

Using Wood Quality Measures to Evaluate Second-Growth Redwood

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Abstract

Redwood (*Sequoia sempervirens*) a valued species for use in appearance grade applications, such as decking, exterior siding and interior paneling, because of its dimensional stability. It is also valued for certain exterior-use applications because of its natural decay resistance. Studies have found that young-growth redwood is less resistant to decay fungi, and also exhibits greater shrinkage and swelling than old-growth redwood. Differences in natural decay resistance and dimensional stability between old-growth and young-growth could be accounted for by changes in the extractives found in the heartwood and changes in the microfibril angle (MFA) in the S2 layer of the cell wall, respectively. Can silvicultural practices that influence growth rate be used to enhance the natural decay resistance and dimensional stability of second-growth redwood? The objectives of this preliminary study were to 1) review anatomical characteristics of redwood that influence in-service performance and 2) present results of measurements made from second-growth redwood stumps that showed different growth rates. Decay testing data is not available.

Key words: dimensional stability, durability, microfibril angle, redwood, wood quality

Introduction

Redwood has long been a valued species because of the natural decay resistance of its heartwood and its dimensional stability. Both of these attributes contributed to redwood's long-term in-service performance, and therefore its value and reputation as a durable species. In this respect, "durability" encompasses both biological and non-biological performance characteristics – redwood that is performing poorly can be removed from service because it is rotting (a biological process) or because it is badly warped (a non-biological process). Common uses for redwood have included decking, siding and fencing (both as boards and posts). Decay resistance and dimensional stability are desirable features for products used for these applications.

The decay resistance of the sapwood (the part of the tree closest to the bark) of any species is considered nonresistant. The decay resistance of the heartwood of any species is related to the amount and type of extractable (i.e., nonstructural) materials that are deposited when sapwood undergoes the transition to heartwood. The decay resistance of heartwood (untreated) is typically classified, from least to most resistant, as "slightly or nonresistant", "moderately resistant" or "resistant or very resistant" (Wood Handbook 1999).

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The ratio of dimensional change in the tangential (the direction tangent to the growth rings) and radial (the direction extending from pith to bark) directions is sometimes considered a measure of dimensional stability. The tangential to radial (or T:R) ratio typically ranges from 1.5 to 2.5 for all wood species, with a lower number indicating greater dimensional stability. Whereas longitudinal shrinkage and swelling is normally considered negligible, it can be relatively large in products containing wood from near the center of the tree, often referred to as the pith. Dimensional change in the longitudinal (and tangential) direction is a function of the microfibril angle (MFA) in the S2 layer of the cell wall. When this angle is small, dimensional change in the longitudinal direction is also small. As this angle increases, so does longitudinal shrinkage and swelling. Meylan (1968) reported only negligible longitudinal shrinkage for Jeffery pine (*Pinus jeffreyi*) when the MFA was less than 25° but a rapid increase in longitudinal shrinkage when MFAs were greater than 25 to 30°. This change results in a corresponding reduction in dimensional change in the tangential direction. Because the S2 layer constitutes the largest portion of an individual wood fiber, it dominates the respective physical properties (e.g., dimensional change and some mechanical properties).

Differences in decay resistance and dimensional stability between “old growth” and “young growth” redwood have been summarized in the *Wood Handbook* (Forest Products Laboratory 1999). In the *Wood Handbook*, the natural decay resistance of old growth redwood is listed as “resistant or very resistant” and that of young growth as “moderately resistant”. This difference in decay resistance is based on published research by Clark and Scheffer (1983). The decay resistance of redwood has been attributed to its water soluble extractives (Anderson 1961) and, more recently, its non-water soluble extractives (Wilcox and Piirto 1976). Regardless of the particular type of extractives that impart decay resistance to redwood, it is clear that the resistance of young growth redwood is lower and more variable than that of old growth. This is particularly true in the inner heartwood area (Clark and Scheffer 1983).

