FLEXURAL PROPERTIES OF LUMBER FROM TWO 40-YEAR-OLD LOBLOLLY PINE PLANTATIONS WITH DIFFERENT STAND DENSITIES[1]

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ABSTRACT

The effects of stand density on the flexural properties and compliance-to-grade requirements of lumber from two 40-year-old loblolly pine plantations were evaluated. The results indicate that stand density is positively influencing the flexural stiffness and grade compliance of the lumber produced from these plantations. On the other hand, stand density had no effect on the flexural strength of the lumber from these plantations. The lumber from the denser 40-year-old stand, which had 28 m/50 yr site index, 2.4-by 2.4-m original spacing, never thinned, with 679 trees/ha and 11.4-sq m basal area at harvest, has 96% and 66% compliance to required flexural strength and stiffness values, respectively. The lumber from the thinned 40-year-old stand, with 28 m/50 yr site index, 2.4-by 2.4-m original spacing, thinned at age 25, with 450 trees/ha and 10.2-sq m basal area at harvest, has 96% and 53% compliance to required flexural strength and stiffness values, respectively. It is now evident from the results of these studies that even dense stands must be older than 40 years of age before they can be harvested for lumber production to ensure attainment of at least 95% lumber grade compliance, i.e., strength and stiffness values that are consistent with assigned visual grades.

Keywords: Loblolly pine, lumber, plantations, flexural properties.

INTRODUCTION

In the South, pine sawmills are increasingly becoming more dependent on plantations for their sawlogs. In some southern states, approximately one-half of the available pine now comes from intensely managed plantations of loblolly pine (*Pinus taeda* L.) and slash pine (*Pinus elliotti* Engelm.) timber. Generally speaking, the trees in these plantations grow faster than those in natural older stands; but the wood produced by these trees, particularly at young ages, also has lower specific gravities and contains greater proportions of juvenile wood (Bendtsen and Senft 1986; Zobel and Blair 1976; Taras 1965). Consequently, lumber from such plantation timber is on average structurally inferior to that derived from naturally grown older timber (Bendtsen 1978; Koch 1966; Pearson and Gilmore 1971 and 1980; MacPeak et al. 1990). This was confirmed by Biblis et al. (1993 and 1995) in their

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TABLE 1. *Characteristics of the two 40-year-old loblolly pine stands investigated.*

Stand No.	Age	Site index	Original spacing	Thinned at age	Trees/ha	Basal area
	(yr)	m/yr	(m)	(yr)		(m^2)
1	40A	28/50	2.4 by 2.4	25	450	10.2
2	40B	28/50	2.4 by 2.4	None	679	11.4

TABLE 2. *Measurements of the tree samples (30 from each stand) representative of each stand.*

Measurement	Mean	SD*	Minimum	Maximum
40-year-old stand A				
DBH, (cm)	35.6	5.6	26.7	47.0
40-year-old stand B				
DBH, (cm)	29.7	6.4	19.1	41.9

* Sd = Standard deviation.

studies on flexural properties of lumber from plantations of different stand densities and ages up to 35 years. They have evidence to show that although the structural quality of lumber from plantations increases with stand age and stand density, it does not seem to meet the flexural standard requirements for the assigned visual grades. As a logical consequence of this, the question was then raised whether older plantation timber stands would do better.

Therefore, a follow-up study on the subject was conducted. More specifically, the flexural properties of lumber from two 40-year-old loblolly pine plantations with different stand densities were investigated. The results of such an investigation are presented in this paper. The focus on stand density as a factor influencing flexural properties stems from the fact that it affects the development of juvenile wood and branches in the tree. In another study (Biblis 1990), however, it was found that lumber from a 27-year-old slash pine plantation planted on a 6- × 6-ft original spacing, with no thinning and a lower growth rate, exhibited exceptionally good lumber properties and compliance to visual lumber grades. The number and size of branches directly relate to the number and size of knots as well as to the localized slope of wood grain in lumber produced from such a tree. Clearly, the presence of knots in lumber affects its visual grade and structural properties. The question that still needs resolution is whether the actual strength values of a piece of lumber from older than 35-year-old plantations are consistent with the requirements of the assigned visual grades. The results presented in this paper will provide more useful insights into this important issue.

