WOOD DETERIORATION, PROTECTION AND MAINTENANCE

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Wood Deterioration, Protection and Maintenance

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Preface

It is well known that wood has been used since ancient times as a structural material for buildings, as the main or auxiliary material in agriculture and later in industrial products, and as a material for furniture and various artistic products.

The service life of wooden products depends first of all on the natural durability of the wood species and wooden composites used, but also very significantly on their design, their methods of chemical and modifying protection, their exposure and their maintenance.

People are able to prolong the lifetime of wooden products based on practical knowledge related to wood-damaging agents (e.g. solar radiation, water, fire, aggressive chemicals, wood-decaying fungi, moulds, wood-destroying insects or marine borers), and also from theoretical studies related to the mechanisms of their action on wood at the molecular, anatomical, morphological and geometry levels.

The structural protection of wooden products is based first of all on the application of durable wood species and other high-quality materials. Simultaneously, the presence of wood-damaging agents has to be limited by using suitable designs with the aim to reduce contact of wood with rain and other sources of water, to reduce the creation of water condensate, and to reduce the impact of ultraviolet (UV) light and fire. So, for this purpose, suitable atmospheric, moisture-impermeable, UV and fire-retardant insulations are applied.

Chemical protection of wood is performed with preservatives; that is, mainly with fungicides, toxic and hormonal insecticides, fire retardants and UV-protective finishes that are applied on the wood's surface and also into its depth. Currently, for wood preservatives not only is their efficiency important, but also their effects on human health and the environment. The optimization of wood pretreatment (e.g. debarking, drying, improving permeability) and its chemical preservation technology (e.g. time of dipping, vacuum, and/or pressure) derive from the theoretical principles of flow and diffusion of preservative substances in the capillary structure of wood. Plywood, particleboards and other wooden composites can be chemically treated during their production or subsequently.

The modifying protection of wood is a prospective mode for improving its resistance against biological agents and dimensional changes. Using active chemical modification, the —OH groups of the lignin–saccharide wood matrix react with molecules of a suitable chemical. This results in a decrease in wood hygroscopicity, and fungi, insects or marine borers then have less interest in this treated wood (e.g. acetylated wood). Thermally modified wood also leads to good resistance to atmospheric factors and biological damage, mainly where there is no contact with the ground.

Wooden products have to be regularly maintained with the aim to increase their lifetime. However, when they became damaged, a thorough inspection of their actual state is important; that is, the diagnosis of the cause, type, degree and range of their damage. Biologically damaged wood should be sterilized. Subsequently, for restoration of smaller wooden elements are used conservation methods, working with natural and synthetic substances. Load-bearing elements of wooden houses, roofs, ceilings and other constructions can be reinforced with prostheses, splicing, special bracing or other methods.

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Ladislav Reinprecht
Zvolen, December 2015

About the Author

Ladislav Reinprecht is a professor at the Faculty of Wood Sciences and Technology, Technical University in Zvolen, Slovakia. He obtained an MSc degree in organic chemistry, a postgraduate degree in mycology and a PhD degree in wood technology. For students and specialists he has written many books and monographs, both in Slovak (e.g. *Wood Protection, ThermoWood, SilanWood, Processes of Wood Deterioration, Reconstruction of Damaged Wood Structures, Wooden Buildings – Constructions, Protection and Maintenance, Wooden Ceilings and Trusses – Types, Failures, Inspections and Reconstructions*), and in English (e.g. *Strength of Deteriorated Wood in Relation to its Structure, TCMTB and Organotin Fungicides for Wood Preservation*). His primary research interest lies in the analysis of abiotic and biological defects in wood structure – the conditions for their creation and the methods of their detection, inhibition and prevention. He has published the results of his experimental work in many articles in scientific journals and presented results at various international and domestic conferences.

Contents

1 Wood Durability and Lifetime of Wooden Products

Wooden products (furniture, flooring, doors, etc.) and constructions (log cabins, bridges, ceilings, trusses, etc.) produced from various species of wood and types of wooden composites are in practice exposed to different environments, where they can be subjected to more forms of degradation (see Chapters 2 and 3).

With the aim to suppress the degradation processes in the wood, and also in glues, paints and other materials used for wooden products and constructions, it is desirable to use suitable forms of their structural, chemical and modifying protection so that their lifetime can be suitably increased (see Chapters 4, 5 and 6).

The service life of wooden products and constructions can be increased by their regular maintenance. However, when degradation processes in wood and/or in additional materials occur and cause damage, appropriate restoration methods should be used (see Chapter 7).

