THE IMPACT OF JUVENILE AND COMPRESSION WOOD ON LUMBER FROM SMALL LOGS

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Introduction

Small log processing is a growing concern for Western lumber mills. Process development, however, has generally emphasized larger logs. Consequently, the properties of large, old-growth logs have determined much of the evolution and calibration of sawing, drying and grading systems. As the volume of small logs increases, more attention must be paid to the influence of wood quality on small log processing.

The purpose of this paper is to bring attention to the characteristics of the "abnormal" wood found in small logs. Two types of "abnormal" wood, compression wood and juvenile wood (Figure 1), are considered. Logs in the 4 to 11 inch diameter class are emphasized.

Concern for small log material, and for the influence of "abnormal" wood in drying, is not new to the Western Dry Kiln Club. At the 1980 annual meeting, both the Dedrich and Smith-Arganbright papers touched significantly on these issues. Unfortunately, however, the majority of technical literature on "abnormal" wood is inaccessible and incoherent to most processors. The authors believe it is time to focus more pointedly on the interaction of technology and quality in small log processing. We hope this attention will help process specialists and mill operators to better understand the origins of some of their process problems.

Background and Sources

This paper began as an informal discussion of small log issues with members of the Western Dry Kiln Club during a mill tour hosted by the Frank Lumber Company. The authors were requested to record this discussion in paper format to share with a broader audience.

The content of this paper derives directly from two sources: 1) an in-depth survey by B. Alan Bendtsen of the U.S. Forest Products Laboratory, and published by the Forest Products Research Society in 1978; and 2) a literature search in response to concern for the influence of compression wood on the quality of glu lam. The purpose of Bendtsen's paper was to develop a sensitivity for juvenile wood in small logs, improved trees and plantation-grown wood. The literature search supported limits on the quantity of juvenile and compression wood in laminated beams in order to preserve beam performance.

Some of the statistics and illustrations used in this paper are from Bendtsen; others are abstracted from cited research. By this brief paper, the authors hope to stimulate...
further scrutiny of the literature for the relevance of wood processing to the changing character of the forest.

Juvenile Wood

The literature contains a vast scientific treatment of the formation, extent and species effects of juvenile wood. The message for processors is more simple: juvenile wood is inferior, both in strength and in properties important for lumber size, shape and stability.

All trees, from the butt to the crown, contain juvenile wood. In a mature tree, as few as 5 and as many as 20 rings may be juvenile. What is important to processors is the percentage of juvenile wood in cross-section, and the symmetry of juvenile wood in the final product.

The percentage of juvenile wood is much greater in a small log than in a larger log. Bendtsen shows this dramatically with loblolly pine data (Figure 2). While in a large log the juvenile core may be overlooked or boxed in a timber, the small log processor is troubled with a significantly higher volume of juvenile material. This problem is accentuated in fast-growing timber, where the influence of the juvenile volume can be very pronounced.

The strength of juvenile wood is inferior to that of "normal" wood. The specific gravity of juvenile wood is lower; the angle of the fibrils in the critical S-2 layer of the fiber is steeper. The result is greater longitudinal shrinkage and lesser strength and stiffness. In tests of Douglas-fir and Southern Pine lumber, pieces containing pith-associated wood were as much as 50% lower in tensile strength and 10 to 20% lower in stiffness (Figure 3). Lumber cut from rapidly grown Caribbean Pine (principally juvenile) was found to have less than 50% of the strength and stiffness of natural forest wood (Figure 4).

In evaluating these findings, it is important to recognize that there is no abrupt end to the juvenile zone. The farther from the pith, the more "normal" the wood becomes (Figure 5). Desirable features such as specific gravity increase as wood matures; undesirable features, such as the fibril angle and the degree of longitudinal shrinkage, decrease as the wood reaches mature character.

The symmetry of juvenile wood in the final product also influences strength, stiffness and shrinkage. As drying experts are aware, a major cause of warped lumber is pith which is off-center, or which runs at an angle to the sides of the piece. The cross-section in Figure 6 shows an off-center pith in a 2 x 4 with close to 100% juvenile content.

As a general reference, we have tabulated some ranges in the physical and mechanical properties of juvenile wood as related to mature wood. This data was abstracted from various sources in the literature and summarized to provide some general rules-of-thumb. Recall that the transition from pith to mature wood causes variability, and that general rules are qualified by interacting species and environmental influences.
Physical Properties of Juvenile Wood

Longitudinal shrinkage: Up to 20 times more than mature wood.
Transverse shrinkage: Decreased to as little as 1/2 mature wood shrinkage.
Fiber length: 1/3 to 1/4 the length of mature wood. (There are other important cell differences.)
Specific gravity: Often 15% and as much as 50% lower than mature wood.

Mechanical Properties of Juvenile Wood

Strength: Can be 1/2 or less the strength of mature wood.
Stiffness: Can be 1/2 or less the stiffness of mature wood.

Compression Wood

Today, the small log processor inherits a log size and type which a few years ago would never have reached the sawmill. The modern small log mill is now fed by thinnings and trees from less than optimal terrain; often, these trees are bucked close to the ground (Figure 7). Accordingly, the volume of compression wood confronting processors has increased.

The importance of percentage of the cross-section, as discussed for juvenile wood, also applies to compression wood: in a small log, a few streaks of compression wood influence a greater proportion of the wood than a similar volume of compression wood in a log of larger size.