MATERIALS AND METHODS

Two loblolly pine stands, identified as 40A and 40B, located in east Central Alabama were used in this study. The characteristics of the stands are listed in Table 1. Both stands were established on equal site index of 28/50 m/yr. One stand (40A) was thinned at age 25, whereas the other (40B) was never thinned resulting with 450 and 679 trees/ha, respectively, at harvesting at age 40.

Prior to tree selection from each stand, the timber size distribution for each stand was established by measuring diameter at breast height (DBH) of all trees in four 0.1-hectare plots in each stand. Thirty trees representing the DBH distribution for each stand were then selected as samples for the study. These were identified, harvested, and measured. (See Table 2). The average DBH of stands 40A and 40B was 35.6 and 29.7 cm, respectively.

Sample trees from each stand were segregated. Each tree was bucked into logs in the field, and the large end of each log was spray-painted with a color to identify each stand. The small end of each log was spray-painted with a different color to identify the location of the log within a tree (first, second, third log). Afterwards, the large-and the small-end diameters outside bark and the length of each log were measured and recorded. Logs from each stand were transported to the cooperating sawmill in two batches and processed separately. All green lumber was sorted by width and length and then stacked and kiln-dried to approximately 15% moisture content (MC). After kiln-drying, all the lumber pieces were dressed to the specifications of the mill and subsequently graded to SPIB (Southern Pine

TABLE 3. *Flexural properties and compliance to visual grade requirements of southern pine lumber obtained from a 40-year-old thinned loblolly plantation A[a], tested edgewise according to ASTM D 198 with third-point loading over the spans of 228.6 cm for 2 × 4's and 335.3 cm for 2 × 6's and 2 × 8's.*

Log type	SPIB visual grade	Pieces tested	MC %	SG[b] (odb)	MOE[c] Gpa	MOR[c] Mpa	5th[d] Mpa	SPIB required BSV[e] Mpa	SPIB required MOE Gpa	Meet standards "F_b" %	Meet standards "E" %
					Lumber size 2″ × 4″						
All logs	1	69	9.8	0.58	12.5 (0.9)	61.7 (6.7)	32.1	26.8	11.7	100	57
	2	194	8.5	0.49	10.9 (0.9)	42.3 (6.1)	19.2	21.7	11.0	94	53
	3	59	8.1	0.47	8.9 (0.9)	27.2 (7.8)	8.5	12.3	9.7	95	39
All logs + grades		322								96	52
					Lumber size 2″ × 6″						
All logs	1	24	9.3	0.51	13.3 (0.2)	53.6 (8.9)	21.4	23.9	11.7	100	79
	2	71	9.5	0.47	10.4 (0.9)	35.5 (6.1)	14.5	18.1	11.0	92	45
	3	15	9.2	0.46	8.7 (1.4)	26.3 (6.4)	—	10.8	9.7	100	40
All logs + grades		110								95	52
					Lumber size 2″ × 8″						
All logs	1	15	8.4	0.57	14.2 (1.2)	65.6 (19.1)	—	10.1	9.7	100	87
	2	18	8.5	0.46	10.7 (0.7)	37.4 (9.6)	—	17.4	11.0	100	56
	3	3	8.9	0.49	9.4 (2.3)	29.2 (9.3)	—	10.1	9.7	100	33
All logs + grades		36								100	67

[a] See Table 1 for characteristics of 40-year-old loblolly plantation A.
[b] odb stands for oven-dry basis.
[c] Numbers in parentheses are standard deviations.
[d] Nonparametric estimate of 5th percentile at 75% confidence limit.
[e] BSV is the required bending strength value obtained by multiplying the "F_b" by 2.1.

Inspection Bureau) visual grades by qualified lumber graders. The lumber, prior and during testing, was stored in the laboratory at drier conditions; thus the MC during testing was between 8 to 10%, as indicated in Tables 3–5.

