

Causes and Cures for Warp in Drying

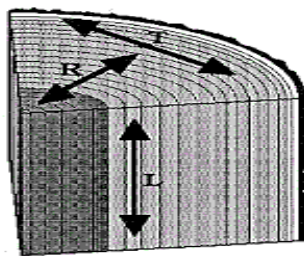
Eugene M. Wengert and Dan Meyer
University of Wisconsin School of Natural Resources
Department of Forestry
No. 68 - November 1993

Lumber warps in many different ways, but all warp is caused by differential directional shrinkage as the wood dries from its green state. When one edge or face or end of a piece of wood shrinks more than the opposite edge or face or end, the piece warps. The three types of warp are cup, bow and crook. Following an introduction to wood shrinkage, each type of warp will be discussed in terms of its causes, likely locations in a log from which lumber might suffer from it, and preventative measures which can alleviate the warping problem, where possible.

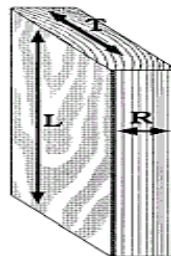
Wood Shrinkage

Wood shrinks in all of its three directions--longitudinal, radial and tangential (Figure 1)--as its moisture content changes. Wood shrinks the least in the longitudinal direction, or along the grain. Wood from the juvenile core, the wood closest to the center of the tree, shrinks more longitudinally than does more mature wood. Tension and compression wood tend to amplify longitudinal shrinkage. When going from green (wet) to kiln-dried, mature wood will shrink less than 0.1% along the grain. Thus, a 10-foot green piece of lumber will lose less than 1/8-inch in total length when dried. For most species, longitudinal shrinkage is so small that it is of no concern.

Radial shrinkage is shrinkage in the direction from the center of the tree to the bark (Figure 1). Radial shrinkage in North American species ranges from 4 to 6 percent. A 2-inch thick, wet, flatsawn piece of lumber, when dried, will thus lose up to 1/8-inch in thickness due to shrinkage.



Flatsawn Lumber



Quartersawn Lumber

Figure 1. Shrinkage directions in wood: L--Longitudinal; R=Radial; T=Tangential.

Tangential shrinkage is directly perpendicular to radial shrinkage and roughly double in magnitude. For North American species, tangential shrinkage ranges between 6 and 12 percent. A flatsawn 6-inch wide board, when dried, could shrink in width as much as 3/4-inch.



Figure 2. For purposes of clarity, herein, the different surfaces of lumber are referred to as the ends, edges and faces, without regards to grain pattern.

Causes and Cures for Warp

Cup

Cup is warp across the width of the face of a piece of lumber. It occurs when one face shrinks more in width than the opposite face. The end becomes cup shaped (Figure 3).

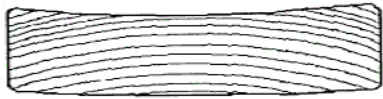


Figure 3. End view of a cupped, flatsawn board.

For true quartersawn lumber (ring pattern is symmetrical), both faces will shrink evenly, and cup will not occur. For any other grain pattern, the outer face (that which faced away from the center of the tree) will shrink more than the other face, causing the board to cup towards the outer face.

Figure 4 shows the location of the lumber with respect to its location in the tree. The heavy, longer arrows represent shrinkage in the tangential direction, while the lighter, shorter arrows are the direction of radial shrinkage. Shrinkage along surface A is more in the tangential direction than in the radial direction (i.e. surface A is more closely aligned with the dark arrow). Along surface B the shrinkage is mostly radial (surface B is closely aligned with the lighter arrow). Because wood shrinks nearly twice as much in the tangential direction as the radial direction, surface A will shrink more than surface B, causing the lumber to cup towards surface A. This is always the case: lumber cups away from the center of the tree, or towards the bark.

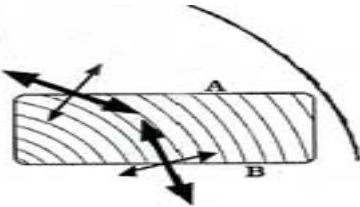


Figure 4. Radial and tangential shrinkage directions in relation to the board's original position in the tree. The large arrows represent shrinkage in the tangential direction; the small represent radial shrinkage. A = bark face, or sap face; B = heart face.

Several factors can influence the severity of cup in lumber. The difference in shrinkage between the faces is greater as the lumber approaches a perfectly flatsawn piece. It is also greater when the lumber is sawn from areas closer to the center of the log. (Note: With smaller logs, a greater percentage of the lumber is close to the center of the tree. Hence, small timber has a greater tendency to result in more cupped lumber.) Also, there is a variation in cup among species due to differences in tangential and radial shrinkage rates--the greater the ratio between tangential and radial shrinkage values (percent), the greater the tendency to cup.