Compression wood properties are in some ways similar to those of juvenile wood. Compression wood has a steep fibril angle; consequently, longitudinal shrinkage is great, and many mechanical characteristics of compression wood are inferior to those of "normal" wood. There are important differences, however, between compression and juvenile wood. Compression wood tends to occur in bands--off-center in cross-section--as opposed to the "pith center" geometry of juvenile wood (Figures 1 and 8). Thus, shrinkage and warping may appear to be both greater and more difficult to predict in compression wood. A further difference is that compression wood generally has a higher specific gravity than "normal" wood; in many cases, it may actually be stronger. On a unit weight basis, however, compression wood is much weaker than "normal" wood. For this reason, selecting wood with weight or specific gravity as strength criteria is hazardous when compression wood is present.

Scientists have studied the reasons for compression wood formation, the degrees and locations of compression wood within a tree, and many other relevant aspects of this "abnormal" wood. Again, the authors prefer to present an overview of the important physical and mechanical properties of compression wood as compared to "normal" wood. We suggest the references for supplemental reading.
Physical Properties of Compression Wood

Longitudinal shrinkage: Up to 20 times more than normal, mature wood.

Transverse shrinkage: Decreased as much as 1/2 of normal, mature wood shrinkage.

Fiber length: Smaller than normal wood. (There are other important cell differences.)

Specific gravity: Up to 40% higher than normal, mature wood.

Water content: Lower green MC, higher dry moisture content than normal wood under the same conditions.

Mechanical Properties of Compression Wood

Hardness: Generally higher than normal wood.

Compressive strength: Generally lower than normal wood (especially if on an equal weight basis.)

Tensile strength:

Stiffness:

Toughness:

Processing

The basic physical and mechanical properties of wood influence the quality of processing from log breakdown through the final grading. Drying and breakdown technology in small log processing must react to the problems of "abnormal" wood.

Several recent research efforts have approached this issue. At the U.S. Forest Products Laboratory, for example, Hallock initiated research in log breakdown and drying methods in an effort to minimize "abnormal" wood influence. (Figures 9 and 10 are familiar views of the effects of "abnormal" wood on kiln dried lumber.) This was one of a number of attempts to adapt drying technology to meet the challenge of juvenile and compression wood in North American species. In Australia, the Radiata Pine Association applies a minimum requirement for restraint and high temperature drying in an effort to control the influence of "abnormal" wood, and thus to present a more uniform quality product. As noted, papers in the Western Dry Kiln Club Proceedings have addressed this issue. Currently, researchers at Oregon State University are attempting to quantify the effect of drying variables on the warping of small log Hem-Fir lumber.

Wall and floor lumber markets are primarily sensitive to straightness and visual quality. Thus, if drying technology can maintain straightness and stability, great strides will have been made with small log lumber. In products where stress grading is more critical, such as truss lumber and lam stock, the criteria are more stringent. Because of the mechanical inferiority of both juvenile and compression wood, only limited amounts are accepted as lam stock by the American Institute of Timber Construction. The only relief from this type of restriction may be through the use of more advanced grading technology such as Machine Stress Rating (MSR), where the reduced stiffness...
of "abnormal" wood tends to "grade out" the most seriously aberrant pieces.

Conclusions

"Abnormal" wood, found to some degree in many logs, is often present in greater proportion as log size decreases. Because changing forestry practices may bring more "abnormal" wood into the processing plant, processors of small logs must adapt to the character of the wood in their log supply. Proper handling of this increased percentage of "abnormal" wood is necessary if optimal use is to be made of the small log.

A wealth of knowledge exists on the physical and mechanical characteristics of "abnormal" wood. With this knowledge as a guide, more dialogue is needed between foresters, technologists, processors and research personnel so that practical solutions to the increasing incidence of "abnormal" wood can be developed.

References

A Sampling of Literature on Abnormal Wood


Dedrick, Dallas S. "Some Comments On Warping." Proceedings, Western Dry Kiln Clubs, School of Forestry, Oregon State University, Corvallis, Oregon. (1980)


Onaka, F. "Studies on Compression- and Tension-Wood." Bulletin Wood Research Institute, Kyoto University, Wood Research No. 1. (1949)


Figure 1. A longitudinal and cross section of Western Hemlock containing both extreme compression wood and a high percentage of juvenile core.
Figure 2. Increase in percent juvenile wood with decrease in age, based on different age plots of loblolly pine, each plot containing 22 trees. From Bendtsen.

Figure 3. The change in wood properties as a function of the degree of juvenility, as measured by the number of rings from the pith. From Bendtsen.
Figure 4. Lower properties of lumber containing the juvenile pith (two studies, dotted and open bars) as compared to non-pith lumber (dashed line). From Bendtsen.

Figure 5. Comparison of juvenile wood from Caribbean pine (two studies, dotted and open bars) compared to published values derived from tests of natural forest trees. From Bendtsen.
Figure 6. A Hem-Fir 2x4 primarily composed of juvenile wood.

Figure 7. A badly deformed small log bucked close to the ground line and likely containing high quantities of compression wood.
Figure 8. Severe compression wood bands in a Hem-Fir 2x4.

Figure 9. Warp in a 2x4 caused by excessive longitudinal shrinkage due to abnormal wood in an "unbalanced" position in the piece.
Figure 10. Short lengths of 2x4 Hem-Fir removed from rough dry lumber so that the balance of the piece can pass through the planer. All were warped excessively by abnormal wood.