THE EFFECT OF AGE AT HARVEST ON BENDING AND TENSILE PROPERTIES OF LOBLOLLY PINE FROM THE COASTAL PLAIN

ROBERT H. MCALISTER
ALEXANDER CLARK III
JOSEPH R. SAUCIER

ABSTRACT

The effect of rotation age on strength and stiffness of lumber produced from unthinned loblolly pine stands in the Coastal Plain of Georgia was examined. Six stands representing 22-, 28-, and 40-year-old roations were sampled. A stratified random sample of trees 8 to 16 inches in diameter at breast height was selected from each stand and processed into lumber. Dimension lumber from the study was tested for strength and stiffness in both static bending and tension according to the provisions of the American Society for Testing and Materials standard method D 198. The strength and stiffness in both bending and tension generally increased with increasing rotation age.

It costs money to carry standing timber to longer rotation ages. Interest on capital invested in site preparation and planting, annual ad valorem taxes, and insurance are among the many factors that influence the decision to harvest timber. Moreover, a land manager who seeks to maximize profit should also consider differences in yield by grade of structural lumber resulting from rotation age when calculating the value and profit potential of a timber stand. Older stands generally produce a higher percentage of No. 1 and Better Grade structural lumber (6).

Age at harvest is an important element in financial planning. It is also an important silvicultural tool because it affects wood properties. When dealing with the mechanical properties of structural lumber, stiffness and strength are of special concern. Stiffness is measured as modulus of elasticity (MOE), which is the slope of the load/deflection curve in the elastic range. Strength is determined from the maximum load at failure and calculated as modulus of rupture (MOR). Among the factors that affect MOE and MOR within a given structural grade is the proportion of juvenile wood present. Fast-grown wood from the juvenile core is much lower in these values than mature wood (8). However, the proportion of juvenile wood in a stem decreases as the tree grows older.

Allowable design properties for stiffness and strength have been published (1) for commonly available species and grades of structural lumber. These allowable design properties are determined through the use of American Society for Testing and Materials (ASTM) standard procedures (2-5). Based on recent studies on the influence of juvenile wood on the strength properties of southern pine dimension lumber (7,9,10), lumber cut from the juvenile zone of young, fast-growing plantation pine may not meet the design requirements (1). This study examined the effect of rotation age on the strength and stiffness of No. 2 grade (12) dimension lumber cut from unthinned loblolly pine stands in the Coastal Plain of Georgia. Determination of allowable design properties requires rigid sampling protocols, which are far beyond the scope of the present study.

OBJECTIVES

This study examined the effect of rotation age on the strength and stiffness of No. 2 Grade dimension lumber cut from unthinned loblolly pine stands in the Coastal Plain of Georgia.

PROCEDURES

STUDY STANDS

Six unthinned loblolly pine stands located on good sites in the Atlantic Coastal Plain of Georgia were sampled (6). The stands were selected to represent 22-, 28-, and 40-year-rotation age classes. Two stands representing each age class were sampled. **Table 1** shows the planting density, age, location, site indices, and number of trees sampled. The stands in the 22- and 28-year classes were planted at a spacing of 7 by 9 feet (691 trees per acre (TPA)). Because no plantations in the 40-year class were available,

The authors are, respectively, Wood Scientist (retired); Wood Scientist; and Project Leader (deceased), USDA Forest Service, Southern Research Sta., Forestry Sci. Lab., 320 Green St., Athens, GA. 30602. This paper was received for publication in March 1996. Reprint No. 8506.

Forest Prod. J. 47(5):85-88.

unthinned 40-year-old natural stands were sampled.

SAMPLE TREES

A stratified random sample of 4 to 5 trees per 2-inch diameter at breast height (DBH) class from 8 to 16 inches DBH was selected from each stand **(Table 2).** The trees were felled, measured to a 6-inch diameter inside bark top, bucked, and hauled tree-length to the mill yard. The tree-length logs were bucked into 8- to 16- foot sawlogs. The 127 sample trees produced 433 sawlogs.

SAWING AND LUMBER GRADING

The 433 logs were sawn into 4/4 boards and 2 by 4, and 2 by 6 dimension lumber in a sawmill equipped with a chipping-saw headrig and a vertical gang resaw. Lumber cut from each log was identified and graded dry after planing by certified Southern Pine Inspection Bureau lumber graders (12). The 8/4 dimension lumber was visually graded and placed into one of the following grades: dense select structural (DSS), No. 1, No. 2 dense (No. 2D), No. 2 nondense (No. 2ND), No. 3, or No. 4.

