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Effect of Veneer Grade Layup on Bending Propeties of Lobolly Pine LVL

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Abstract

The effect of A-grade veneer within 13-ply laminated veneer lumber (LVL) was investigated. Loblolly pine was harvested from a silviculturally termed crop trees stand. Significant differences were found to exist between the five different layups. The most favorable mechanical properties for veneer grade arrangement were obtained with a layup that placed two A-grade veneers on one face, a single A-grade veneer on the other face and a C-grade core. This finding has possible economic implications since some other layups included more A-grade veneer. Several of the groups met the requirements for dense select structural 2 in. x 4 in. southern yellow pine visually graded lumber.

Keywords: Laminated veneer lumber, Layup, Loblolly pine, Modulus of elasticity, Modulus of rupture, Veneer grade.

Introduction

LVL is one of the latest of the ever evolving new types of wood-based composites, which possesses more reliable strength for design purposes and allows for superior utilization efficiency of our timber resource. It provides not only larger and more convenient product sizes but also higher and more reliable engineering properties. LVL possesses many of the critical mechanical properties of lumber and has been researched and commercially produced for several years in the United States.

The rise in global population has lead to a greater demand for wood. Many different wood-based composites have been developed to help reduce the demand on solid wood. Products such as plywood, oriented strand board, and flakeboard provide building materials in a much larger and are accepted for sheathing purposes. However, many of these wood-based composites lack the necessary strength and stiffness properties required for structural applications.

Research by Koch has shown that a greater mean modulus of elasticity (MOE) and allowable fiber stress can be obtained with 2 in. x 4 in. southern yellow pine (SYP) LVL compared to sawn lumber of equal dimensions (Koch 1967a, Koch 1967b). Also, beam strength has been found to be optimum with the stiffest veneers on each face (Biblis and Carino 1993, Koch 1967a, Koch 1967b, Koch 1973). Additional information regarding the effect of butt joints (Koch and Woodson 1968) and finger joints (Biblis and Carino 1993) is also available.

The objective of our study was not to determine the already well-known effect of veneer stiffness on LVL bending properties, but rather to study the effect of five different veneer grade arrangements, i.e. layups on LVL bending properties. We attempted to determine the optimal placement of different veneer visual grades in a LVL panel based on both flatwise and edgewise modulus of rupture (MOR) and MOE.

Materials and fabrication

Five representative trees each from an unevaged-aged "crop trees" stand growing near Crossett, AR were harvested and bucked into peeler bolts. The stand is described in detail by Baker and Bishop (1986). This mature, uneven-aged site had been under selection management for 50-years. During this time, two age-classes of trees developed. One