1.1 Basic information about wood structure and its properties

The structure of wood and wooden composites (Figures 1.1 and 1.2) and their exposure in conditions suitable for the action of abiotic factors and/or the activity of biological pests (Figure 1.3) are the basic prerequisites for potential damage of wooden products and constructions.

Wood is a biopolymer, created by a genetically encoded system of photosynthetic and subsequent biochemical reactions in the cambial initials of trees (Figure 1.1). Trees consist of approximately 70–93 vol.% of wood, with the rest being bast, bark and needles or leaves. Wood is the internal, lignified part of the stem, branches and roots. The characteristics of wood include: (1) anisotropy, typical in three anatomical directions – longitudinal, radial and tangential;

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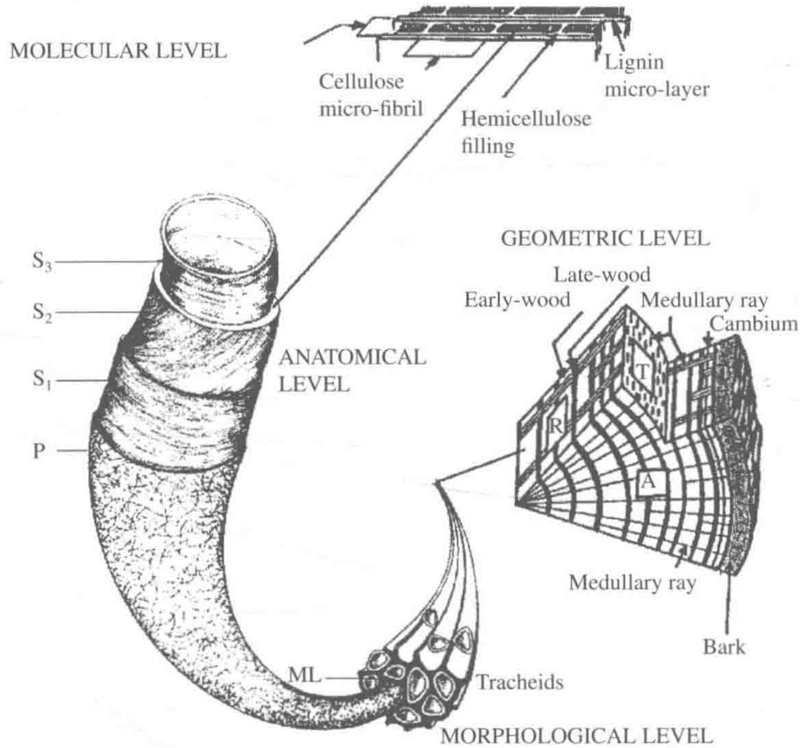


Figure 1.1 Structural levels of wood (modified from Eriksson et al. (1990) and Reinprecht (2008))

Source: Eriksson, K-E., Blanchette, R. A. and Ander, P. (1990) Microbial and enzymatic degradation of wood and wood components. Springer Verlag – Berlin Heidelberg, 407 p. Reproduced by permission of Springer

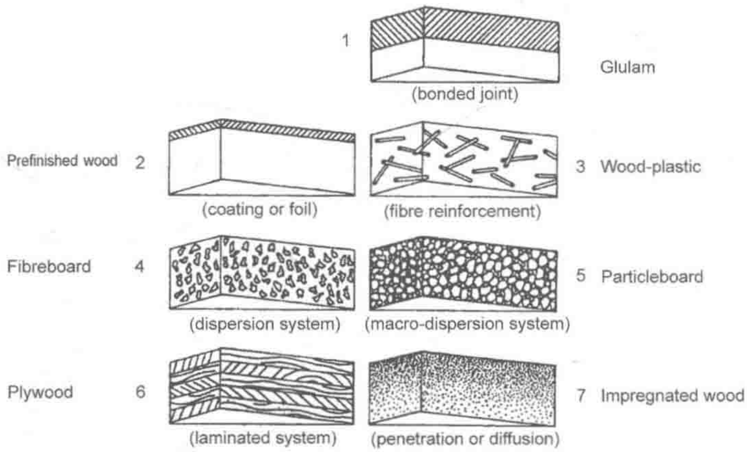


Figure 1.2 The basic types of wooden composites: (1) glulam (glued joints); (2) prefinished wood (coatings or foils); (3) wood–plastic (fibre reinforcement); (4) fibreboard (dispersion systems); (5) particleboard (macro-dispersion systems); (6) plywood (laminated systems); (7) impregnated wood (penetrations or diffusions). (Note: composite is a multicomponent system of materials consisting of at least two macroscopically distinguishable phases, of which at least one is solid)