All sawn lumber from each stand was transported and stored inside the Auburn University's Forest Products Laboratory for a minimum of 3 weeks prior to testing. The 3.81-by 20.5-cm and 3.81-by 15.2-cm test pieces were trimmed to 3.67 m long, while all 3.81-by 10.2-cm pieces were trimmed to 2.44 m long. All test samples that were trimmed to the desired size were regraded by a qualified lumber grader. A total of 966 pieces of lumber was destructively tested edgewise in flexure to failure with third-point loading according to ASTM D 198-84 (1994). The 3.81-by 20.5-cm and 3.81-by 15.2-cm pieces were tested over a span of 3.35 m, and the 3.81-by 10.2-cm pieces were tested over a 2.29-m span. A Tinius-Olsen hydraulic testing machine with a capacity of 54,480 kg was used to test the lumber. For flexure tests, the machine was equipped with an extended base made from a steel double I-beam 6.2 m long and a steel loading head 2.1 m long. Load and corresponding deflection-to-failure data were obtained with a Hewlett-Packard (H-P) data acquisition system connected to an H-P desk computer for processing. The modulus of rupture (MOR), modulus of elasticity (MOE),

TABLE 4. *Flexural properties and compliance to visual grades requirements of southern pine lumber obtained from a 40-year-old unthinned loblolly plantation B[a], tested edgewise according to ASTM D 198 with third-point loading over the spans of 228.6 cm for 2 × 4's and 335.3 cm for 2 × 6's and 2 × 8's.*

Log type	SPIB visual grade	Pieces tested	MC %	SG[b] (odb)	MOE[c] Gpa	MOR[c] Mpa	5th[d] Mpa	SPIB required BSV[e] Mpa	SPIB required MOE Gpa	Meet standards "F_b" %	Meet standards "E" %
					Lumber size 2″ × 4″						
All logs	1	339	8.3	0.54	12.8 (1.4)	60.1 (17.6)	25.1	26.8	11.7	98	72
	2	194	8.4	0.48	11.7 (0.4)	41.0 (8.0)	20.6	21.7	11.0	96	72
	3	59	9.1	0.48	10.5 (0.8)	32.5 (5.3)	17.0	12.3	9.7	99	75
All logs + grades		339								97	73
					Lumber size 2″ × 6″						
All logs	1	24	8.9	0.51	11.9 (0.6)	51.7 (11.3)	22.8	23.9	11.7	96	50
	2	83	9.0	0.47	9.0 (0.5)	32.5 (6.5)	14.1	18.1	11.0	90	35
	3	7	9.7	0.46	9.0 (1.4)	28.6 (1.2)	—	10.7	9.7	100	43
All logs + grades		114								92	39
					Lumber size 2″ × 8″						
All logs	1	15	9.8	0.52	13.8 (0.3)	53.2 (0.1)	—	21.6	11.7	100	88
	2	18	8.5	0.48	11.4 (1.5)	35.0 (6.1)	11.4	17.3	10.9	89	77
	3	3	8.9	0.45	6.7	16.7	—	10.1	9.7	50	50
All logs + grades		45								89	78

[a] See Table 1 for characteristics of 40-year-old loblolly plantation B.
[b] odb stands for oven-dry basis.
[c] Numbers in parentheses are standard deviations.
[d] Nonparametric estimate of 5th percentile at 75% confidence limit.
[e] BSV is the required bending strength value obtained by multiplying the "F_b" by 2.1.

TABLE 5. *Flexural properties and percent compliance to visual grade requirements of southern pine lumber from two 40-year-old loblolly pine plantation stands.*

Stand ID	SPIB visual grade	No. of pieces tested	Grade (%)	MC (%)	SG (odb)	MOE Gpa	MOR Mpa	Required "E" Gpa	Meet standards "F_b" (%)	Meet standards "E" (%)
40A[a] Thinned	1	108	23	9.5	0.56	12.9	60.5	11.7	100	69
	2	283	60	8.7	0.48	10.7	40.5	11.0	94	51
	3	77	17	8.4	0.47	8.9	27.1	9.7	95	39
All		468			0.50				96	53
40B[b] Unthinned	1	79	16	8.6	0.53	12.7	56.9	11.7	97	67
	2	296	59	8.7	0.48	11.2	38.0	11.0	94	63
	3	123	25	9.2	0.48	10.4	32.1	9.7	96	66
All		498			0.49				96	66

[a] Stand A's Basal Area = 106 sq ft.
[b] Stand B's Basal Area = 141 sq ft.

