



**TIMBER
DEVELOPMENT
UK**

Supply

S.00.03-01

Date Published

November 2023

Document Type

Timber Knowledge Sheet

Category

Supply | Design

Audience

Designer | Merchant | Supplier

Theme

Source

Author

Marlene Cramer for TDUK

KNOWLEDGE LIBRARY

Wood-Water Interaction

Interactions between water and wood have serious implications for the drying of timber, and for design choices.



Wood-Water Interaction

Wood is a hygroscopic material, which means it interacts with water, absorbing moisture when water is present or the surrounding humidity is high - and desorbing moisture in dry environments.

Water plays a vital role in a living tree and is contained in every part, including the stem. Most of the stem's water is contained in the lumen of fibres (earlywood tracheids in softwoods and vessels in hardwoods). As water evaporates from the tree's leaves, the water inside the wood fibres is pulled upwards by transpiration pressure. In both the radial and tangential directions, it is transported mostly via pits, which are small openings in the cell wall.

As the tree ages, older cells closer to the pith die and no longer conduct water. However, these older cells still contain water inside their cell walls, and water is transported between cells through diffusion processes.

Water in Wood

When a tree is felled, the wood contains free water (as both liquid water and water vapour in the fibre lumen) and bound water (in the cell wall). Less dense species contain more water, up to seven times their dry mass. The mass of the water inside

wood in relation to its dry mass is referred to as the wood's moisture content (mc).

Before use, timber is usually dried. Free water evaporates from the cells first, most rapidly via the end grain. The drying speed depends on wood anatomy, especially the size and distribution of water-conducting fibres. Ring-porous hardwoods, as compared to diffuse-porous hardwoods or softwoods, tend to dry more slowly, as their pore size is highly variable and the moisture exchange between cells is inhibited. Dense woods also tend to dry more slowly as they contain more wood substrate in the cell wall and more water bound to it. Tyloses and other cell contents also hinder water transport in wood and slow down the drying process.

The stage at which no free water is present in the fibres, but the cell walls are fully saturated with bound water, is called the fibre saturation point (FSP). At and above FSP, wood has its largest volume. The FSP depends on the species and wood density, and it is commonly around 30% mc.

As wood continues to dry, bound water leaves the cell wall and cellulose microfibrils move towards each other. The wood starts to shrink as the cell wall reduces in thickness and the fibre lumen increases. Overall shrinkage is higher in denser woods because the cell wall is bigger compared to its lumen and contains more water molecules that are desorbed when drying.

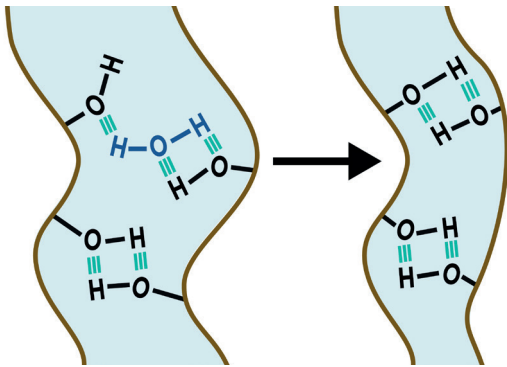
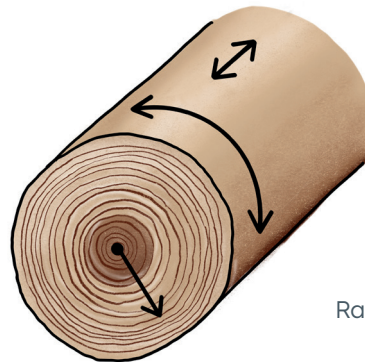


IMAGE: Microfibrils moving towards each other as water leaves the cell wall

Shrinkage also differs in different grain directions. Wood barely shrinks in a longitudinal direction, as most water molecules are stored between cellulose microfibrils. The fibres therefore reduce in thickness, rather than in length. Shrinkage in radial direction is inhibited by the rays (radially oriented parenchyma cells). Therefore, tangential shrinkage is the highest, around 20 times the longitudinal shrinkage and double the radial shrinkage.

Shrinkage or swelling is relatively minor along the length, at approx. 0.3%



Tangential shrinkage or swelling, approx. 8%

Radial shrinkage or swelling, approx. 4%

IMAGE: Shrinking in a softwood log from felled to dried

The diffusion resistance of the wood increases with decreasing mc, which means that the water transport via diffusion is slowed down. The more the wood dries, the slower the drying process becomes. In an oven at elevated temperature and low relative humidity, wood can be dried to 0% mc, known as oven dry state. At this point, virtually no water is contained in the cell wall, although some water always remains. In this state, the cell walls have shrunk to their smallest thickness and the lumen have reached their maximum diameter.

When back in contact with air containing water, dry wood absorbs water again. Water molecules are adsorbed to the hydrophilic groups (mostly to hydroxyl groups) of hemicellulose and the amorphous areas of the cellulose fibrils. A one-molecule layer of water molecules is absorbed directly to the wood substrate (primary water), and further water molecules are bound to the first and subsequent water molecule layer (secondary water).