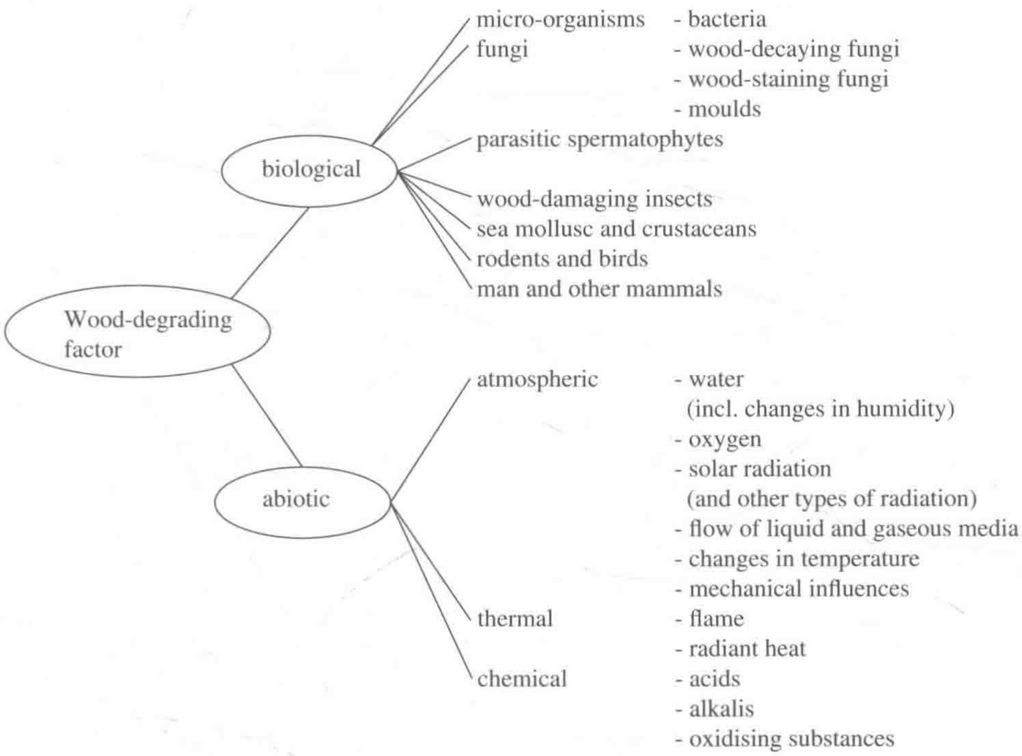


Figure 1.3 Biological and abiotic wood-degrading factors

Source: R., L. (2013) *Wood Protection*, Handbook, TU Zvolen, Slovakia, 134 p. Reproduced by permission of TU Zvolen

(2) inhomogeneity, influenced by the sapwood and heartwood, the early wood and late wood, and so on; (3) specificity, given by the wood species; and (4) variability, given by the growth conditions of the tree of a given wood species.

Wood is a traditional material, used for producing wooden buildings, furniture, work and sport tools, as well as art works. It is currently an irreplaceable raw material for the production of bio-based composites with the targeted combination of wood particles in various stages of disintegration and pretreatment with a complementary system of adhesives, waxes and other additives (Figure 1.2).

1.1.1 Wood structure

The *structure of wood* (Figure 1.1, Boxes 1.1, 1.2, 1.3 and 1.4) and *wooden composites* (Figure 1.2) is defined at four levels:

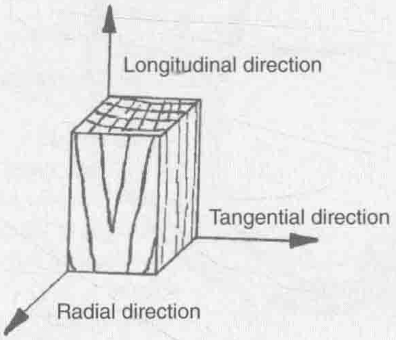
- primary (i.e. molecular/chemical structure);
- secondary (i.e. anatomical/submicroscopic structure);
- tertiary (i.e. morphological/microscopic structure);
- quaternary (i.e. geometric/macroscopic structure).

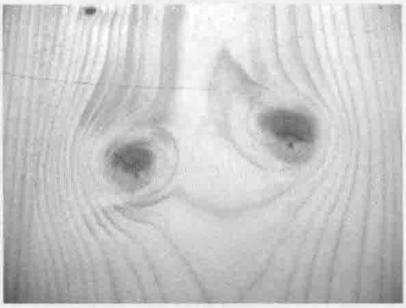
Box 1.1 A basic preview of the geometric structure of wood

The geometric structure of wood

Defines

The external appearance – shape, volume, colour, the ratio of tangential, radial and facial areas, the proportion of sapwood, heartwood and/or mature wood, the proportion of early and late wood in annual rings, the roughness and overall quality of the surfaces, and so on.