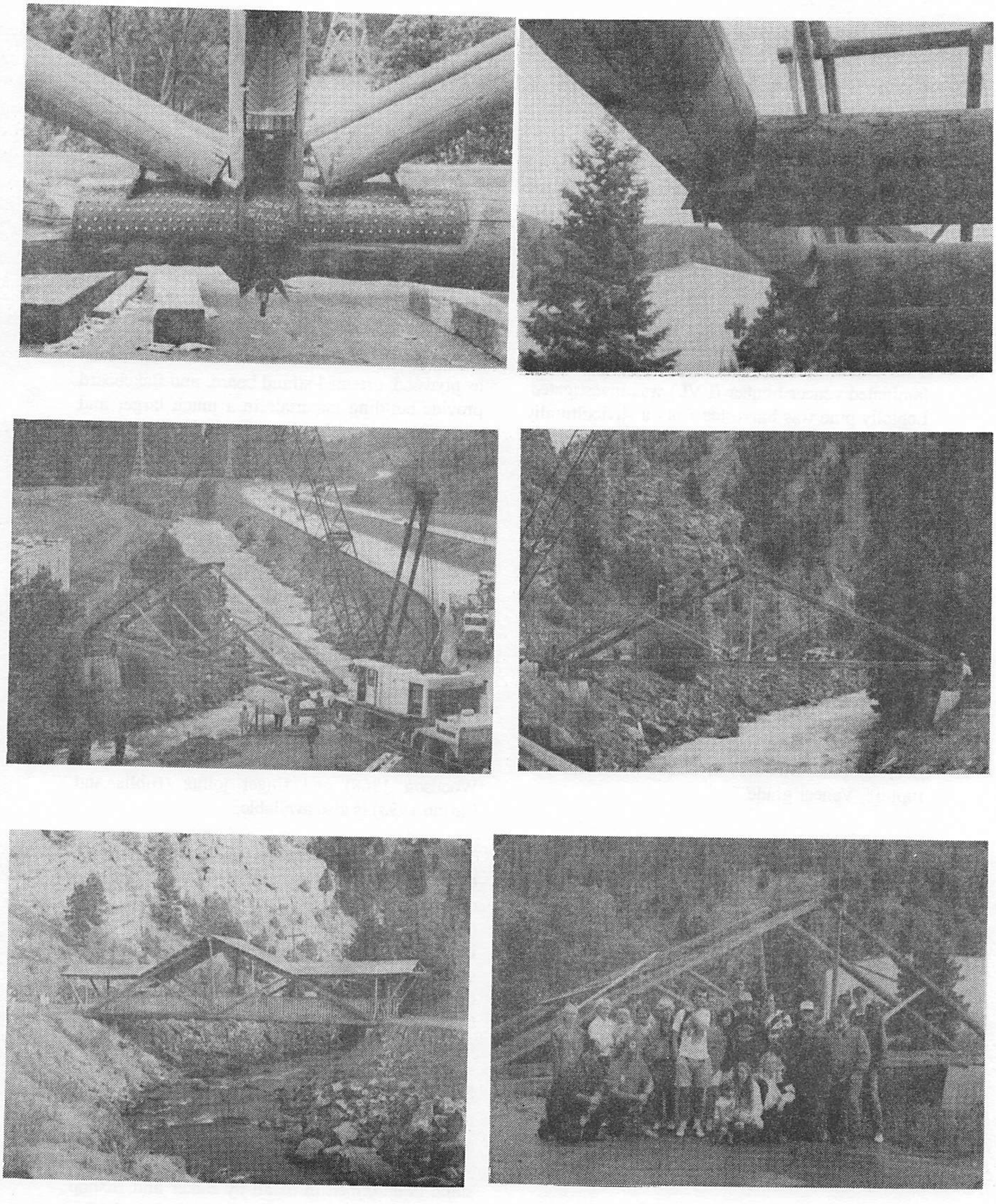

Figure 2. Bridge construction: g) midspan joint, h) floor beam connection, i) lifting, j) in-place frame, k) completed bridge, l) a proud work crew.

age-class included 47- to 51-year-old dominant and codominant trees. We sampled from the 77- to 85- years-old age-class. These crop trees had been left uncut by all previous thinning operations and were easily separated from the younger age-class based on size and tree morphology.

The bolts were rotary-peeled by Hunt Plywood at Pollock, LA to a target thickness of 1/8-in. and clipped to approximately 54 in. x 98 in. The veneer was coded according to stand, tree number, and bolt number as it was peeled. The veneer was dried commercially to a moisture content (MC) of 6 - 8%, transported to the USDA - Forest Service, Southern Research Station in Pineville, LA, stored in a controlled environment of 72 F and 36 percent relative humidity (RH), and graded by an APA - The Engineered Wood Association veneer grader.

