HOW WOOD DRIES

The Influence of Wood Structure

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To understand the drying of wood one must know its make-up, both gross and minute, because the behavior of an entire board in seasoning is really the sum total behavior of its elements, no matter how small.

Every kiln operator knows that, as wood dries past the fiber saturation point, it shrinks in all directions and that if this shrinkage is not in balance, distortion results. This shrinkage originates in the cell walls and progresses cell by cell.

Wood is an organic product. Like all plant products, it is made up of billions of tiny cells. These cells may be called the structural elements of wood, much like bricks are the structural elements of a wall. If the cells were all of one kind; all of one size; uniform in size in all directions; and arranged in a simple, homogeneous pattern; it might be very easy to dry wood. But such is not the case. Actually, there are several kinds of cells; they vary widely in size; they are many times longer than they are wide; their walls vary in thickness; and they are arranged in various patterns. This makes wood a very complex material. The western kiln operator is really lucky in that he has only coniferous woods to season - - pines, firs, Douglasfir, redwood and others. These woods are comparatively simple when compared with such hardwoods as the oaks, madrone, chinquapin, laurel, and eucalyptus. In general, the greater the complexity, the greater the care necessary to prevent distortion.

The mass of cells that makes up wood can be likened to a crowd of people. In a crowd, each individual has his own idea of what he wants to do, - - which way he will push or pull. Crowd behavior becomes a sort of algebraic sum of the individual behaviors. Similarly in wood, each cell has its own peculiar individual behavior, and the behavior of a piece of wood is merely the aggregate behavior of its individual cells.

There are two systems of cells - one is vertical and the other horizontal, as determined by the cells' long dimensions. These systems, at right angles to one another, set up complications of their own.

A further complication is caused by the arrangement of the cells in concentric layers, known as growth rings (annual rings). They are composed of distinguishable zones - - springwood, summerwood, and a transition zone between these two. Springwood and summerwood are often called 'early wood' and 'late wood', respectively. These zones represent the progress of annual growth.

All diameter growth originates in the cambium, the layer of cells that is at the same time the last layer of wood and the first of bark, and is thus common to both wood and bark. It is just one cell thick. Cambium cells have the power to divide and form new, or additional, cells. When growth begins in the spring, the new cells are large and thin-walled. Hence they have large cavities. In the aggregate this

springwood is relatively soft, light in weight or density, and weak. Later on, the cells added to those already formed, are smaller (in radial direction), thicker-walled, denser, heavier, and stronger. Since they are smaller and the walls are thicker, it follows that the cell cavities are much smaller. This is the so-called summerwood, that part of the growth ring that is dark and hard.

In some woods, like sugar pine, Idaho white pine, spruce, Port Orford cedar, and incense cedar, the change, or transition, from springwood to summerwood is very gradual. In other woods like Douglasfir, western larch, western red cedar, redwood and some true firs, the transition is generally rather abrupt, thus giving rise to the effect of definite bands of light and dark layers.

The rays deserve some additional comment. In coniferous woods they are very thin - - just one cell thick except where horizontal resin canals are involved. One cell lies atop another, like bricks in a wall, and thus form a thin vertical sheet. To get an idea of the relation between the two systems, imagine a handful of strings each about a foot long. The strings, held vertically are comparable to the vertical system of cells. Then imagine a paper-thin sheet of horizontal finer-strings, five or more strings high and one thick, inserted between the vertical mass. This thin sheet would be comparable to the rays. The rays, even though fine, can be seen when a piece of pine or other conifer, is split radially. If the rays were very thick, like in white oak in which they may be 25 cells wide and several hundred cells high, they would be very conspicuous in all views. On the radial, or vertical grain face, the rays would give rise to what is known as quartered oak.

In coniferous woods the principal cells are the wood tracheids. They are angular in cross section and are many times longer than wide. Tracheids are easily seen on a smoothly cut cross-section of sugar pine or redwood, in which woods the tracheids are particularly large. Viewed under a low-power hand lens, the cross section resembles a honey comb. Another type of cell is the parenchyma. This occurs mainly in the rays. On cross sections the ray parenchyma tissue forms what appear to be radial lines.

