



## Lumber Dry Kiln: Warp

William T Simpson of the Forest Products Laboratory maintained at Madison, Wisconsin by the Forest Service of the United States Department of Agriculture in co-operation with the University of Wisconsin, discusses the common forms of warp and what can be done to minimize them in the timber drying process.

Warp in lumber can cause significant yield losses and discourage the utilization of lumber from warp-prone species. All warp can be traced to two causes; differences in shrinkage within the wood as it dries, and growth stresses. Although little can be done to prevent shrinkage or growth stresses, we can identify ways to reduce warp during drying. First, however, we need to understand the forms of warp and how they develop.

Six common forms of warp are: cup, crook, bow, twist, diamond, and oval. Cup is caused by greater shrinkage parallel (rather than perpendicular) to the growth rings. The greater the difference between this tangential (parallel) and radial (perpendicular) shrinkage, the greater the cup. It occurs in flat sawn boards, where the growth rings are parallel to the wide face. The concave surface of the cup is toward the face that was closest to the bark. Boards cut from the outer portion of large trees will have relatively little growth-ring curvature and thus less cup than boards from small logs or the inner portion of large logs where growth ring curvature is pronounced.

Two other forms of warp, crook and bow, are caused by a difference in longitudinal shrinkage on two opposite faces of the board. Juvenile wood, which is wood formed near the centre of a tree, shrinks more longitudinally than mature wood.

Reaction wood, which is formed in parts of leaning or crooked stems and in branches, also shrinks more longitudinally than normal wood. When one edge or face of a board contains normal wood and the opposite edge or face contains either of the two forms of abnormal wood, the difference in shrinkage along the length of the board causes crook or bow. Grain deviations on the edges or faces of boards can also cause unbalanced longitudinal shrinkage. Cross grain, where the wood fibres are not lined up with the long axis of a board, can also lead to unbalanced shrinkage. Knots are another source of localized grain deviation that can cause crook or bow.

Twist is a form of warp caused by a combination of unequal longitudinal shrinkage and grain deviations such as spiral, wavy, diagonal, locally distorted, or interlocked grain.

Diamond is a form of warp found in squares. It results from the difference between radial and tangential shrinkage in squares where the growth rings run diagonally from corner to corner. Oval occurs in rounds, and is also caused by the difference between radial and tangential shrinkage.

The other cause of warp, growth stresses, is not related to drying but can nevertheless be serious. Longitudinal growth stresses can cause crook or bow to develop immediately after sawing boards from logs. The growth stresses develop in a tree as it grows; causing tension in the outer periphery of the stem and compression in the inner portion. When logs containing growth stresses are sawn into lumber, the internal stresses become unbalanced. Release of the stresses after cutting causes crook, bow, and twist. The bark side of these boards shortens relative to the pith side, and distortion results.

Warp in lumber can be reduced by careful sawing, stacking, restraining, and drying.

The first operation in which warp can be controlled is sawing. This controls orientation of annual rings, juvenile and reaction wood, and localized grain deviations relative to board edges and faces. In manufacturing lumber, planned positioning of these characteristics can reduce the effect of their different shrinkage rates and thus reduce warp. If cup becomes a serious problem, lumber can be quarter sawn instead of flat sawn. If growth rings are oriented perpendicular to the wide face of a board, cup will be reduced greatly. Wood near the pith, which may contain juvenile or reaction wood, often has abnormally high longitudinal shrinkage. This is a good reason for "boxing" the heart in sawing so that the pith does not fall near one edge or face. Localized grain deviations, such as knots, can also be placed (or eliminated) so that they do not cause unequal shrinkage on opposite faces.

After careful sawing, good contact between lumber and stickers can further reduce warp, and uniform lumber thickness is necessary to ensure good lumber-sticker contact. Any sawmilling or maintenance procedures that can reduce variation in lumber thickness are a good first step in ensuring that good stacking procedures will be effective in reducing warp. A light surfacing or blanking, is sometimes necessary to improve thickness uniformity.

Uniform lumber thickness is only the first step in ensuring good sticker contact to reduce warp. In a well-stacked lumber pile, every piece is held flat during drying and shrinking. The pile foundation, kiln floor, or kiln trucks must provide a firm, flat bearing surface for the lumber pile. A crooked or uneven surface will cause twist or bow in lumber during drying. Properly sized and placed stickers are important, with uniform lumber thickness a prime requirement. Broken or distorted

stickers can increase warp and should be discarded. Sticker spacing of 40 to 60 cm is satisfactory for many tropical hardwoods, provided all tiers of stickers are fully supported by bolsters and their alignment is perfectly vertical. Highly valuable or especially warp-prone lumber may benefit from spacing as close as 30 cm.

Random-length lumber should be box piled. The ends of lumber piles should be even with no overhanging boards, and board ends should be supported by stickers wherever possible. Piles should be covered so that the top layer is not exposed to sun and rain that will cause alternate shrinking and swelling and thus aggravate warp.

End racking should not exceed 3 to 4 days for 2.5 cm thick lumber or one week for 5 cm lumber. End racking during rainy periods should be done under shed roofs. After the end racking period, the lumber should be stacked in stickered piles or immediately bundled if dry enough for shipment.

Boards at the bottom of a pile develop less warp than those near the top because weight of the pile prevents distortion. Some form of restraint, such as spring-loaded clamps anchored lower in the pile or added weights (concrete blocks for example), applied to these upper layers can reduce warp.

Research has shown that weights effective in reducing warp vary from 250 to 1,000 Kg/m<sup>2</sup>, depending on species, lumber thickness, and degree of warp reduction accomplished. Regardless of added restraint, if wide, flat-sawn boards make up part of the board mix, they should be placed at the bottom of the pile.

Strategic sawing, good stacking, and restraining are the most effective ways to reduce warp, but drying procedures can also be helpful. When kiln drying, schedule modifications that provide initial conditions of lower temperature and lower relative humidity than those recommended in drying manuals can reduce warp. For example, cup in American elm can be reduced by 50 percent when a schedule starting at 38 C and 65 percent relative humidity is used instead of one starting at 54 C and 81 percent relative humidity. Lower initial relative humidity causes a large amount of tension set to develop in the outer shell, which helps to hold lumber flat in later stages of drying. Equalizing and conditioning to relieve this stress following kiln drying is essential for lumber that will be resawn or machined in any way that removes unequal amounts of material from opposite faces of a board. This machining creates an imbalance in the drying stresses, and distortion is the response that restores balance.

Though many opportunities exist to help control warp, the characteristics of wood that cause it are beyond our control. Nevertheless, recognizing and understanding them can lead to processing strategies that will minimize their effect. An example of one such strategy is Saw-Dry-Rip (SDR), a procedure developed at the Forest Products Laboratory to reduce crook caused by longitudinal growth stresses in lumber from small hardwood logs.

The SDR method uses both sawing and drying procedures to reduce warp. First, the log is live sawn through and through on the same plane. This sawing pattern retains the balance between the longitudinal tension growth stresses at the edges of the flitch and the compression growth stresses at the centre of the flitch. During high-temperature kiln drying, compression stresses develop at the edges to counteract the tension growth stresses, and tension stresses develop at the centre to counteract the compression growth stresses. When lumber is then cut from the dried flitches, the stresses are reduced and the result is a significant reduction in crook compared to lumber cut before drying.

By using established warp-reducing procedures such as those discussed in this paper, and by developing and using new procedures such as SDR, mill owners can increase their lumber yield and profits. Failure to do so results in an unnecessary waste of natural resources.



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