TABLE 1. — Location, planting density, site index, and number of sample trees per stand.

Rotation age class	Stand location	Planting density	Average stand age	Site index	Sample trees
(yr.)		(TPA)	(yr.)		(no.)
22	Glynn Co., Ga.	691	22	85	20
	Liberty Co., Ga.	691	23	85	20
28	Glynn Co., Ga	691	28	80	20
	Liberty Co., Ga.	691	29	85	17
40	Bryan Co., Ga.	Natural	43	70	25
	Brantley Co., Ga	Natural	38	70	25

TABLE 2. — Summary of tree characteristics by rotation age class for unthinned loblolly pine sampled in the Coastal Plain of Georgia.

Rotation age class	Sample trees	DBH		Sawlog merch. height		Sawlog cubic volume	
		Average	Range	Average	Range	Average	Range
(yr.)		--- (in,). -		(ft.)		----- (ft.^{3})	
22	40	11.7	8.3 to 16.9	44	25 to 62	20.0	6.0 to 36.1
28	37	12.4	8.3 to 16.3	51	11 to75	26.1	4.2 to 54.2
40	SO	12.1	8.1 to 16.8	SO	23 to 67	24.7	5.2 to 59.2
All classes	127	12.0	8.1 to 16.9	49	11 to75	23.6	4.2 to 59.2

TABLE 3. — Number of test specimens by stand age, replication, and test ***procedure.***

Lumber grade	Size	Age 22, Rep 1		Age 22, Rep 2	
		Tension	Bending	Tension	Bending
No. 2	2 by 4	9	8	11	17
No. 2	2 by 6	8	4	10	7
		Age 28, Rep 1		Age 28, Rep 2	
No. 2	2 by 4	12	10	10	20
No. 2	2 by 6	11	10	4	10
		Aee 40. Rep 1		Aee 40, Rep 2	
No. 2	2 by 4	16	17	10	7
No. 2	2 by 6	16	12	11	4

TABLE 4. — Average lumber grade yield by stand age for unthinned loblolly pine in the Coastal Plain of Georgia.

Stand age	Proportion of 8/4 dimension lumber by visual grade					
	DSS	No. 1	No. 2D	No. 2N	No. 3	No. 4
(yr.)	------------------------- (%) ----------------------------					
22	1	18	3	50	21	7
28	2	20	5	45	21	7
40	13	19	13	34	15	6

STRENGTH AND STIFFNESS TESTING

A total of 255 pieces of No. 2 dimension lumber were available for testing. **Table 3** shows the number of No. 2 boards in each size class. Selection for testing in tension or static bending was accomplished by selecting alternate boards, i.e., assigning even numbers to static bending and odd numbers to tension testing. All specimens were measured for width and thickness to the nearest 0.001-inch at midpoint. This measurement was used for all subsequent calculations of stiffness and strength properties.

Static bending. — The static bending samples were tested using a hydraulic universal test machine of 120,000-pound capacity. The provisions of ASTM D-198 (2) were followed: one- third point loading and a load rate of 300 pounds per minute maintained until failure. The load/deflection data were taken at 3-second intervals using an analog/digital board mounted in a portable computer. The linear variable distance transducer (LVDT) was removed when specimen deflection reached approximately 1.5 inches to prevent damage to the LVDT. The test data were imported into a spreadsheet template that calculated the MOE from the slope of the load/deflection curve using regression techniques. The MOR was calculated from the maximum load. The summarized data were analyzed with Statistical Analysis System (SAS) procedure GLM (11) using a split-plot ANOVA model. The whole-plot factor was stand age and the subplot factor was specimen size.

Tension testing. — The tension specimens were tested on a portable, hydraulic, trailer-mounted tension tester. Test set-up was as follows: 24 inches of each end of a test board were in the tension grips; the gauge length for tensile strain measurements was 72 inches in the center of the test board between the grips. Load and deflection data were taken at 3-second intervals by connecting the data-acquisition system integral to the test machine and a portable computer.

