Structural lumber from suppressed-growth ponderosa pine from northern Arizona

Thomas M. Gorman[+]
David W. Green[+]
Aldo G. Cisternas
Roland Hernandez
Eini C. Lowell[*]

Abstract

Lumber was sawn from 150 suppressed-growth ponderosa pine trees, 6 to 16 inches in diameter, harvested near Flagstaff, Arizona. This paper presents grade recover and properties for dry 2 by 4's sawn from the logs and graded by a variety of structural grading systems. Flexural properties met or exceeded those listed in the National Design Specification. When graded as Light Framing 43 percent of the 2 by 4's made Standard and Better and as Structural Light Framing, 34 percent made No. 2 and better. Warp was the biggest factor limiting grade yield. About 7 percent of the lumber would make a machine stress-rated (MSR) lumber grade of 1450f, but with no established market such production is not recommended. If graded as laminating stock, about 8 percent of the lumber qualified as L3 or better. A comparison of the results from this study with those from a companion study indicates that appearance grades offer the highest value alternative for lumber produced from this resource.

Ponderosa pine (*Pinus ponderosa*, L.) is one of the most important softwood species in western North America. It is found in commercial quantities in every state west of the Great Plains. Wood from mature trees is relatively lightweight, nondurable, nearly white, and has straight grain and a medium texture. It is easy to work with hand tools, glues well, and is average in paint- and fastener-holding abilities. It is a principal millwork species, being used for window framing, sashes, doors, moulding, shelving, and paneling. In roundwood form, it is used for posts, poles, and house logs (Lowery 1984). As structural lumber, it is sold as part of the Western Woods species grouping (NDS 2005).

Natural regeneration of ponderosa pine is sporadic over much of its range, with successful germination thought to be the result of the chance combination of a heavy seed crop and favorable weather during the following growing season (Burns and Honkala 1990). Historically, the ponderosa pine forests were primarily open stands of mature trees interspersed with pockets of younger trees and grassland. Prior to the early 1900s, frequent low-intensity fires killed off competing vegetation, including ponderosa pine seedlings, and help maintained open stands of large, fire-resistant trees (Fiedler et al. 1997). Fire suppression, along with livestock grazing and timber harvest, has promoted the conversion of

The authors are, respectively, Professor and Dept. Head, Dept. of Forest Products, Univ. of Idaho, Moscow, Idaho (tgorman@uidaho.edu); Supervisory Research Engineer Emeritus, USDA Forest Serv. Forest Products Lab., Madison, Wisconsin (levangreen@hughes.net); Instructor Professor, Dept. of Wood Engineering, Faculty of Forestry, Univ. of Chile, Santiago, Chile (acistern@uchile.cl); Senior Engineer, TECO, Sun Prairie, Wisconsin (roland.hernandez@tecotested.com); and Research Forest Products Technologist, USDA Forest Serv., Pacific Northwest Research Sta., Portland, Oregon (elowell@fs.fed.us). Funding for this project was provided by USDA Forest Serv., Region 3, and USDA Forest Serv., State and Private Forestry, Technology Marketing Unit, Madison, Wisconsin. We gratefully acknowledge the assistance provided by the Grand Canyon Forests Partnership in obtaining the logs, the Fremont Sawmill of the Collins Companies in sawing and kiln drying, USDA Forest Serv. Region 6 for measurements assistance, and the Western Wood Products Assoc. for lumber grading. The assistance of Ms. Pamela Byrd in completing the statistical analysis of this data is much appreciated. The Forest Products Lab. is maintained in cooperation with the Univ. of Wisconsin. This paper was received for publication in February 2007. Article No. 10311.
* Forest Products Society Member.

Forest Prod. J. 57(12):42-47.

the historical forest to dense stands containing a preponderance of small-diameter trees. Under these conditions, tree growth is often suppressed. Because ponderosa pine is intolerant of shade, rapid growth of seedlings prior to crown closure will produce a relatively large core of juvenile wood, generally defined as the first 20-years of growth (Shuler et al. 1989, Voorhies and Groman 1982). Juvenile wood tends to have higher than normal longitudinal shrinkage and may warp excessively. This has been identified as a primary problem in the utilization of small-diameter ponderosa pine (Fahey et al. 1986).

Management goals for ponderosa pine forests include reducing stand density to increase resistance to insect and disease attack, reduce the risk of catastrophic wildfires, provide diverse mosaics of wildlife habitat, and provide economic benefit to local communities (Willits et al. 1997). Increasing product utilization, along with reducing harvesting and processing costs, is critical for restoring ecological processes in ponderosa pine forests (Fiedler et al. 1997, Larson and Mirth 1998, Rummer et al. 2003). Several studies have shown that old growth trees (generally defined as more than 150 years old) produce a larger proportion of high value "shop and select" grades of lumber than do younger ("blackjack") trees (Ernst and Pong 1985, Fahey and Sachet 1993, Fahey et al. 1986). Fahey and Sachet (1993) concluded that lumber from second growth ponderosa pine logs is primarily in the Dimension grades. These older studies, however, were not specific to suppressed stands and often were limited in the lumber grading options investigated, especially for engineered product applications. Recent studies have shown that small-diameter trees growing in dense stands may have higher annual ring density and smaller knots than more open-grown trees and can be used as an input raw material for higher value products ranging from visually and mechanically graded lumber to veneer for structural composite lumber (Willits et al. 1997, Erickson et al. 2000, Green et al. 2005).