Cures for Cup

Cup can be prevented, or at least minimized, with careful handling procedures. There is little hard evidence that closer sticker spacing or better sticker alignment in stacking will reduce cup, yet these practices will certainly not promote cup, and they are beneficial in reducing other types of warp. Placing heavy weights on a stacked lumber pile can be beneficial in preventing cup, but the load required is at least 150 pounds per square foot and it must remain on top of the pile for three days after drying is complete. Finally, in stacking, avoid, as best as possible, placing lumber with different thickness variations in the same layer. The thinner lumber, even if only a fraction thinner than the thickest lumber, is not held tightly flat by the stickers and is prone to cupping.



When drying lumber in the predryer or kiln, follow correct practices, as they reduce cupping:

- Do not allow partially dried lumber to inadvertently regain moisture quickly;
- Do not dry lumber too slowly;
- Do not over-dry lumber (even if equalizing is used to bring up the moisture level at the end of drying)

Bow

Bow is warp along the length of the face of lumber. It occurs when one face of lumber shrinks more in length than the other. It causes the lengthwise curvature of a piece of lumber such that it resembles a bow used in archery (Figure 5).

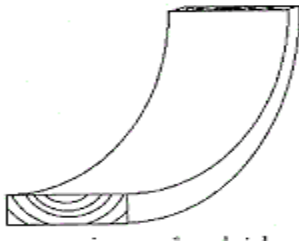


Figure 5. Bow occurs when one face shrinks more longitudinally than the other. The board will bow towards the center of the tree.

Wood does not normally shrink along the grain by any appreciable amount. Hence, bow due to wood characteristics is a rare event. However, wood close to the center of a tree (within 20 years of the center) does shrink more along the grain than more mature wood. So, it is possible to have either a flatsawn or a quartersawn piece of lumber that has mostly wood from the juvenile core on the heart side and mostly mature wood on the bark side. The juvenile side will exhibit longitudinal shrinkage, causing the lumber to try to bow excessively during drying. Most pieces that show this characteristic would be No. 2 Common or below in grade, as they are typically close to the center of the tree.

It is also possible to get longitudinal shrinkage in a piece of lumber sawn from a crooked log or in wood around a large branch. The wood cells in the resulting lumber are oriented at an angle, causing longitudinal shrinkage and a tendency to bow.

Cures for Bow

Consistency in sawmilling can alleviate some bow problems. Lumber should be of uniform thickness. Improper saw feed speeds or lapses in saw maintenance can result in lumber that is thinner on the ends than in the middle. This leads to a type of bow, called "pile bend," which appears in the upper layers of a pack.

Proper and timely handling and drying of lumber will also help to reduce or eliminate bow. Wood that is wet and warm can bend quite easily. In fact, the shrinkage, or bending, that causes warp usually occurs at high MCs (above 40% MC).

Make sure the stacking procedure itself is not contributing to bow. The 4x4s and stickers must be of uniform thickness. Careful stickering practices, such as maintaining good vertical alignment and assuring no stickers are up on edge, are a "must" for flat lumber. Foundations for green lumber piles, whether in the kiln, predryer or air-drying yard, must be flat.

Certain drying procedures should also be avoided, especially at high MCs, as, once warp occurs at the higher MCs, it is difficult, if not impossible, to straighten the lumber in the kiln at low MCs, no matter what kiln-drying procedures are used. Drying wood too slowly will exacerbate bow. Fast drying, especially at high MCs, can reduce the amount of bow, but fast drying with a species such as oak results in checks and honeycomb.

Likewise, rewetting partially dried lumber will increase the MC of the surface fibers and allow the shrinkage stresses in the wood to more easily bend the lumber. (Note that lumber can be rewetted



inadvertently in several ways: using higher than required kiln relative humidities (RH), perhaps in an effort to dry cautiously; an accidental discharge of the fire sprinklers; starting a kiln with steam spray before reaching required dry-bulb temperature; or because the load of lumber has widely varying initial MCs, meaning that the high RH used to protect the wet lumber is actually rewetting the drier lumber.)

Crook

Crook, or side bend, is warp along the length of the edge of lumber. It occurs when one edge shrinks more in length than the other. It causes the edgewise curvature of a piece of lumber (Figure 6). As lumber does not normally shrink along the grain, crook, like bow, is an abnormal event caused by shrinkage of "abnormal" wood in the lumber.