Knots

The macroscopic inhomogeneities – knots, compression or tension wood, juvenile wood, false heart, resin chanals, and so on, together with their type, frequency and state of health (e.g. damage by rot).

Depends on

- the morphological structural level (i.e. the proportional and spatial distribution of various types of cell elements in the wood);
- the growth defects and anomalies in the wood;
- the mechanical and other loads/treatments of the wood.

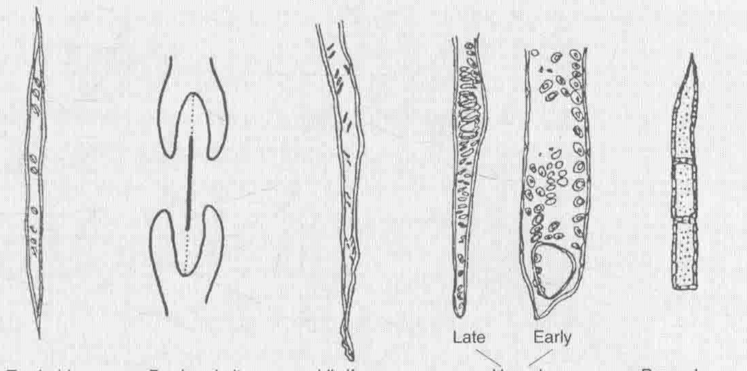
Source: R., L. (2008) *Ochrana Dreva* (*Wood Protection*), Handbook, TU Zvolen, Slovakia, 453 p. Reproduced by permission of TU Zvolen.

Box 1.2 A basic preview of the morphological structure of wood

The morphological structure of wood

Defines

The individual cells – type, shape, dimensions, slenderness factor, orientation to the pith (longitudinal, radial), thickness of the cell wall, thinning in the cell wall (type, frequency, location), and so on.



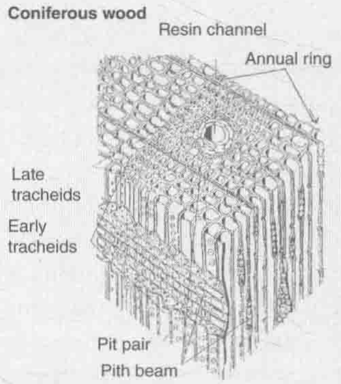
The grouping of cells – proportion and location of parenchymatic, libriform, vessel, tracheid and other cell-types in the wood tissues.

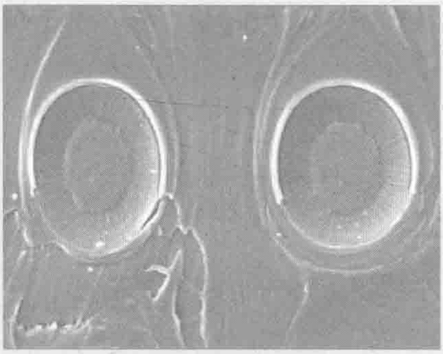
Depends on

The wood species (Fengel & Wegener, 2003; Wagenführ, 2007; Wiedenhoeft, 2010; Wiemann, 2010):

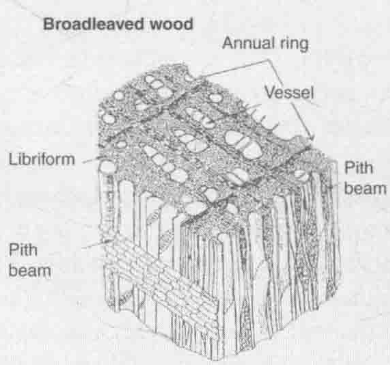
- *Wood of coniferous species* has a simple and fairly regular morphological structure. Approximately 90–95% of wood volume is formed of early and late tracheids. Tracheids have a conductive and strengthening function. They are 2–5 mm long (late are approximately 10% longer) and 0.015–0.045 mm wide. Their cell walls, with a thickness of 0.002–0.008 mm, contain a fairly high number of pit pairs, usually 60–100 in early tracheids and 5–25 in late tracheids. Pit-pairs with a diameter of 0.008–0.03 mm are mainly at the end of tracheids on their radial walls. Opened pit-pairs provide interconnection between tracheids, which is used in the transport of liquids into the wood at its chemical protection and modification. Parenchymatic, thin-walled cells form stock tissue with living protoplasm. They are located in radially oriented pith beams and in longitudinally oriented parenchymatic fibres and resin channels. Resin chanals are lacking in some coniferous species (i.e. they are not present in fir or yew wood).
- *Wood of broadleaved species* has a more complicated morphological structure compared with coniferous wood. Libriform fibres, present in a volume of 36–76%, have a strengthening function. They are relatively short, from 0.3 to 2.2 mm, with a width from 0.005 to 0.03 mm. They have a weak connection with other types of cells due to the small number of simple pit or half-pit thinned areas. Vessels, present in a volume of 20–40%, have a conductive function. Their conductive function is important for the transport of nutrients during a tree's growth, as well as for transport of preservatives and modifying substances into wood.