Panel fabrication was accomplished at a Riverwood Internationa plywood mill at Joyce, LA. A commercial extended phenolic resin (52 % solids) was applied to veneers with a curtain coater at a rate of 92 pounds per 1,000 $ft.^2$ of double glue-line. The tight side was outermost on both faces of all panels and inner veneers were assembled randomly with respect to tight side and loose side. There were four different groups based on veneer visual grade arrangement within the panels. The LVL groups were as follows:
Group 1 layup = AACCCCCCCCCAA
Group 2 layup = ACCCACCCACCCA
Group 3 layup = AACCCCCCCCCCA
Group 4 layup = ACCCCCACCCCCA
Group 5 layup = AACCCCACCCCAA
Finished billets were stored at the mill for 10 hours before shipping. The four replicate billets of each specific assembly type were cut into beams of approximately 1.5 in. x 3.75 in. x 8 ft. Beams that showed obvious glue-line defects, such as blowout, were discarded.

Edge-wise bending specimens were cut to 86-in. lengths and tested over an 80-in. span. Flat-wise bending tests were conducted with 38-in.-long specimens over a 30-in. span using a computer a driven software package on an Instron testing machine with a MTS upgrade. The software package allowed for data to be downloaded and analyzed using a factorial analysis on SAS (1989). Tukey's Honest Significant Difference test was employeed to determine significance between means. Sample beams were air-dried to an approximate equilibrium MC of 11 %. The airdry specimens were stacked for six months in a constantly air-conditioned laboratory with lumber stickers every 18 inches to allow for proper airflow. Repeated weightings yielded constant results and indicated that the equilibrium moisture content of most specimens was near 10 - 11 percent. Testing was done in accordance with ASTM D-198 (1994). Mechanical properties tests were accomplished with an Instron testing machine using a computer drive software package. Deflection was measured to the nearest 0.001 in. After each test, a six-inch long sample was cut from outside the failure zone for specific gravity (SG) and moisture content (MC) determination.

Results and discussion

The effects of veneer layup on edgewise and flatwise MOR and MOE of SYP LVL is summarized in Table 1. Table 2 summarizes the basic physical properties of these five groups, i.e., I, II, III, IV, and V.

Table 1 - Ratio of mean values of loblolly pine laminated veneer lumber groups of differing veneer visual grade layups.

	Edgewise		Flatwise	
Group comparison[1]	MOR	MOE	MOR	MOE
I / II	0.99	0.87	0.87	0.78
I / III	0.78	0.83*	0.74	0.66*
I / IV	0.83	0.82*	0.84	0.76
I / V	0.99	0.89	1.06	1.22
II / III	0.79	0.95	0.85	0.85
II / IV	0.84	0.94	0.97	0.98
II / V	1.00	1.03	1.23*	1.57*
III / IV	1.06	0.99	1.13	1.15
III / V	1.27	1.08	1.44*	1.84*
IV / V	1.20	1.09	1.27*	1.61*

*Denotes significance at alpha = 0.05.
[1]Group I = AACCCCCCCCCAA
Group II = ACCCACCCACCCA
Group III = AACCCCCCCCCCA
Group IV = ACCCCCACCCCCA
Group V = AACCCCACCCCAA

No significant differences were detected for edgewise MOR values. This was expected due to the importance of the 12 rigid glue lines in edgewise loading. Group III and group IV gave the highest mean values of 9,850 psi and 9,299 psi, respectively (Figure 1). The mean

Table 2 - Effect of various veneer grade layups on basic physical properties of 13-ply loblolly pine laminated veneer lumber of different veneer visual grade layups.

Group[1]	Moisture content (%)	Specific gravity[2]
I	11.7[3] (7.68)[4]	0.65 (5.59)
II	11.8 (7.35)	0.64 (3.53)
III[5]	11.3 (5.99)	0.66 (7.14)
IV	11.1 (3.72)	0.65 (4.70)
V	11.6 (6.04)	0.64 (4.25)

[1]Group 1 layup = AACCCCCCCCCAA
Group 2 layup = ACCCACCCACCCA
Group 3 layup = AACCCCCCCCCCA
Group 4 layup = ACCCCCACCCCCA
Group 5 layup = AACCCCACCCCAA
[2]Specific gravity based on volume at 11% equilibrium moisture content and ovendry weight.
[3]Represents the mean of 11 samples.
[4]Values in parenthesis are coefficient of variation (%).
[5]Group III was tested with AA side in compression and A side in tension; all other layups were symmetric with regards to veneer grades within the panel.

comparison range was fairly small (0-27 percent) (Table 1).