The test data were imported into a spreadsheet that calculated the tensile MOE using regression techniques to determine the slope of the load/deflection curve and calculate the tensile strength from the maximum load. The summarized data were analyzed with SAS procedure GLM (11) using a split-plot ANOVA model. The whole-plot factor was stand age and the subplot factor was specimen size.

RESULTS AND DISCUSSION

LUMBER GRADE YIELD

The 127 study trees produced 20,245 board feet (BF) of lumber; 96 percent of the lumber produced was 8/4 dimension and 4 percent was 4/4 boards. Eighty-five percent of the 8/4 dimension was 2 by 4's and the remainder was 2 by 6's. The average lumber grade yield by rotation age is shown in **Table 4.** A detailed discussion of the lumber grade yield by tree size and age is reported in a previous paper (6).

BENDING

Table 5 presents the average values of MOE, MOR, and specific gravity for No. 2 dimension tested in bending for each age class and specimen size. **Table 6** shows the F-values and associated probability values for a split-plot design. Bending MOE for No. 2 lumber from the 40-year-old rotation age was significantly higher than the bending MOE for No. 2 lumber from the 28- and 22-year-old rotation ages as indicated from the Duncan's Multiple-Range Test option of the GLM procedure. MOR and specific gravity for No. 2 lumber from the three rotation ages did not differ significantly when using the indicated split-plot error terms.

Differences between 2 by 4 and 2 by 6 No. 2 dimension lumber were not significant for MOE, MOR, and specific gravity when using the indicated split-plot error term.

TENSION

Table 7 presents the average values for tensile MOE, tensile strength, and specific gravity for No. 2 dimension lumber tested in tension. **Table 8** presents the F-values and associated probability values for the split-plot ANOVA.

TABLE 5. — Average values of bending MOE, MOR, and specific gravity for No. 2 dimension lumber by rotation age and specimen size.

Stand age	Rep	MOE 2 by 4	MOE 2 by 6	MOR 2 by 4	MOR 2 by 6	Specific gravity 2 by 4	Specific gravity 2 by 6
(yr.)		-- (million psi) --		-- (psi) --			
22	1	1.35	1.96	4,197	6,167	0.51	0.57
	2	1.63	1.45	5,759	6,039	0.54	0.55
28	1	1.29	1.53	3,978	6,368	0.50	0.55
	2	1.68	1.61	5,779	5,668	0.56	0.58
40	1	1.93	2.01	5,917	7,504	0.60	0.61
	2	1.79	2.54	5,345	9,348	0.56	0.67

TABLE 7. — Average values of tensile MOE, tensile strength, and specific gravity for No. 2 dimension lumber by rotation age and specimen size.

Stand age	Rep	Tensile MOE 2 by 4	Tensile MOE 2 by 6	MOR 2 by 4	MOR 2 by 6	Specific gravity 2 by 4	Specific gravity 2 by 6
(yr.)		(million psi) --		----- (psi) -----			
22	1	1.24	1.47	2,486	3,117	0.43	0.48
	2	1.30	1.65	2,662	3,164	0.43	0.42
28	1	1.53	1.75	2,774	3,422	0.48	0.46
	2	1.54	1.54	2,393	2,244	0.45	0.52
40	1	1.60	2.35	2,643	3,530	0.45	0.48
	2	1.47	2.18	2,786	3,490	0.45	0.51

TABLE 6. — Type III analysis of variance (split-plot design) for bending MOE, MOR, and specific gravity for No. 2 dimension lumber

Class variable	Degrees of freedom	MOE F	MOE Pr > F	MOR F	MOR Pr > F	Specific gravity F	Specific gravity Pr > F
Stand Age[a]	2	8.69	0.0565	7.60	0.0669	4.21	0.1347
Rep (Stand Age)	3	1.72	0.1662	0.88	0.4524	2.35	0.0757
Size[b]	1	1.91	0.2607	6.23	0.0879	6.11	0.0900
Stand Age x Size	2	0.35	0.7290	0.65	0.5820	0.20	0.8298
Rep x Size (Stand Age)	3	3.70	0.0139	2.96	0.0351	1.94	0.1267

[a] Error term for Stand Age is Rep (Stand Age).
[b] Error term is Rep x Size (Stand Age).

