Laminating Butt-Jointed, Log-Run Southern Pine Veneers into Long Beams Of Uniform High Strength

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Abstract

Twenty laminated beams were constructed of log-run, butt-jointed, loblolly pine veneers 1/6 inch thick and 100 inches long. The beams were 18 inches deep, 2 inches wide, and 25 feet long. Veneers were arranged in the beams according to their modulus of elasticity (MOE). The stiffest were placed outermost, and the most limber in the center. The veneers, which were cut on a lathe, ranged in MOE from 510,000 to 2,960,000 psi and averaged 1,690,000 psi. This average was 110,000 psi lower than the accepted species average. The beams had an average effective MOE of 2,110,000 psi. Average modulus of rupture was 9,020 psi, with a 95-percent exclusion limit of 7,170 psi, thus justifying an allowable stress in bending of 3,370 psi. A single beam constructed on the same principle but made from veneers selected to simulate log-run slash pine had an MOE of 2,400,000 psi and an MOR of 10,080 psi. The three butt joints in each lamina did not seriously reduce beam MOE.

In the United States, beams having outer laminae of upper grades of 1-inch, kiln-dry, southern pine lumber are assigned maximum allowable design values as follows:

Modulus of elasticity (MOE)	1,800,000 psi
Stress in bending	2,600 psi
Stress in horizontal shear	200 psi

If they were stronger, laminated southern pine beams could compete more vigorously in structural applications now dominated by steel bar joists.

Several experiments on the effects of locating southern pine laminae in beams according to elastic modulus have been executed since 1963 at the Alexandria, Louisiana, laboratory of the Southern Forest Experiment Station. A paper reviewing this series of experiments was presented at the 1967 IUFRO meeting at Munich and later published by the Southern Forest Experiment Station (5). The paper hypothesized the possibility of constructing 18-inch-deep, 25-foot-long beams that would justify assignment of an average effective MOE of 2,400,000 psi and an allowable bending stress of 3,470 psi. The beams were to be made of log-run, rotary-cut, thin, butt-jointed, slash pine (*Pinus elliottii* Engelm.) laminae arranged with the stiffest outermost in the highly stressed tension and compression zones and the most limber near the neutral axis.

The present paper reports further research that substantially confirms the hypothesis. Twenty beams 2 inches in width were constructed to the dimensions and by the system proposed. They were laminated from butt-jointed, log-run veneers 1/6 inch thick and 100 inches long, but the wood was loblolly (*Pinus taeda* L.) rather than slash pine.

When the beams were broken in bending, their values of modulus of elasticity (MOE) and 95-percent exclusion limit for modulus of rupture (MOR) were somewhat lower than the target values. When results were adjusted to take account of the higher species strength of slash pine, both target values were achieved.

Procedure

At a central Louisiana plywood plant, 102 southern pine bolts, principally loblolly, were randomly selected over a period of a few hours as they came down the infeed chains to the 8-foot lathe. The bolts averaged 14.6 inches in diameter inside bark (range 7-1/2 to 23 inches) and 5.2 rings per inch (range 2 to 14). They were roughly estimated to have 47 percent latewood outside a 5-1/4-inch core (range 25 to 70 percent).

After being steamed at 160° F. for 12 hours, the bolts were peeled on a lathe equipped with a roller nosebar. The green veneer, 0.172 inch thick and 102 inches long, was clipped into 26-inch widths.

The pieces were dried at about 400° F. in a jet dryer on the usual mill schedule. Emerging veneer

This paper was presented at Session 11—Wood Engineering—of the 22nd Annual Meeting of the Forest Products Research Society, June 26, 1968, in Washington, D.C. It was received for publication in June 1968.