In a previous paper we compared volume and value recovery from 6- to 16-inch (152- to 406-mm) diameter breast height (DBH) suppressed-growth ponderosa pine harvested near Flagstaff, Arizona (Lowell and Green 2001), which was manufactured into structural and nonstructural lumber. In that paper, the structural dimension lumber was limited to the Structural Light Framing grading system (WWPA 1998). The objective of this paper is to further investigate the yield of structural lumber graded under a wider range of structural grading systems.

Procedures

Log selection and processing

Trees were selected from the Fort Valley Research and Demonstration Forest, Flagstaff, Arizona, and harvested in summer 2006. The demonstration project contained three experimental blocks with four treatment plots each. The experimental blocks represented different initial stand conditions: blackjack (young growth), yellow pine (old growth), and a mixture of the two age groups. The treatments within blocks were different thinning prescriptions designed to return stands to presettlement conditions. This involved thinning from below in which the larger, older trees were retained. Trees to be left had been marked, but no thinning treatment had been applied prior to sample selection for this study. Sample trees came from three of the four treatment plots in the mixed age block.

A sample of 150 trees ranging in DBH from 6 to 16 inches (152 to 406 mm) was selected. A matrix of five 2-inch (51-mm) diameter classes was used, and the trees selected represented those that would have been removed under the silvicultural prescription. The trees had an average age of 88 years. The sample was randomly divided into two subsamples, one to be sawn for dimension lumber and the other for appearance-grade lumber. Only the 2 by 4's from the dimension lumber sample are discussed in this report. The logs were sawn and the lumber kiln-dried by the Fremont Lumber Company, Lakeview, Oregon, owned by the Collins Companies. A more detailed discussion on selection and processing procedures and the overall results for both subsamples are presented in Lowell and Green (2001). Simpson and Green (2001) give additional information on kiln-drying procedures in the Fremont Lumber Company sample.

Grading and testing

The dry and surfaced 2 by 4's were shipped from the sawmill to the University of Idaho where they were graded as structural products by a lumber inspector of the Western Wood Products Association (WWPA). Each 2 by 4 was graded under several structural grading systems including Structural Light Framing, Light Framing, and the visual requirements for machine stress-rated (MSR) lumber and laminating grades (AITC 1993, WWPA 1998). If the grade of the lumber could be increased by trimming 2 to 4 feet (0.6 to 1.2 m) from the end, the trimmed length and trimmed grade were recorded. The lumber was conditioned for several months at approximately 70 °F (21 °C) and 55 percent relative humidity.

Modulus of elasticity (MOE) was determined by transverse vibration (Etv) using a E-Computer (Metriguard, Inc., Pullman, Washington) with specimens supported at the ends and vibrated in the flatwise orientation. Specimens were then tested to failure on edge in static bending using third-point loading and a span-to-depth ratio of 21:1 following the procedures of ASTM D 198 (ASTM 2005). The rate of loading was approximately 2 inches (51 mm) per minute. In accordance with ASTM Standards D 2395 and D 4442-92, ovendry moisture content (MC) and specific gravity (SG) based on ovendry weight and ovendry volume were determined from sections taken near the failure region after testing (ASTM 2005).

MSR simulation

Simulations of MSR grades were conducted for a range of potential grades having static edgewise MOE values ranging from 1.0 to 2.4 × 10^6 psi (6.9 to 16.5 GPa). Individual pieces in the simulation of MSR grades had to meet four criteria to qualify for a specified grade: (1) fifth percentile (minimum) MOE, (2) fifth percentile (minimum) modulus of rupture (MOR), (3) grade average MOE, and (4) visual grading requirements for edge knots. Traditionally, for mechanically graded lumber, the fifth percentile non-parametric point estimate must equal 82 percent of the target average MOE value (i.e., 0.82 × average grade MOE). This limits the variability of the lower half of the MOE distribution of the grade to a coefficient of variation (COV) of 11 percent. Thus, the minimum MOE for a 1.3E grade would be $0.82 \times 1.3 = 1.07 \times 10^6$ psi (7.4 GPa). The minimum MOR value would be 2.1 times the allowable bending strength (Fb) for the specified grade. In

Table 6. — Distribution of flatwise MOE values by transverse vibration (Etv) by knot size class for 2 by 4's cut from suppressed-growth ponderosa pine.