The *Wood Handbook* reported T:R ratios for old growth and young growth redwood were 1.7 and 2.2 respectively (Forest Products Laboratory 1999). This increase in T:R ratio increases the likelihood of “cup” in a deck board. Another component of dimensional stability is movement in the longitudinal direction (i.e., in the length direction of a board or post). If longitudinal shrinkage was uniform throughout a given member (e.g., a board, post or plank), the expected change in dimension could be accounted for during the manufacturing process (i.e., the member could be cut longer). However, as discussed by Nault (1989), longitudinal shrinkage provides an indication of warping through *differential* (non-uniform) shrinkage. The non-uniform shrinkage in a member (i.e., having higher and lower levels of longitudinal shrinkage) would result in twist or crook in service.

The wood formed in the central zone of the tree near the pith has been referred to as “juvenile wood”, “core wood”, and “crown” or “crown formed” wood (Amarasekara and Denne 2002) and has important influences on dimensional stability of lumber. Wood further from the pith has been referred to as “mature wood” and “outer wood”. Characteristics of wood vary with distance away from the pith, and become more stable with distance (Amarasekara and Denne 2002). The transition to dimensional stability is not abrupt, which makes it difficult to discuss the “juvenile wood zone” (the term used in this publication) in absolute terms, however,

juvenile wood is negatively influenced by larger MFAs. Much of the research on physical properties of juvenile wood has been conducted on southern yellow pine (*Pinus palustris*) grown in the southeastern U.S. and radiata pine (*Pinus radiata*, various clones) grown in New Zealand and Australia. The lack of an abrupt transition means that the number of growth rings that make up the juvenile zone is variable. The juvenile zone is often considered to encompass the first 15 to 20 growth rings and anatomical characteristics and physical properties that would result in more durable in-service performance are lower in the juvenile region (Bendsten 1978).

Juvenile wood in trees is inevitable, but when silvicultural practices are followed that result in an increased growth rate (and therefore increased volume) during this period, the relative proportion of the tree's cross-section that is comprised of "juvenile wood" is much larger than when silvicultural practices result in slower growth. When processing siding, deck boards, or posts from the tree, the chance of a given piece having some juvenile wood is greater in the "managed for volume" tree.

Can silvicultural practices that influence growth rate be modified with redwood in such a way to maximize quality attributes? The purpose of this preliminary study was to begin exploring whether there was an effect of different growth rate in redwood based in quality measures that have traditionally been relied for long-term in-service performance. This portion of the study was limited to evaluating the effect of growth rate on the MFA in the S2 layer (and inferring the resulting impact on longitudinal shrinkage). The decay resistance of side-matched samples is being evaluated at another institution and is not currently available.

Methods

Experimental study site and management history

The forest stand where the tree cross sections were taken is located near Arcata, California. The forest was classified as a Site II – III redwood. The stand was originally harvested in the 1890s and again partially harvested in the 1950s. For these entries the largest and best formed trees were harvested. Since in the 1980's, three commercial thinnings have occurred. Today redwood is the most common tree species with lesser components of Douglas-fir (*Pseudotsuga menziesii*) and grand fir (*Abies grandis*). The trees used in this study were harvested from the stand in 2010. While it is known that wood quality is responsive to both silvicultural and genetic manipulation (Zobel 1984), no information was collected about the genetics of this stand.

Sample collection – stump to cross-section

In January 2011, four recently harvested stumps from different sprout clumps were selected for study. Five centimeter thick cross section samples were taken from the entire top of each stump at stump heights ranging from 20 cm to 68 cm above the ground (*table 1*). The sample trees were characterized as either "slow" or "fast" growing as defined by the amount of growth between rings.

Table 1—*Growth information on trees selected for use in this study.*

Tree number	Number Of rings detected	Growth rate classification	Stump height Mm (in)	Diameter mm (in)	Average growth (rings/mm)
2	72	Fast	685 (27)	775 (30.5)	10.7
6	74	Fast	225 (9)	940 (37)	12.7
3	88	Slow	335 (14)	520 (20.5)	5.9
4	100	Slow	200 (8)	445 (15.5)	4.5

Sample processing – creating radial rectangular specimen

The sections collected were delivered to the University of California Richmond Field Station for processing the samples into square rods approximately 18mm by 18 mm by the radial (pith to bark) length of the sample. Two sets of side matched square rods were cut from each tree sample. One square rod specimen was used for the MFA analysis and one was reserved for use in a decay resistance test. After processing, all square rods were placed in a controlled environment room to dry. After equilibrating, one set of the square rods was shipped to FP Innovations, Paprican Division (Vancouver, British Columbia, Canada) for further processing and MFA analysis. The second set was shipped to Mississippi State University for additional analysis and testing to determine decay resistance. The specimens were further processed at Paprican, cutting the 18 x 18 mm square rods into rectangular sections that were 7 mm in the longitudinal direction, 2 mm in the tangential direction, and the length from pith to bark in the radial direction. The MFA was then evaluated using a Silviscan instrument that utilizes x-ray densitometry, x-ray diffraction and image analysis to measure a range of wood properties (age, density, and the modulus of elasticity (MOE) that indicates stiffness).

Results and discussion

The relationship between growth ring and MFA is shown in *fig. 1*. Elevated MFA was most evident in tree #5. In this case the MFA did not decrease with tree age as was the case with the other trees. Local increases in MFA were observed in trees # 6 (around year 40), #2 (around year 30) and #3 (around years 50 and 80). Based on results from studies on southern yellow pine variation in MFA can be expected, but according to Megraw (1985), a negative relationship exists between MFA and tree age during the first 15 to 20 years, and at which time MFA remains relatively constant with increasing tree age. These localized increases in MFA could result from changes in growth rate during those periods. Trends in MFA that do not agree with published trends, such as those observed here, are possible with small sample sizes³. As previously stated, the samples for this study were taken from the tree stumps and this sampling location may drive some of the observed relationships reported here, with higher MFA typically being observed at lower heights above the ground (Megraw 1985). Future research should incorporate a much larger sample size and include multiple samples from a given tree.

The relationship between MFA and modulus of elasticity (MOE and a measure of stiffness) and MFA and density are given in *figs. 2 and 3*. In the Silviscan analysis, MOE is generated using a correlation developed with several species between MFA

³ L. Schimleck, Professor, University of Georgia, personal communication, 2011.

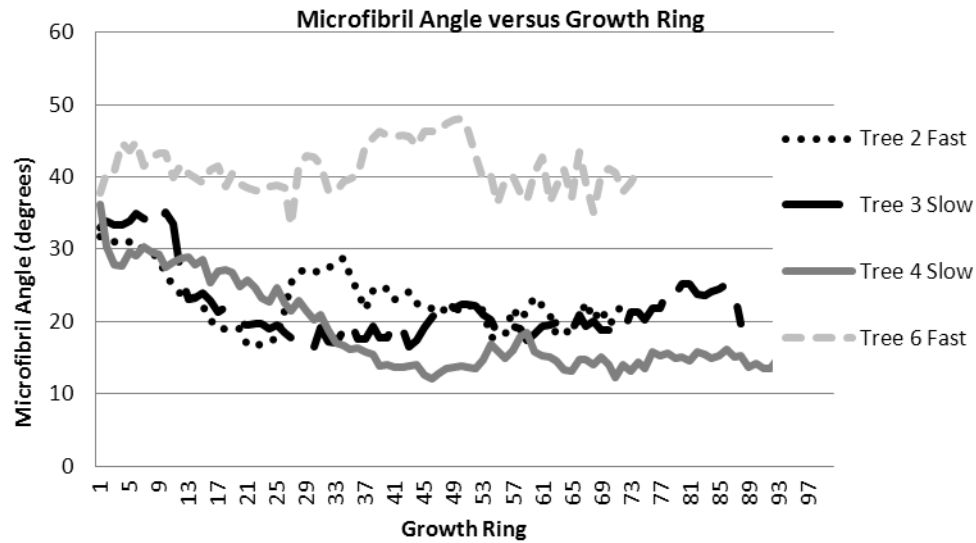


Figure 1—Microfibril angle as a function of growth ring in the four sampled trees characterized by their rate of growth.