In the pines there are openings between the cells, (really gaps or spaces, and not cells) that are so much larger than the cells that they are often conspicuous - as in sugar pine. These are called resin canals, or resin ducts. Resin canals are horizontal and vertical and, somewhere in their length, they cross one another. Resin canals are present also in larch, Douglasfir and spruce, but not so abundantly and conspicuously as in the pines. As far as I know the resin canals have no important influence in seasoning. However, resin may ooze from the horizontal canals to form little beads on the surface of the wood long after seasoning.

It would appear that the cell is the smallest element we need to be concerned about. But, small as it is, the cell is made up of still smaller particles and we could pursue these smaller parts down to the molecules themselves. The ultra-microscopic structure of the cell wall is of interest to the researcher who must get at the basic causes of wood behavior. Because, after all, the behavior of the individual cell is determined by its wall characteristics.

The more minute the part, the more difficult it is to study it. Cells themselves

require a compound microscope for study. But the wall make-up requires ultra-microscopic examination which may call for the use of X-rays and the marvelous electron microscope. Scientists in several parts of the world, particularly Germany and England, have studied the cell wall and have had theories of its make-up for a hundred years. These theories, from time to time, have had to be revised as new instruments and new techniques were developed. Even today, there is no complete aggreement, but there is enough to permit some explanations in an address like this.

Wood from a chemical standpoint, is made up primarily of cellulose and lignin. The cellulose forms the frame work of the cell wall. The cell wall particles may be in the form of rods, or fibrils; these fibrils will be made of micro-fibrils and these in turn are made up of chains of molecules forming a meshwork of cellulose crystallites. This is an over-simplification of the complexity involved.

The importance of the above lies in the fact that water occurs between the particles of the cell wall; that these water layers have thickness and strength; that these water layers get thinner after the free water has been depleted and the drying proceeds from the cell walls; that the cell particles adjoining the layers of water, are drawn together as the intervening layers or films of water become thinner; that the end result is shrinkage.

To carry this over-simplification still farther let us take wet soil as an analogy. It is not a perfect analogy but it helps. Soil is made up of particles. Clay soil has fine particle; sand soil has large particles. When soil is completely saturated, every particle is surrounded by a film of water. Water, in very thin layers, has high tensile strength and binds the particles together, nevertheless the films of water also hold the soil particles apart. When the soil particles are fine there are many more films of water in a given dimension than when the particles are coarse. Thus, clay soil, having more particles, swells more than sandy soil. Conversely, if the soil is dried, the films of water lose thickness; the soil particles come closer together; and shrinkage of the soil mass results. The clay soil shrinks more than the sandy soil only because there are more films of water to lose thickness.

Similarly in wood, the cell wall particles, down to the crystallites of cellulose, are separated from one another by water. Where soil particles are as long as they are wide, the cell wall particles of wood are much longer than wide. This is true of the molecule itself; of the crystallites; of the fibrils; and of the cell. Consequently, where a mass of soil, because its particles are more or less cubical, will shrink rather uniformly in all directions, wood, which is made up of elongated particles, shrinks much less lengthwise than crosswise.

The above difference in shrinkage can be explained by viewing the elongated character of the particles; suppose we assume a body made up of long narrow particles, call them strands, fibrils, rods or other such name. Each one is surrounded by a film of water. There are not as many particles lengthwise as there

are crosswise and hence fewer films of water lengthwise. There being fewer films lengthwise, there is less water to lose thickness, and hence less shrinkage. Now, this is open to severe criticism, because in such a simplification I have omitted some other important cell wall characteristics, for example, that the wall may actually be a series of layèrs, in each of which the elongated particles incline at different angles. This inclination itself probably affects the relation between the horizontal and vertical components of the shrinkage, pretty much like a pressure applied at an angle to a wall will resolve into a vertical and a horizontal component. In fact, the inclination of the fibrils in a special case like the so-called "compression wood", is such that the longitudinal component is increased so significantly that end-wise shrinkage becomes really troublesome, whereas in normal wood it can be ignored.

It follows from the above that the denser the wood the thicker the cell walls; the more wood substance there is; the larger the number of cell wall particles, the larger the number of water films; and, consequently, the greater the shrinkage. Thus a dense wood can shrink and swell more than a light weight wood. And of course it follows that summer wood, being denser, will shrink more than spring wood. Obviously, we have a bad situation in having summerwood and springwood in alternate bands, and in that the bands are curved.