When the moisture content increases, the vapour pressure inside small capillaries is reached as the vapour pressure is lowered in narrow spaces, and water condenses. The liquid water is bound in intermicellar and interfibrillar spaces. Water in the wood cell wall is therefore present in three forms:

- **Chemisorption:** primary water molecules bound to hydrophilic groups, mostly hydroxyl groups. A strong chemical bond is formed.
- **Physisorption:** secondary water is bound to other water molecules, using van-der Waals force. The bond is weaker than in chemisorption.
- **Capillary condensation:** water vapour condenses in narrow capillaries and fills intermicellar and interfibrillar spaces.

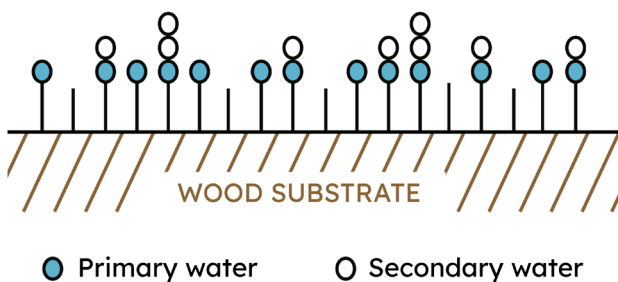


IMAGE: Water molecule absorption in wood

The absorption is not fully ordered, meaning not all secondary water molecules are bound after the primary water molecules, but both happen at the same time. This is one reason the adsorption (“wetting”) process does not exactly resemble a reverse desorption (“drying”) process (and the swelling process does not exactly resemble a reverse shrinking process).

The moisture content of wood (below FSP) is commonly around 1 to 2% lower in adsorption than in desorption. The difference between the moisture content in water adsorption and desorption is called hysteresis.

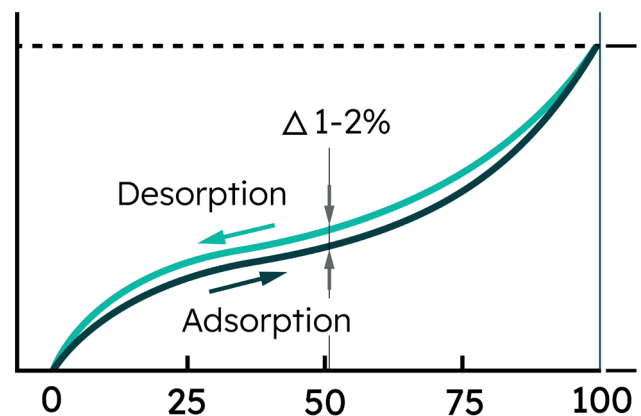


IMAGE: Sorption isotherm over relative humidity with hysteresis indicated

In use, wood constantly adsorbs and desorbs water to the cell wall until it reaches an equilibrium with the surrounding air. Wood usually has a mc of 10-20% while in use, depending on the climate (the temperature, pressure, and relative humidity of the surrounding air). Where the mc is below FSP (in most uses), water is present in the wood as bound water in the cell wall and is transported in diffusion processes. The more water is adsorbed to the cell wall, the more swelling occurs.

Wood in contact with water can also absorb liquid water and can contain free water, which is conducted in the capillary system, from wider to narrower capillaries and between fibres via pits. Fibre lumen are much larger than pit openings, and water can be absorbed much more rapidly by the end grain and is conducted more easily in longitudinal direction than across the grain.

Date Published	Document Type	Category	Audience	Designer Supplier	Theme	Author
November 2023	Timber Knowledge Sheet	Supply	Merchant		Source	Marlene Cramer for TDUK

This means that, even when wood contacts water, often only the outer wood layers increase in moisture content, while the inner wood layers stay dry. The speed of rewetting is also dependent on the wood anatomy – such as the wood’s density, porosity, and tyloses.

Technical Relevance of Wood-Water Interaction

Wood usually needs to be dried before use. Because the interaction of wood and water depend on the wood anatomy and moisture content, there is no “one size fits all” approach for drying. Timber drying needs to be carefully planned and executed to avoid drying defects.

In use, wood still adsorbs water from the air. The hygroscopicity of wood is often regarded as an undesirable effect. The problems of dimensional stability and decay are particularly linked to moisture in wood. Designing with wood requires planning for moisture in timber and its effects.

Several techniques, such as thermal and chemical wood modification, aim at reducing the wood’s ability to bind water molecules to the cell wall. These processes make the wood more dimensionally stable and rot resistant.

However, its hygroscopicity makes wood a desirable choice for indoor furniture and other products. Wood balances the room climate, as it is constantly absorbing and desorbing water from the air to reach an equilibrium. The humidity inside rooms with wooden materials is therefore more stable.

When treating wood with preservatives and other treatments, its ability to adsorb and conduct liquid water is of critical importance. The same anatomical features that decrease the speed of water transport in wood (such as tyloses and pore arrangement) also make wood less impregnable when treating it with chemicals.

Only certain species can be impregnated with chemicals, and the process needs to be adapted to the wood’s properties.