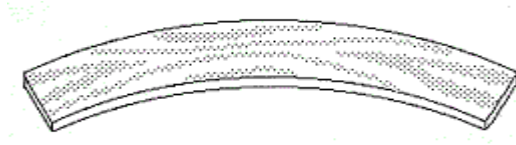


Figure 6. (Face view) Crook occurs when one edge shrinks more, longitudinally, than the other. The board will bend towards the edge closest to the Juvenile core.

There are several types and grain patterns of wood which have the characteristic of shrinking along the grain, including wood from the juvenile core, compression wood, tension wood, sloped grain and cross grain. If this special wood is distributed evenly throughout the piece of lumber, longitudinal shrinkage, and therefore warp, is not a problem. The special wood becomes a problem when it is on one edge and not the other.

The biggest factor influencing the degree of crook in a piece of lumber is its original location within the log. Perfectly flatsawn lumber (Piece D, Figure 7) is unlikely to experience crook because both edges were equidistant from the tree's core, and thus should experience the same magnitude of longitudinal shrinkage. On the other hand, quartersawn lumber is the most susceptible to crook, as one edge is closer to the center of the tree, and this edge is more likely to consist of wood from the juvenile core, than the other edge (Piece A, Figure 7). When two boards (such as pieces B and C) are ripped from a wide, flatsawn board (such as Piece D), they become susceptible to crook during drying even though the original wide board (D) was not susceptible. The rings of the smaller boards are "off-center," indicating that one edge is closer to the tree's juvenile core.

Cures for Crook

First and foremost, use a sawing pattern which keeps the rings centered, from edge-to-edge, within the lumber. Usually this means that after sawing one face of the log, the opposite face should be sawn next (that is, the log should be turned 180°). Because the rings are centered, any longitudinal shrinkage on one edge will be balanced by the same shrinkage on the other edge. Saw such that the grain of the wood is parallel to the edges of the lumber. Sawyers should avoid purposely orienting the log such that the lumber is sawn at an angle to the grain. Although this practice may produce more aesthetically pleasing lumber, the loss to crook may be substantial. Crook, unlike cup and bow, is not usually affected by drying procedures.

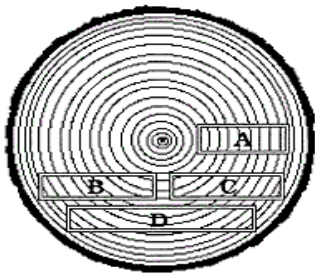


Figure 7. Boards A, B and C are susceptible to crook, or side bend; board D is not as both edges are equidistant from the core, and the rings are centered, edge-to-edge.

Drying Defects – Causes and Prevention

Drying defects are typically the result of differential shrinkage in the wood. Differential shrinkage may be due to: 1) the natural differences between the three principal directions of the wood, 2) differences due to the presence of “abnormal” wood, such as juvenile wood in the core of tree, and reaction wood, i.e. compression wood in softwoods, and tension wood in hardwoods, or 3) to the differences in drying rates at different locations within a piece of lumber. The first two items are discussed in the Wisconsin Tech Bulletin, by Wengert and Meyer.

Differential shrinkage due to differences in drying rates throughout a piece of lumber can lead to casehardening, surface and end checks, and honeycomb. The following is a taken from the Dry Kiln Operators Handbook, and describes the formation of these defects.

Differential shrinkage between the shell and core of lumber also causes drying defects. Early in the drying process, the fibers in the shell (the outer portion of the board) dry first and begin to shrink. However, the core has not yet begun to dry and shrink, and consequently the core prevents the shell from shrinking. Thus, the shell goes into tension and the core into compression. If the shell dries too rapidly, it is stressed beyond the elastic limit and dries in a permanently stretched (set) condition without attaining full shrinkage. Sometimes surface checks occur during this early stage of drying, and they can be a serious defect for many uses. As drying progresses, the core begins to dry and attempts to shrink. However, the shell is set in a permanently expanded condition and prevents normal shrinkage of the core. This causes the stresses to reverse—the core goes into tension and the shell into compression... These internal tension stresses may be severe enough to cause internal cracks (honeycomb) to occur.

Casehardening

Casehardening occurring as a result of air drying is usually not considered a defect, as it is usually addressed and relieved in the dry kiln (Air Drying of Lumber, 1999). However, as dry kilns are not as prevalent in Colorado as in other regions, casehardening may go uncorrected. If no further processing is performed on the wood, the casehardening may not be a problem. However, further processing can result in unbalanced stresses in the wood. For example, casehardened wood that is ripped along its length may pinch the sawblade, likewise, planing the wood to uneven depths on each side of the lumber can result in cupping.