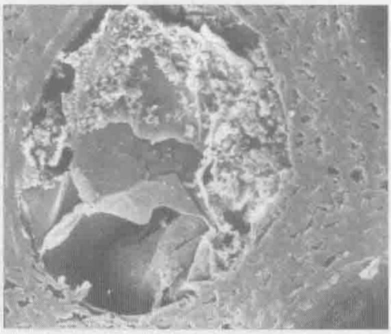
In ring-porous species (ash, elm, hickory, oak), large vessels in early wood have a diameter from 0.2 to 0.5 mm, whilst small vessels in late wood are from 0.016 to 0.1 mm. The length of vascular systems are usually up to 0.1 m, but in some wood species this can even be several metres (e.g. as long as 7 m in oak). They are created from a long, vertical line of vessels connected via openings – simple, reticular or ranking perforations. Cell walls of vessels have circular and spiral thickenings. The conductive function of vessels decreases under the influence of tyloses (i.e. when blocked by outgrowth from the surrounding paratracheal parenchyma). Parenchymatic cells, present in a volume of 2–15%, mainly have a storage function. Longitudinal, paratracheal parenchymata (single-sided, group, vasicentric, etc.) group around the vessels and vessel tracheids and connect to them via single-sided pit pairs. Longitudinal, apotracheal parenchymata do not come into contact with the vessels. In radially oriented pith beams, several parenchymatic cells are combined with a rectangular shape, horizontal or vertical, either in morphological unity (homogeneous beam) or in morphological diversity (heterogenic beam).





Closed pit pairs in tracheids





Vessel blocked by tyloses

Source: R., L. (2008) *Ochrana Dreva* (*Wood Protection*), Handbook, TU Zvolen, Slovakia, 453 p. Reproduced by permission of TU Zvolen.

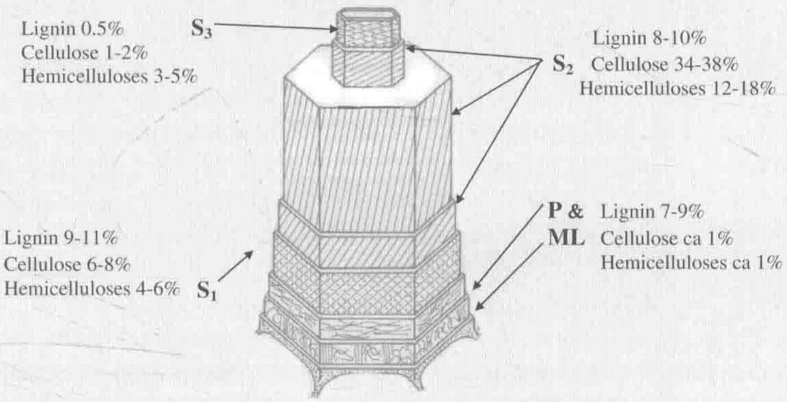
Box 1.3 A basic preview of the anatomical structure of wood

The anatomical structure of wood

Defines

The structure of the cell walls of wood's cells:

- layering (i.e. the individual layers ML, P, S_1, S_2, S_3 – see Figure 1.1);
- proportion and localization of the structural polymers (cellulose, hemicelluloses and lignin) and extractives in the individual layers of the cell wall.



Depends on

The wood species and the type of cell (Fengel & Wegener, 2003; Wiedenhoeft, 2010):

- Elementary fibrils, formed usually of 40 macromolecules of cellulose, are the basic elements of the cells' walls with a cross-section of ca 3.4 nm × 3.8 nm. Microfibrils consist of 20–60 elementary fibrils. Macrofibrils consist of cellulose microfibrils as well as of hemicellulose fillings and lignin microlayers.
- Microfibrils and macrofibrils form substantial lamellae that are the structural base for individual layers of a cell wall (i.e. the ML, P, S_1, S_2 and S_3):
  - ML → middle lamella, mainly formed of lignin granules;
  - P → primary wall, with a thickness of 0.06–0.09 μm, formed of a high proportion of lignin and cellulose fibrils orientated randomly into a multilayered network;