TABLE 8. — Type III analysis of variance (split-plot design) for tensile MOE, tensile strength, and specific gravity for No. 2 dimension lumber:

Class variable	Degrees of freedom	MOE F	MOE Pr > F	MOR F	MOR Pr > F	Specific gravity F	Specific gravity Pr > F
Stand Age[a]	2	16.08	0.0249	1.06	0.4484	3.69	0.1553
Rep (Stand Age)	3	0.47	0.7005	1.48	0.2247	1.05	0.3739
Size[b]	1	96.04	0.0023	18.14	0.0237	4.11	0.1358
Stand Age x Size[b]	2	24.54	0.0138	1.58	0.3402	0.33	0.7393
Rep x Size (Stand Age)	3	0.12	0.9476	0.42	0.7402	1.88	0.1361

[a] Error term for Stand Age is Rep (Stand Age).
[b] Error term is Rep x Size (Stand Age).

Tensile MOE was significantly higher for the No. 2 dimension lumber from the 40-year-old stands compared to the younger harvest ages as indicated from the Duncan's option of the GLM procedure. Differences between the three rotation ages were not statistically significant for tensile strength or specific gravity.

The differences between 2 by 4 and 2 by 6 No. 2 dimension lumber were statistically significant for both tensile MOE and tensile strength with the 2 by 6's having the higher values. Specific gravity was not significantly different between the two sizes when the split-plot error term was used in the analysis.

Conclusions

The MOE (stiffness) of the No. 2 dimension lumber in this study was higher in both bending and tension for material from the unthinned 40-year rotation age. Therefore, if stiffness is a preferred property, longer rotation ages are desirable. The strength of No. 2 dimension lumber increased with increasing rotation age, but this increase was not statistically significant at the 0.05 level of probability. Specific gravity showed a slight, but statistically insignificant, increase with increasing rotation age.

Literature Cited

1. American Forest&Paper Association. 1991. Design values for wood construction. A supplement to the 1991 edition of the National Design Specification. AF&PA, Washington, DC. pp. 51.
2. American Society for Testing and Materials. 1994. Standard 'methods of static tests of timbers in structural sizes. ASTM D-198-84. ASTM Annual Book of Standards, Volume 4.10. Wood. ASTM, West Conshohocken, Pa. pp.69-87.
3. ________ 1994. Standard methods for establishing structural grades and related allowable properties for visually graded lumber. ASTM D-245-93. ASTM Annual Book of Standards. Volume 4.10. Wood. ASTM. West Conshdhocken, Pa. pp. 88-105.
4. ________ 1994. Standard method for evaluating allowable properties for grades of structural lumber. ASTM D-2915-90. ASTM Annual Book of Stand., Vol. 4.10. Wood. ASTM, Philadelphia, Pa. pp. 407-418.
5. ________ 1994. Standard practice for establishing allowable properties for visually graded dimension lumber from In-Grade tests of full size specimens. ASTM D1990-91. ASTM Annual Book of Standards, Vol. 4.10. Wood. ASTM, Philadelphia, Pa. pp. 299-323.
6. Clark, A., III, R.H.McAlister, and J.R. Saucier. 1995. Effect of rotation age on lumber grade, yield, and strength of unthinned loblolly pine. Forest Prod. J. 46(1):63-68.
7. Kretschmann, D.E. and B.A. Bendsten. 1992. Ultimate tensile stress and modulus of elasticity of fast-grown plantation loblolly pine lumber. Wood and Fiber Sci. 24(2):189-203.
8. McAlister, R.H. and A. Clark III. 1991. Effect of geographic location and seed source on the bending properties of juvenile and mature loblolly pine. Forest Prod. J41(9):1-4.
9. MacPeak, M.D., L.F. Burkhart, and D. Weldon. 1990. Comparison of grade, yield, and mechanical properties of lumber produced from young fast-grown and older slow-grown planted slash pine. Forest Prod. J. 40(1):11-14.
10. Pearson, R.G. 1988. Compressive properties of clear and knotty loblolly pine juvenile wood. Forest Prod. J. 38(7/8):15- 22.
11. SAS Institute, 1988. SAS/STAT User's Guide, Release 6.03 ed. SAS Institute Inc., Cary, N.C. 1,028 pp.
12. Southern Pine Inspection Bureau. 1994. Standard grading rules for southern pine lumber. SPIB, Pensacola, Fla. 134 pp.