WHY DOES MY WOOD SHRINK LIKE THIS?

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Wood shrinks approximately 8% along the tangential surface, 5% along the radial surface, and for "normal" wood, only about 0.1% along the longitudinal surface. Therefore, the very best behaving wood will change shape, and do this differently in different directions, while losing or gaining moisture.

The story is: wood will shrink when placed in an environment of lower moisture content and swell when placed in an environment of higher moisture content. We can see the results but we cannot see why this occurs because it happens at the microscopic level.

Three main components of wood are: Lignin, cellulose and hemicellulose. Lignin makes wood fibers stiff and strong and is the "cement" between individual fibers. It deters insect and fungal attack and functions as a water barrier. Chemically, it is a complex, 3-dimensional substance. Cellulose is the major chemical component of wood fibers. It is composed of long chains (10,000+) of glucose sugar molecules. Cellulose is a straight-chain polymer, that is, the glucose molecules are strung end to end to make, at the molecular level, a large molecule. Hemicelluloses "coat" the cellulose chains and help the lignin bind to the cellulose. Hemicellulose are branched-chain polymers made up of sugars, one of which is glucose. Hemicellulose is made up of hundreds of sugar molecules rather than tens of thousands for cellulose.

Basic Structure of the Cell Wall

Microfibrils can be considered the building blocks of wood. Microfibrils are a core of crystalline cellulose encased in a shell of short-chain hemicelluloses that are partly linked to the cellulose core. Wood cells are made up of microfibrils. The way microfibrils are laid down in the cell wall depends on where in the cell wall they are located.

The Primary Cell Wall and Compound Middle Lamella

Please refer to FIGURE 1 for the following section. The primary cell wall is very thin. It is made up of microfibrils that are dispersed in a loose, irregular interwoven pattern. The microfibrils are laid down at an angle of orientation of about 85 degrees with the cell axis. The angle of orientation becomes successively smaller from the inner to the outer parts of the primary cell wall as the maturing cell enlarges.

Intercellular material, extending between the cell walls of adjacent wood cells, is known as the true middle lamella. It is made up of an isotropic, plastic-like substance that is mostly pectin. The plastic nature allows slippage between cells as they are enlarging. Since the primary cell wall is very thin, it is hard to distinguish where the primary cell wall starts and the true middle lamella ends.

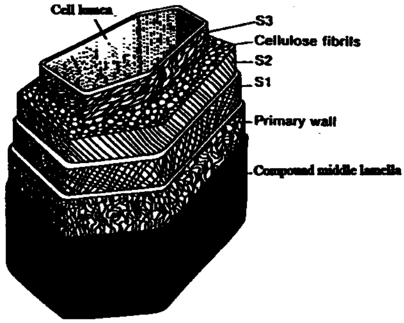

FIGURE 1. Layering structure of a wood cell.
Source: Dry Kiln Operator's Manual

Compound middle lamella refers to the true middle lamella and the primary cell walls of two adjacent wood cells, that is, it fills the space between two wood cells.

The Secondary Cell Wall

The secondary cell wall is much thicker than the primary cell wall. It is divided into layers, S1, S2 and S3, and contains a high percentage of cellulose. Because of the density, volume and structure of the secondary cell wall, it is responsible for the major source of strength for the woody cell. More importantly for this paper, the secondary cell wall plays a major roll in the shrink/swell behavior of wood. This is especially true of the S2 layer because it is much thicker than the S1 and S3 layer.

The S1 layer and the S3 layer of the secondary cell wall in softwoods is about 4 to 6 lamellae thick. A lamellae is a cluster of microfibrils. The microfibrils of the S1 layer are laid down at an average angle of 50 to 70 degrees measured from the cell axis. The microfibrils of the S3 layer are laid down at an average angle of 60 to 90 degrees measured from the cell axis, about the same as the S1 layer.

The S2, or central, layer of the secondary cell wall consists of a dense network of lamellae that are aligned nearly parallel to each other The S2 layer in softwoods can be up to 40 lamellae thick in thinner walled springwood, and over 150 lamellae thick in summerwood. The microfibrils of the S2 layer, for normal mature wood, are laid down at an average angle of 10 to 30 degrees from the cell axis (close to being parallel to the axis). It is the microfibril angle of the S2 layers within individual wood cells that drives the shrink/swell behavior in a larger piece of wood.

Shrinking and Swelling

As wood loses moisture below the fiber saturation point, it loses bound water and it shrinks. This bound water is held in the cell wall structure and because the S2 layer is the thickest, it holds most of the bound water. Shrinking occurs as bound water escapes from between cellulose and hemicellulose molecules, between microfibrils. As water leaves, the microfibrils move closer together. Swelling is the reverse of this process.

Wood shrinks across the grain, both tangentially and radially, but not much along the grain. Since the microfibrils are aligned almost parallel to the long axis of the cell, we can envision these microfibrils coming closer together as the water leaves the cell but without much change lengthwise in their relationship with the cell axis. As an example, place two pencils parallel and even on a piece of paper. Mark the top and bottom with a mark. Now bring them together. They get closer but there isn't any change as far as up and down is concerned. But as microfibrils come closer together, the cell gets narrower. Because the microfibrils are not exactly parallel to the cell axis there is some longitudinal shrinkage but it is usually only 0.1% to 0.2%.

Juvenile Wood and Compression Wood

Juvenile wood is the first wood produced in a stem. It extends out from the center of a stem from 5 to 25 annual growth rings depending on species. We are interested in the S2 layer of these juvenile wood cells. Juvenile wood has a much higher microfibril angle in the S2 layer than mature wood cells, those produced later in the stem. This means less shrinkage across the grain as the microfibrils come closer together but up to ten times more shrinkage in the longitudinal direction. Grab your two pencils. Place them parallel to each other but at an angle of about 45 degrees to the long axis of the paper. Mark the top pencil at its top and mark the bottom pencil at its bottom. Now, move the pencils together and remark the top and bottom. Its obvious that these have shrunk much more longitudinally than those at only a slight angle to the long axis.

Let's use an example to see how this affects drying your lumber. A 20 ft. two-by-four, will shrink longitudinally about a quarter of an inch (mature wood shrinks longitudinally about 0.1% so .001 X 240 inches = 0.24 inches, actually only about half of this since you will dry it to about 15% MC and not 0%). Your next 20 ft. two-by-four came from near the center of the log and is about half juvenile wood and half mature wood. Half of your two-by-four wants to shrink 0.24 inches along its length but the other half wants to shrink up to 2.4 inches along its length. In this case the piece of lumber will either bow or crook depending on where the two zones of wood are located.

Compression wood forms in softwoods. It forms on the underside of leaning trees and the underside of branches. Fiber length is shorter than in normal mature wood and, as with juvenile wood, has a much higher microfibril angle in the S2 layer than normal mature wood. Although behaving similarly to juvenile wood when losing moisture, compression wood has been reported to shrink up to seventy times more in the longitudinal direction than normal mature wood. If your 20 ft. two-by-four contains half compression wood, that half may want to shrink as much as 16 inches in the longitudinal direction. Severe bow or crook can be expected.

We can definitely see the results of shrinking and swelling of wood even though we cannot see how this occurs since it is occurring at the molecular level.

References

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