A similar pattern was detected for flatwise MOR with group III (11,806 psi) and group IV (10,483 psi) possessing the largest means (Figure 1). Statistical significance was detected in that group II (10,128 psi), group III (11,860 psi), and group IV (10,483 psi) were all significantly greater than group V (8,253 psi), which was not statistically different from group I (8,777 psi).

Edgewise MOE was the only test in which group III did not yield the highest mean value. Group III (2.00×10^6 psi) and group IV (2.02×10^6 psi) were both statistically similar to each other and group II (1.90×10^6 psi) and group V (1.85×10^6 psi) as well. All other groups were significantly higher than group V (1.65×10^6 psi). Group II, group III, and group IV all met the requirements for Dense select structural 2 in. x 4 in. SYP visually graded lumber (Table 3).

For flatwise MOE, group III (2.01 x 106 psi), group IV (1.75 x 106 psi), and group II (1.71 x 106 psi) were all statistically similar. Group III was 34 and 16 percent greater than group I and group V, respectively. A similar pattern for edgewise and flatwise MOE is evident from Table 3 and Figure 1.

Table 3. Edgewise design values for 2 in. - 4 in. thick x 2 in. - 4 in. wide visually graded Southern pine lumber and the groups that meet the design value based on edgewise MOE mean values.

Commercial grade	MOE ($\times 10^6$ psi)[1]	Groups[2] meeting requirement
Dense select structural	1.9	II, III, IV
Select structural	1.8	V
Non-dense select structural	1.7	--
No. 1 Dense	1.8	--
No. 1	1.7	
No. 1 Non-dense	1.6	I
No. 2 Dense	1.7	--
No. 2	1.6	--
No. 2 Non-dense	1.4	--
No. 3	1.4	--
Stud	1.4	--

[1]Source: American National Standards Institute/National Forest Products Association.
[2]Group I = AACCCCCCCCCAA
Group II = ACCCACCCACCCA
Group III = AACCCCCCCCCCA
Group IV = ACCCCCACCCCCA
Group V = AACCCCACCCCAA

These results have many implications. One is that group III, which contained two A-grade veneers on one face and one A-grade veneer on the oppostand face, showed the highest mean for all categories except edgewise MOE. Group IV, which had a single A-grade veneer on each face and one in the middle of the panel, gave the highest edgewise MOE and was second for all other categories. These two groups gave much higher values than those of group I and group V, which contained 4 and 5 A-grade veneers, respectively.

A possible financial gain may be realized by using only 3 A-grade veneers but placing them in a manner similar to group III or group IV. This theory was first proposed by Koch and Bohannan (1965), and Koch (1967a, 1967b). They proposed placing the stiffest laminae in the outer portions and the most limber in the center of the billet. There is little to gain by placing a single A-grade veneer in the middle of the panel as was the case with group IV. Clearly, mechanical properties can be significantly improved by optimal arrangement of A-grade veneer within a panel.

Conclusions

The highest mechanical properties were generally obtained with a veneer grade layup that placed 2 A-grade veneers on one face and a single A-grade veneer on the other face (i.e., group III). It was shown that stategic A-grade veneer placement in a panel will influence MOE values but not ultimate bending strength.