Having looked into the make-up of the individual cell and its behavior, let us now look at the gross features again - - the growth rings and the rays.

The direction of sawing a board from a log with respect to the growth rings develops what we call "flat-grain" and "vertical-grain" boards. It is common knowledge that a vertical-grain board shrinks less across its face than a flat-grain board. Why? There are several reasons but for our purpose we can pass over the influence of the fibril angle, which I think has the least influence. Evaluating all the data of researchers I offer this explanation: In a flat-grain board the dense summer wood is continuous across all or a large part of the width of the board, whereas in a vertical-grain board there is an alternation of soft springwood and dense summerwood. Thus in a vertical-grain board the full effect of the greater shrinkage of the dense summer wood cannot operate. Now as to the rays.

Since cells shrink less in length than in width we can reason that the ray cells, the lengths of which are cross wise of a vertical grain, tend to restrain the wood tracheids from going ahead fully with their potential cross-wise shrinkage. Thus the rays check cross-wise shrinkage in vertical grain, whereas in the flat grain board the rays can add their cross-wise shrinkage to that of the wood tracheids.

Summarizing: The shrinkage of wood originates in the cell wall. The cell wall particles (crystallites) are separated one from the other by thin films of water. During drying, the water films become thinner; the adjoining particles come closer together; and, the volume of the cell is reduced.

The cells are of several kinds and of varying sizes and wall thicknesses and are arranged in several patterns. Thus, cell behavior is not uniform. During drying, the cells must be given an opportunity to adjust themselves to the stresses set up among their particles, and to one another as each shrinks. Otherwise, distortion of the lumber is certain.
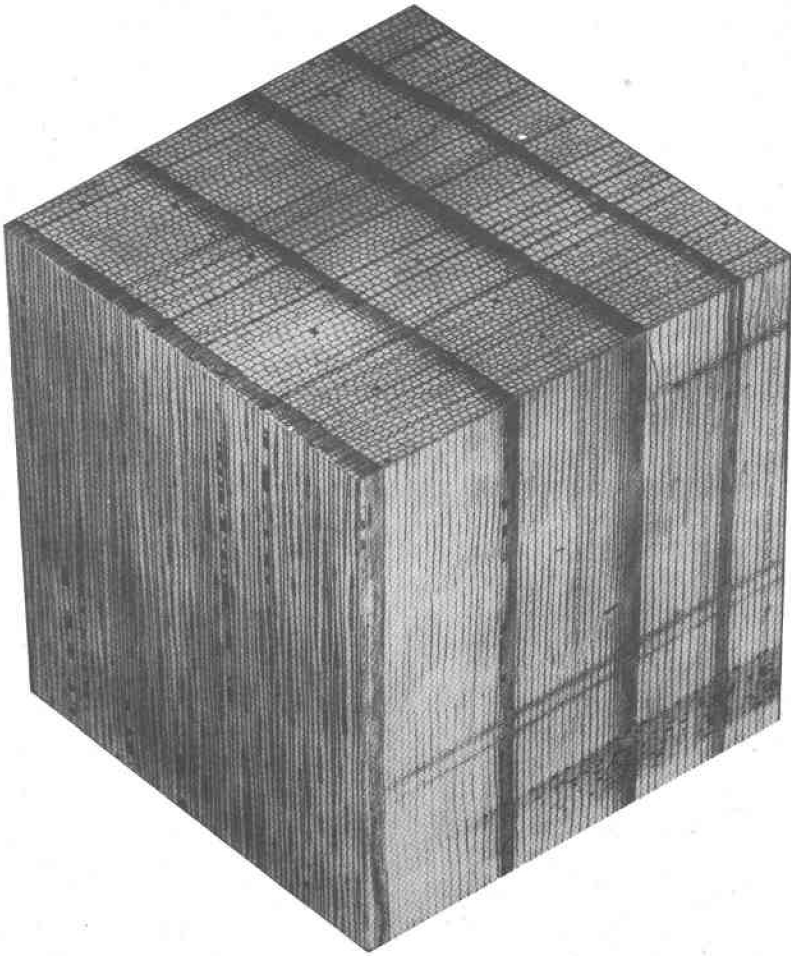
How a small cube of redwood, about 1/4 inch on each side, looks under the compound microscope.