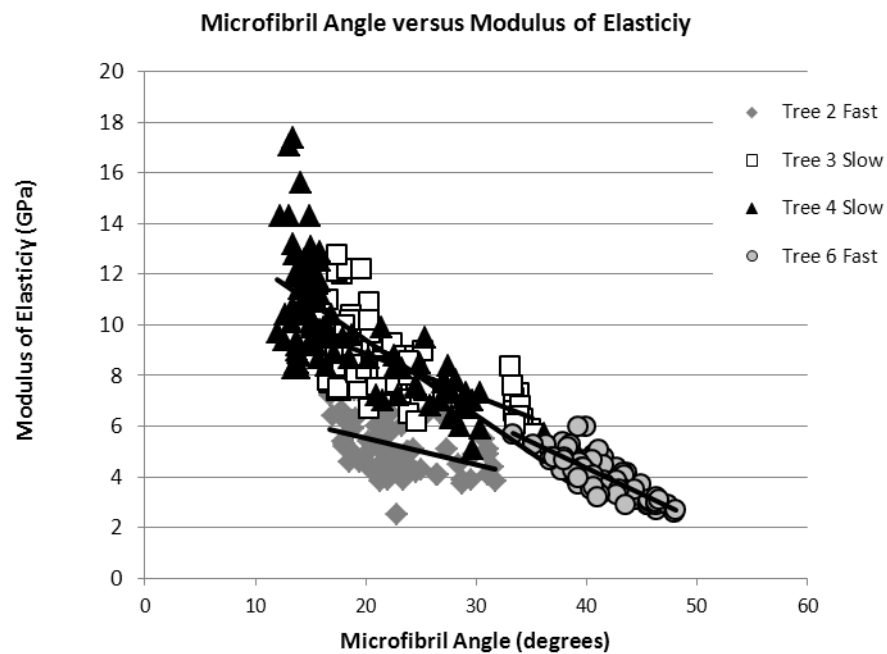


Figure 2—The relationship between microfibril angle and modulus of elasticity in the four sampled trees characterized by their rate of growth.

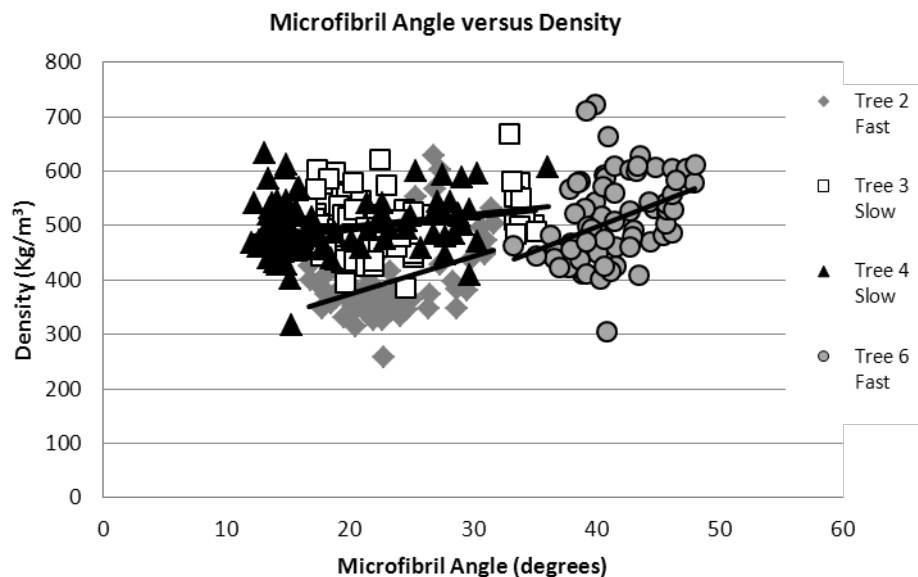


Figure 3—The relationship between microfibril angle and density in the four sampled trees characterized by their rate of growth.