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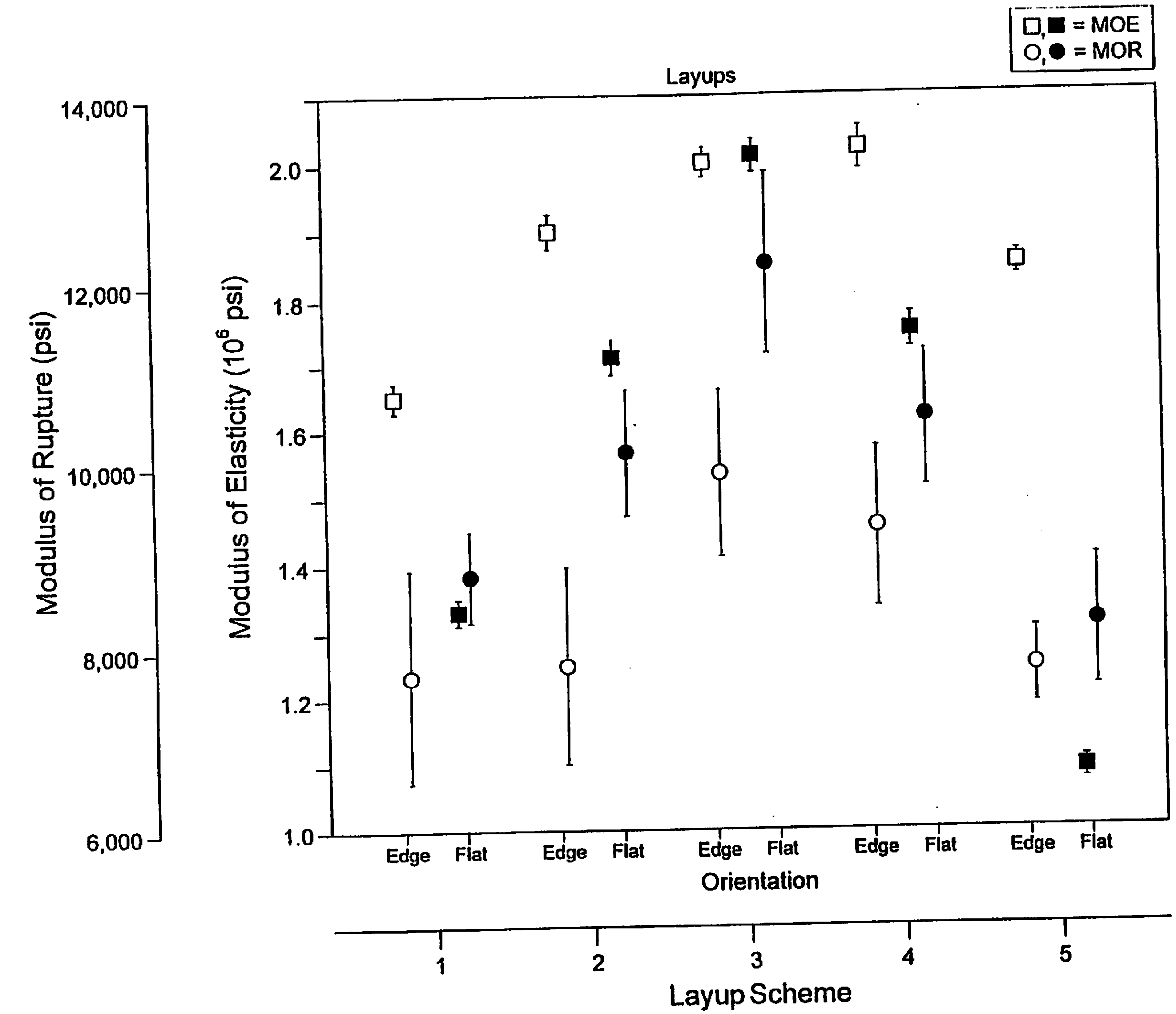

Figure 1 - The effect of five different veneer visual grade layups on edgewise and flatwise modulus of rupture of 13-ply loblolly pine laminated veneer lumber. The white circle and white square denote edgewise properties, and the black circle and black square represent flatwise properties.