MC, and specific gravity (SG, based on oven-dry weight and volume) for each tested piece of lumber were subsequently calculated.

Flexural test results were used for making comparisons with the required bending strength value for each visually graded piece; that is, the obtained MOR value of every piece was compared to the required bending strength value (BSV) of the corresponding visual grade. The BSV was calculated by multiplying the Southern Pine Inspection Bureau (SPIB) required bending design value F_b for each grade by the combined adjustment factor 2.1 for safety and duration of load. This comparison is shown in Tables 3, 4, and 5 and is reflected by the percentage of the number of pieces meeting or exceeding the requirements to the total number of pieces tested. The percentages of the tested pieces with E values above those recommended by SPIB grading rules for the corresponding visual grade are also listed therein.

RESULTS AND DISCUSSION

Tables 3, 4, and 5 summarize the results of the flexural tests conducted on lumber produced from the two 40-year-old planted stands of loblolly pine investigated. Tables 3 and 4 show the flexural properties of lumber by size class and visual grade category of all logs obtained from each stand. Also shown in these tables are the number of lumber pieces tested and the average SG and MC of lumber in the aforementioned classifications. Furthermore, the Nonparametric Tolerance Limit (NTL) estimate of 5th percentile at 75% confidence limit is listed for each lumber size class and grade category. In addition, in the same tables are shown the bending strength value (BSV) required by SPIB (Southern Pine Inspection Bureau 1991) grading rules for each visually graded piece and the stiffness design value, E, recommended by SPIB grading rules as the average value for each visual grade. Table 5 summarizes the overall flexural properties for all sizes of tested lumber from each stand by visual lumber grade irrespective of the lumber origin vis-à-vis log position in the tree.

The average specific gravities of lumber from the thinned and unthinned stands were not significantly different (Table 5). Apparently, the thinning of stand 40A at age 25 had no adverse effect on the specific gravity of lumber derived therefrom when compared to the lumber from the unthinned stand. This could be due to the fact that after 25 years, the formation of most of the juvenile wood in both stands was essentially completed and that any additional growth attributed to thinning was due more to the formation of mature wood. Table 5 also shows that the distributions of the visual grades of lumber from both stands are very similar since about 60% of the lumber from each stand was graded No. 2.

The standard *t*-test was used to compare the mean values for the strength (MOR) and stiffness (MOE) properties of lumber of the same visual grade and size classifications from the two test stands. With 95% level of confidence, *T*-test results indicate that there is no statistical difference between the mean MOR or MOE values having the same grade from the two stands.

Table 5 also presents what is considered to be the most important results of the study, i.e., a measure of the degree of compliance of visually graded lumber to standard requirements of strength and stiffness set for a given visual grade classification. In terms of strength, lumber from both the thinned and unthinned 40-year-old loblolly stands exhibited almost the same very high level of compliance; on average (i.e., regardless of grade), 96% compliance. In terms of stiffness, however, it is a different story. Grades 1, 2, and 3 lumber from the thinned stand (40A) have only 69%, 51%, 39% compliance, respectively—or an average compliance of only 53%. Lumber from the unthinned stand (40B) shows a slightly better, but still considered unsatisfactory, performance with a 66% compliance regardless of grade. It should be noted that although the percentage compliance of individual lumber pieces to required stiffness is alarmingly low, the average stiffness (MOE) values of lumber from both stands, except for No. 3 grade lumber from the thinned stand (40A), meet the required "E" values.

CONCLUSIONS

It can be inferred from the results of the study that a release thinning at 25 years of age on a 40-year-old loblolly stand does not alter the level of compliance to flexural strength requirements of lumber produced. On average, except for No. 3 grade lumber from thinned stands, flexural stiffness (MOE) of lumber from 40-year-old stands of loblolly, unthinned and thinned, can meet the required average "E" value. However, when individual pieces of lumber are considered, the results of the study show that the percentage of pieces of lumber complying to required stiffness "E" is alarmingly low. On average (i.e., considering all grades), only 53% and 66% of the lumber produced from the thinned stand (40A) and unthinned stand (40B), respectively, conformed to required "E" value.

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