Honeycomb

Although honeycomb can occur during air drying, it is encountered much less frequently than surface or end checks. Typically, honeycomb is encountered during kiln-drying, and results from using too high of a temperature too early in the schedule.

End checks

End checks also result from differential shrinkage, and occur due to the fact that moisture moves much more rapidly along the length of lumber (out the ends) than across its width (out the sides). End checks may develop as the log begins to dry in the log yard, and accounts for one reason that large mills in other regions of the U.S. often sprinkle their log yards. As end checks result from the movement of moisture from the ends of the log or lumber, prevention centers on slowing this movement. End checks can be prevented in one of two ways: 1) end coatings can be applied to the cut end of green lumber, or to logs in the log yard, to slow moisture loss from the ends during drying/storage, and 2) stickers can be placed very near the end, or even slightly overhanging the end of lumber when stacking. The stickers will tend to shade the ends of the lumber, and slow the moisture loss.

Surface checks

Surface checks result from the drying stresses exceeding the strength of the wood fibers perpendicular to the grain, in the early stages of drying. Surface checks can occur on both the wide faces and edges of lumber, and are more common to areas of the lumber pile that receive direct sunlight and dry breezes during the early stages of air drying. In later stages of drying, the checks may actually close up on the surface, but will extend deeper and wider through the thickness of the wood resulting in bottleneck checks.

A pile roof, as discussed in Technical Bulletin 1, [How Does You Air Dry Yard Stack Up ?](#), can significantly reduce surface checks on the top course of lumber. In addition, an overhang on the roof can provide protection from direct sunlight to the edges of lower courses of lumber throughout different periods of the day.

Because surface checks result from the wood essentially drying “too fast”, the orientation and layout of air dry yard, use of shade cloths, and the method of stacking the lumber can be used to slow drying. These techniques are discussed Technical Bulletin 3, [Operating an Effective Air Dry Yard](#), by Fred Lamb.

Final Note

Dean Huber, of the U.S. Forest Service was one of the presenters at the Wood Drying Workshop, held in Mancos, CO in February 2001, as many of you remember. Dean recently pointed out that the “gentler” temperatures experienced during air drying can also result in indirect types of defects, such as the preservation of insect pests inside the wood, sticky sap, and growing blue stain.

Temperatures of at least 130 F are necessary to kill insect pests, temperatures of 160 F are needed to set pitch in boards (170 F in thicker material), and temperatures of at least 150 F are needed to kill fungi (blue stain can survive at temperatures below 110 F and moistures contents less than 20%, but it will not grow until conditions change). Although these temperature levels are common in a dry



kiln, they far eclipse the temperatures found in your “outside” kiln.

Sources:

Simpson, W. T., Ed. (1991). Dry Kiln Operator's Manual. Madison, Forest Products Society.

(1999). Air Drying of Lumber. Madison, USDA Forest Products Lab: 62.

This Bulletin...

The article that appears in this Technical Bulletin was written by Gene Wengert and Dan Meyer of the University of Wisconsin Department of Forestry. Gene Wengert was kind enough to grant us permission to reproduce it here.

CSU/CSFS Wood Utilization and Marketing Bulletins...

The Technical Bulletins produced by the CSU/CSFS Wood Utilization and Marketing Efforts are aimed at addressing needs and questions raised by industry members throughout the state on the topics of wood processing and marketing. The first four Technical Bulletins will be focused on drying of lumber, specifically on air drying. The first will “quiz” you, the air drying operator, on how your air dry yard stacks up, and where there might be room for improvement. This bulletin includes a checklist taken from the *Lumber Drying Sourcebook*, published by the Forest Products Society.

The second and third Technical Bulletins will be reprints of a two-part article written by drying expert Dr. Fred Lamb, of the Department of Wood Science and Forest Products at Virginia Tech. These articles are entitled Operating and Effective Air Drying Yard, and although were originally focused on drying hardwoods, the same principles covered hold true for softwoods. The fourth Technical Bulletin will cover drying defects, and will include an article entitled Causes and Cures for Warp in Drying, written by drying expert Gene Wengert and Dan Meyer of the University of Wisconsin.

These first four Technical Bulletins supplement *Air Drying of Lumber* (FPL-GTR 117), a comprehensive, guidebook for air drying lumber. The guide is highly recommended for operators of any size and scale, and can be obtained for free from the Wood Education and Resource Center by calling (304) 487-1510, or emailing: education@werc-hdw.com.

If you have specific questions, please feel free to contact us: Chris Jennings (970)-491-2958, Tim Reader (970) 247-5250, Kurt Mackes (970) 491-4066, or check out our website at: www.colostate.edu/programs/cowood.