	No. of pieces by edge knot displacement[a]			
Etv[b]	1/6	1/4	1/3	1/2
(10^6 psi)				
0.9[c]	4	2	3	18
1.0	14	6	10	14
1.1	20	4	3	18
1.2	14	10	14	22
1.3	18	8	7	15
1.4	14	10	2	10
1.5	8	1	1	3
1.6	4	3	4	1
1.7	5	0	1	0
1.8	2	0	0	0
Mean Etv value for knot class, 10^6 psi	1.259	1.241	1.202	1.140
Number of samples	103	44	45	101
COV of Etv[d]	18.1	15.1	16.5	15.4

[a]Fraction of cross section occupied by edge knot.
[b]10^6 psi × 6.894 = GPa
[c]Values represent the average of the range. The range is from 0.05 below to 0.05 above the listed average.
[d]COV = coefficient of variation (%)

Table 7. — Grade yield of laminating stock from suppressed-growth ponderosa pine 2 by 4's from Flagstaff, Arizona.

Grade	No. of pieces	Volume (BF)	Percentage yield
L1	29	204	3.5
L2	36	249	4.3
L3	89	736	12.6
Reject	553	4641	79.6
Total	707	5830	100

lumber was warp (36%). Because laminations are pressed during the manufacturing process, bow is a less critical form of warp than are cup and twist. About 22 percent of the lumber was limited by cup, 7 percent by bow, and 6 percent by twist. These percentages are based on the primary limiting characteristic listed by the WWPA lumber inspector. It is common for more than one type of warp to occur simultaneously. About 1 percent of the limitations were just listed as "warp" (kind of warp unspecified). About 23 percent of the pieces had wane listed as the grade limiting characteristic. Had this lumber been sawn knowing that it was to be used for glulam production, it could have been sawn a little over size so that when planed to standard dimension there would have been less grade loss due to wane.

Discussion

As has been found in previous studies, warp is the biggest factor limiting the utilization of lumber cut from small-diameter (less than about 16-inches (406 mm) DBH), young growth (less than 150 years old) ponderosa pine. The amount of warp in this study could have been reduced slightly if a top load of 150- to 200-pounds per ft^2 (psf) had been used during kiln-drying. Unfortunately, only enough weights were available to achieve a top load of about 75 psf. It is estimated that the increase in grade recovery might have been up to 17 percent had sufficient top load been applied (Simpson and Green 2001). Additional improvements in warp control could be obtained by employing kiln temperatures of 240 °F, or higher (Simpson 2004). Excess wane was another characteristic that limited grade in this study, especially for production of laminating grades. Sawing the 2 by 4's oversized could have reduced this problem, at the expense of overall yield.

Table 8. — Lumber grade recovery from suppressed-growth ponderosa pine logs sawn for appearance grade products (Lowell and Green 2001).

Board grade	Lumber volume
	(%)
No. 1 Common	3
No. 2 Common	22
No. 3 Common	66
No. 4 Common	7
Molding	<1
No. 3 Clear	<1
No. 1 Shop	1
No. 2 Shop	1

This study supports previous conclusions that structural lumber can be produced from small-diameter trees if careful attention is paid to kiln-drying procedures. However, yields will not likely be as good as those expected from small-diameter trees of other species (Green et al. 2005, Gorman and Green 2000, Willits et al.1997). For mills already cutting small-diameter trees for structural lumber, visual grading in the Light Framing or Structural Light Framing grading systems would provide the highest value. Although not evaluated in this study, production of Stud grade 2 by 4's should also be attractive provided that wane and warp are controlled. Production of MSR lumber is not recommended for this resource. Grade yields would likely be quite low, and no established market currently exists for mechanically graded ponderosa pine or Western Woods. Glulam remains a possible market for ponderosa pine from suppressed-growth ponderosa pine (Hernandez et al. 2005), but potential producers are well advised to investigate the needs of specific glulam buyers before trying to compete in this market.

For this resource, sawing for appearance grades offers a higher value alternative for lumber production from this suppressed-growth ponderosa pine than does structural dimension lumber (Lowell and Green 2001). Had these logs been sawn for appearance-grade products, about 25 percent would have made No. 2 Common or Better with 66 percent grading as No. 3 Common (**Table 8**). The estimated premium for appearance products over dimension lumber at that time was $53 per 1000 cubic feet (gross log scale). Other previous research (Lowell et al. 2000) showed that there are opportunities to increase the value of appearance lumber through further processing into cut-stock material. The Flagstaff resource had a high yield of No. 3 Common appearance lumber, and about 60 percent of the boards were 6 inches (152 mm) wide or wider. While not evaluated in our study, there may be an opportunity to recover additional value by further processing into secondary products.

Conclusions

For the production of 2 by 4 structural lumber from 80- to 100-year-old suppressed-growth ponderosa pine 16 inches and less in diameter, we found that: