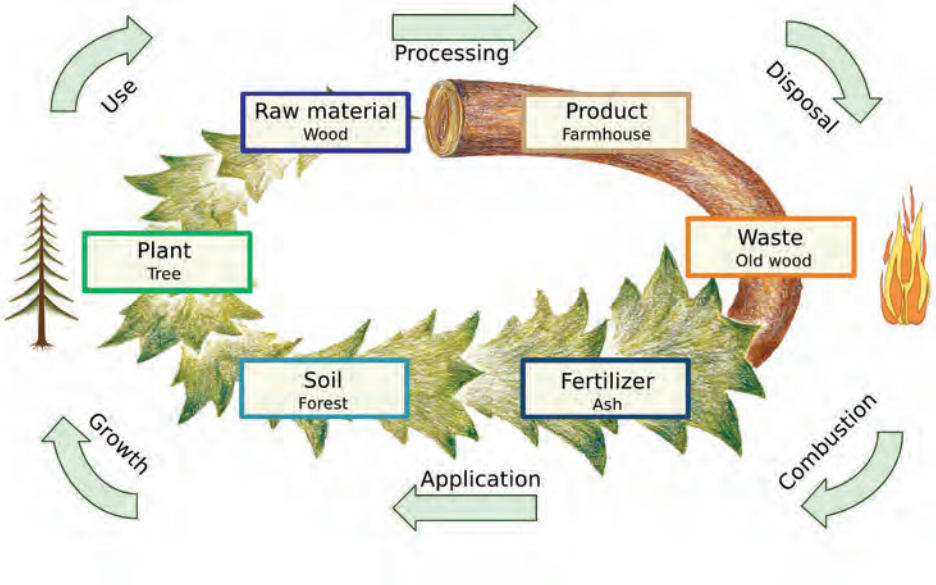
In buildings and other wooden structures, the carbon remains bound for decades as a CO_2 sink. Approximately one tonne of CO_2 is sequestered per cubic meter of wood, and about 7.5 million m^3 of wood and wood-based materials were used in the construction industry in Austria in 2018 CE (Stingl and Teischinger 2019). This means that, after deducting all emissions from the production process, a net total of around 5 million tonnes of CO_2 was stored in wood in that year. In the same year, about 79 million tonnes of CO_2 equivalent were emitted in Austria (Anonymus 2020a). In the same period, more than 6% of this greenhouse gas was sequestered for decades, possibly even centuries.

The biggest contribution, however, is that wood can replace other building materials. As the emissions from the production, use and disposal of wood materials are lower than the CO_2 emissions from the use and production of, for example, concrete and steel, significant emissions can be avoided. A brick wall emits 5 tonnes of CO_2 per 50 m^2 of wall, whereas a timber frame house with softwood panels emits only 1.5 tonnes of CO_2 for the same area. This means that 3.45 tonnes of CO_2 can be saved for an area of just 50 m^2 (Jörg 2015).

Another important aspect in terms of CO_2, and especially in relation to transport, is the weight of 'things' (cars and other vehicles, but also the transport of goods in general). The latest calculations show the importance of reducing weight in order to save fuel and therefore CO_2. And wood can play a key role here. Wood and wood-based materials are much lighter and in some cases have similar strength to other materials such as steel or aluminium (Mair-Bauernfeind et al. 2020).

Circular economy

Unlike other materials, wood is a renewable resource. And it can be reused after its initial useful life – in other words, timber building materials are resource-saving, circular products. Unlike other building materials, which consume fossil energy when they are disposed of after use, wood building materials release the solar energy stored in them in a CO_2-neutral way. For example, when wood is harvested and processed into lumber, all parts are used without creating waste. The sawdust or wood chips are made into paper, chipboard or fibreboard, and the sawn timber is used as a building material or for furniture and everyday objects. The bark is also used, for example, as bark mulch in horticulture. Once this primary use cycle is complete, the deconstructed building material can again be used as a raw material for chipboard, fibreboard or paper, for example. Generating energy from biomass is essentially CO_2 neutral, as the carbon is sequestered in the renewable forest.



Wood is a natural resource that can be used in a cycle: The tree grows, the wood is used, the old wood is reused, the reused wood is burned and the ash is used to fertilise the new trees.

Figure: Weber

But it saves on the import of fossil fuels: it is low in pollutants, and air quality remains significantly better than with the thermal use of fossil fuels. At the end of the cycle, only as much CO_2 is released as was absorbed during photosynthesis.

Photo: BOKU

Wood is an important economic factor.

An important economic factor

The forest and wood industry is an important economic factor in Austria. 172 000 enterprises and companies along the forestry-wood-paper value chain provide jobs for about 300 000 people (Anonymus 2020b). The Austrian wood industry is strongly oriented towards foreign trade. The trade surplus amounts to EUR 1.12 billion. The majority of exports are sawn softwood, glulam or cross-laminated timber, wood-based materials (such as chipboard or fibreboard) or skis. In 2019 CE, exports totalled more than 5.9 billion euros. In 2013 CE, domestic sawmills processed 15 million cubic meters of wood into high-quality sawn timber. In Austria, sawmills cut 98% coniferous wood, but only 2% hardwood (Jörg 2015). This is due to the composition of wood species in Austrian forests, where around 80 % of the forest area is planted with conifers. The paper and board industry processes about 8 million cubic meters of wood.

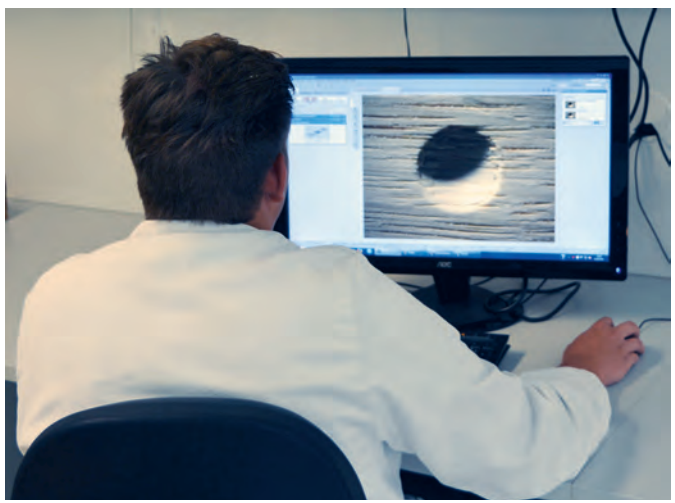


Photo: BOKU

Various tests are used to determine the properties of wood. Here you can see the round imprint of a steel ball used to determine hardness.

The properties of wood

Wood has high characteristics performance: relative to its weight, wood has very high strength (Knuchel 1947, Ramage et al. 2017). This means that for the same load-bearing capacity, wood is significantly lighter than steel and has almost the same compressive strength as concrete.

Image: Austrian open-air museum Stübing/UMJ; Photo: BOKU

Wood not only creates a good indoor climate, but also a pleasant atmosphere.

But unlike concrete, wood can also absorb enormous tensile forces. Relative to its own weight, wood can support 14 times more than steel. The strength properties of wood depend on the direction in which it grows. Wood has its greatest strength in the direction of the grain. It can withstand a hundred times higher tensile forces and four times higher compressive forces in this direction than across the grain (Schmid 2016). The breaking length (the length of a rod at which it breaks under its own weight, i.e. without load) illustrates this well. For example, for aluminium it is around 13 km, but for wood it is around 30 km (Wegst and Ashby 2004). Due to its low production costs, wood can therefore certainly compete with other ‚modern materials' – especially when it comes to tensile-loaded components. Wood's low weight, combined with its high strength, allows for wide spans and slender structures. The lower weight of wood also reduces fuel consumption and the associated environmental impact and transport costs in the mobility sector (Baker and Rials 2013).

- Wood regulates the indoor environment: Wood creates a pleasant, healthy indoor climate thanks to its moisture-regulating properties and its adsorption capacity, i.e. wood has the ability to equalise differences in humidity on the one hand and to bind harmful and odour-intensive substances in the air on the other. As a product of nature, wood creates a sense of well-being that reduces stress and reactivates mental energy.
- Wood is durable: If used dry or kept dry during construction, it will last for generations. In areas of increased humidity, wood can usually be adequately protected with structural measures; only in exceptional cases will additional treatment methods be required.
- Wood and hygiene: Wood has sometimes been wrongly condemned as an unhygienic material and raw mate-

Image: Forest farmers museum Gutenstein; Photo: BOKU

In the dairy industry, only wooden vessels and containers were used.

rial (Gehrig et al 2000). With careful selection of wood and proper handling, wood products can certainly help to improve hygiene in many areas. Pine heartwood and oak heartwood are particularly suitable. Pine sapwood and fir wood follow. Beech and black locust are less suitable (Fürst 2007, Milling et al. 2005).

- Wood is rich in texture and colour: the use of different wood species and the possibility of a wide variety of finishes in terms of texture and colour means that wood is aesthetically very appealing and has an extremely positive effect on our visual senses. Wood comes in different dimensions, but also in different species, which in turn have different properties (Knuchel 1947).
- Wood is easy to work with: Wood has always been a material characterised by its wide distribution and relative ease of extraction and processing compared to other materials (Gayer 1928). The fact that wood grows almost cylindrically means that it can be used directly for poles, posts, and so on.
- Wood has a predictable fire behaviour: The fire behaviour of wood is easy to calculate due to its predictable burning rate (between 0.5-0.65 mm/min depending on the wood species). In addition, when wood burns it does not produce highly toxic fumes, it smokes little and does not drip.
- Timber construction is flexible and fast: The various timber construction methods are very flexible systems that can be easily adapted to the conditions of use and requirements.
- The high degree of prefabrication also reduces construction time. The large formats of engineered wood have made modern timber construction possible. The production of engineered wood is based on a simple principle: wood is cut into boards, chips or fibres and

Photo: BOKU

Plum wood has an attractive color and wood texture.

Image: Austrian open-air museum Stübing/UMJ; Photo: BOKU

Wood is flammable. But that doesn't mean it can't be used as a building material. It burns predictably.

Image: commons.wikimedia.org/wiki/File:Johann_Wilhelm,Bezau1595.jpg#/media/Datei: Johann_Wilhelm,Bezau1595.jpg

In his 1668 work Architectura civilis, Johann Wilhelm depicts carpenters at work. Many wooden buildings from this period still exist.

Image: Office building Unterrainer, Ainet; Photo: Holzbau Unterrainer

An example of modern timber construction combined with tradition (shingle roof).

reassembled into a new shape, usually using glue. The result is products with standardised properties in defined thicknesses and dimensions. Wood-based materials thus create added value and open up additional possibilities for designing with wood. As an inexpensive building material for everyday use, wood-based materials have become indispensable and are available in a very wide range from timber merchants and hobby markets (Schmid 2016).

Wood is a thermal insulator: as long as a tree is growing, its pores carry water from the roots to the leaves. After the tree has been felled, the wood begins to dry and the pores begin to carry air. As a result, dry wood has good natural thermal insulation properties and low thermal conductivity. In this respect, wood is superior to many other materials. Objects made of wood are therefore warm to the touch (Knuchel 1947). On the other hand, the warmth of our hands will not melt the ice cream on a wooden handle.

- Safe in earthquakes: Timber has a low dead weight and the structures are flexible rather than rigid. This means that a timber structure can absorb the forces and vibrations that act on the building during an earthquake and compensate for them through the elasticity and flexibility of the wood. This is why timber is used predominantly in earthquake zones.

The history of wood utilization

The term 'Wood Age', often used as an umbrella term for the period from the Stone Age to industrialisation, is intended to emphasise the importance of wood and the way of life of the people of central Europe, who were closely linked to the forest.

In rural areas, the use and processing of wood was so commonplace until recently that this activity and the technology behind it are not even mentioned in some cultural history literature (Fuchs 2012). Even in contemporary technological history, wood is often not treated in a way that reflects its importance (Fuchs 2012).

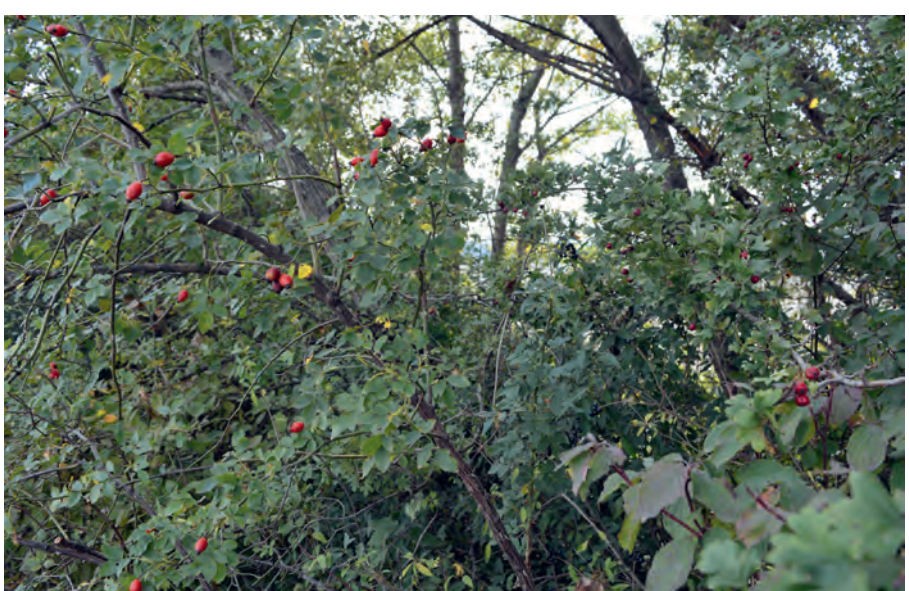


Photo: BOKU

A picture from the mixed forest – dog rose, lilac in the background and hawthorn. All these wood species are no longer in use today, but can be found in historical objects.

Image: Muzeul De Istorie Sighisoara, Romania; Photo: BOKU

Part of a wooden clockwork – a precision wooden machine. (right)