and MOE. As such, it is unlikely that redwood samples were included in the development of the correlation. However, increasing MFA would result in between cellulosic unit hydrogen bonding to predominate during the tension test used to determine MOE. With lower MFA, the covalent β (1-4) linked D glucose units that comprise the cellulose molecule would dominate. It is therefore reasonable to expect increasing MFA to result in lower MOE (in tension parallel to the grain). As seen in *fig. 2*, higher MFA resulted in lower MOE. Again, this was most clear with tree #6. The MFA in tree #2 was not consistently lower than the MFA in trees #3 and #4, but in tree #2 MOE is consistently lower than the MOE in trees #3 and #4. Based on the results of the SilviScan analysis, the average density of tree #2 was approximately 25 percent lower than trees #3 and #4. Since strength is highly correlated with density (Bowyer et al. 2003), this difference in density can help explain the differences in MOE observed in trees #3 and #4 (“slow growth rate”) and #2 (“fast growth rate”), even though the MFAs were similar. This relationship is confirmed when viewing the relationship between MFA and density (*fig. 3*). Density (specific gravity) is one of the physical properties that will increase with age during the juvenile period (Bendsten 1978). The density values for tree #6 ranged from near the minimum to maximum values observed for trees # 2, 3 and 4. Because of the consistently high MFA in tree # 6, the predicted MOE is consistently lower than that for trees # 3 and 4. The overall lower density in tree #2 samples, and that corresponding effect on MOE, explains the relatively low MOE even though tree #2 MFA values are similar to the MFA values for trees #3 and #4.

Summary and conclusions

Higher MFA was observed in the faster growth tree #6. The trend observed in tree #2 was similar to those observed in trees #3 and #4. Particularly with tree # 6,

MFA did not decrease with age as would be expected. Inconsistent results can be expected when measurements are made on an individual tree at a single stem location. A future study would be greatly enhanced by considering genetics and a range of sample locations within the tree bole. However, except for places where redwood is grown in plantations, there will always be genetic diversity in managed redwood forests and silviculture techniques may be used to compensate for some genetic characteristics.

Decay resistance and extractive content are very more important factors regarding the effect of second-growth issues on the in-service durability of redwood. When these data are available it will help round out the results reported here.

With this preliminary study, we have shown that when considering all measurements available with Silvscan, differences in faster growth and slower growth redwood could be discerned that may affect in-service performance of redwood lumber. These redwood samples followed the general trends observed in other conifer species where wood quality measurements have been investigated.

References

- Amarasekara, H.; Denne, M.P. 2002. **Effects of crown size on wood characteristics of Corsican pine in relation to definitions of juvenile wood, crown formed wood and core wood.** *Forestry* 75(1): 51-61.
- Anderson, A.B. 1961. **The influence of extractives on tree properties. 1. California redwood (*Sequoia sempervirens*).** *Journal of the Institute of Wood Science* 8:14-34.
- Bendsten, B.A. 1978. **Properties of wood from improved and intensively managed trees.** *Forest Products Journal* 28(10):61-72.
- Bowyer, J.L.; Shmulsky, R.; Haygreen, J.G. 2003. **Forest products and wood science: an introduction.** Fourth edition. Ames, IA: Iowa State Press. 554 p.
- Clark, J.W.; Scheffer, T.C. 1983. **Natural decay resistance of the heartwood of coast redwood *Sequoia sempervirens* (D. Don) Endl.** *Forest Products Journal*. 33(5):15-20.
- Dinwoodie, J.M. 1981. **Timber: its nature and behaviour.** New York: Van Nostrand Reinhold. 190 p.
- Forest Products Laboratory. 1999. **Wood handbook—wood as an engineering material.** Gen. Tech. Rep. FPL-GTR-113. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 508 p.
- Megraw, R.A. 1985. **Wood quality factors in loblolly pine: the influence of tree age, position in tree and cultural practice on wood specific gravity, fiber length, and fibril angle.** Atlanta, GA: Tappi Press. 88 p.
- Meylan, B.A. 1968. **Cause of high longitudinal shrinkage in wood.** *Forest Products Journal*. 18(4):75-78.
- Nault, J.R. 1989. **Longitudinal shrinkage, Chapter 3.** In: Kellogg, R.M., editor. *Second growth Douglas-Fir: its management and conversion for value.* Special Publication No. SP-32. Vancouver, BC: Forintek Canada Corporation. 173 p.
- Wilcox W.W.; Piirto, D.D. 1976. **Decay resistance in redwood (*Sequoia sempervirens*) heartwood as related to color and extractives.** *Wood and Fiber* 7(4):240-245.
- Zobel, B. 1984. **The changing quality of the world wood supply.** *Wood Science and Technology* 18(1):1-17.