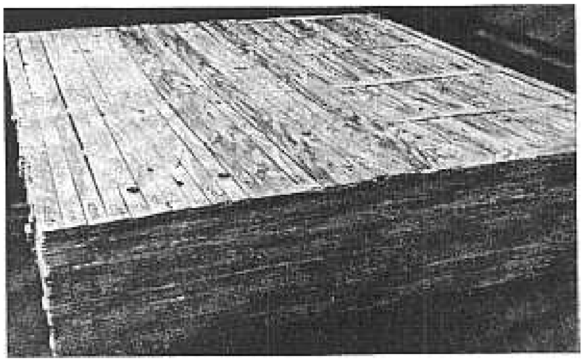

Figure 1. — Log-run strips of 1/6-inch veneer on sticks. Note frequency of knots and knot holes.

averaged about 4 percent in moisture content, was 1/6-inch thick, and exhibited 5.6 lathe checks per inch averaging 0.10 inch deep.

Preparation of Veneer Strips

The mill-dried veneer was transported to the Alexandria laboratory, placed on sticks, and allowed to reach EMC at 50 percent relative humidity and 72° F. dry bulb temperature.

After conditioning, it was straight-line ripped into strips 2.75 inches wide. Only broken or splintered veneers were discarded. Yield totaled 10,350 strips. As the strips came from the saw they were numbered sequentially from 1 to 10,350 and again piled on sticks in the same controlled atmosphere (Fig. 1).

Every fiftieth veneer, for example, those bearing numbers 50, 100, 150. . . . 10,350, was put aside for use in correlating dynamic and static values of modulus of elasticity. Each of these 207 veneers was trimmed to 100-inch length. The 2 trim ends from each strip were ovendried and weighed, and the moisture content was calculated. The volume and weight of each strip at EMC was then measured, and the specific gravity (basis of EMC volume and ovendry weight) was calculated. The average from this 2 percent sample was considered the average specific gravity of the entire lot of veneer.

Determination of Modulus of Elasticity

Experience has indicated the difficulty of measuring the modulus of elasticity of thin, knotty, cupped veneers. In a prior study (Final Report FS-SO-3601-3.8, on file at the Southern Forest Experiment Station's laboratory in Alexandria, Louisiana), 120 rotary-cut southern pine veneers, 1/6-inch thick, were first tested in static tension over a 70-inch gage length to determine static MOE. These veneers were then shipped to Washington State University[1] for evaluation of dynamic MOE (over the same 70-inch span) on equipment developed there. The apparatus propagates, and measures the velocity of, longitudinal stress waves in wood. Velocity of the stress wave is proportional to dynamic MOE (3, 6).

With static MOE plotted on the ordinate and dynamic MOE on the abscissa, a straight-line regression proved to have a coefficient of determination (r^2) of 0.919, with a standard error of the estimate of 98,000 psi. Static MOE averaged 2,060,000 psi, while dynamic MOE averaged 2,170,000.

This was sufficiently encouraging that a new, fast apparatus was constructed at Washington State University and brought to Alexandria for evaluation of all 10,350 veneers. The apparatus is shown in Figure 2. A 92-inch gage length was employed to encompass as nearly as possible the full length of the strips. The Δt, observed in microseconds, was remarkably repeatable. Each Δt recorded was the average of 3 readings. Each reading took about a second; with loading, unloading, recording, and weighing time considered, about 3 man-minutes were required for each strip. Prior to test, each strip was trimmed to 100-inch length and weighed. Measurements on every fiftieth strip averaged 100.03 inches for length, 2.389 inches for width, and 0.169 inch for thickness. These measurements were considered standard for the entire lot of veneers. Volume per strip was therefore assumed constant at 40.386 cubic inches.

The basic equation for determining MOE by this means is:

$$E_d = C^2\rho$$

where:

E_d = dynamic modulus of elasticity, psi

C = velocity of stress wave propagation

$$= \frac{\text{gage length}}{\Delta t}, \text{ inches/second}$$

$$\rho = \text{density} = \frac{\text{mass}}{\text{volume}}$$

$$= \frac{\text{wt.}}{(g)\ (\text{vol.})} \text{ or } \frac{\text{lbs.}}{\frac{\text{in.}}{\text{sec.}^2}\ (\text{in.})^3}$$

$$= \frac{\text{lbs. sec.}^2}{\text{inches}^4}$$

$$\therefore E_d = \left(\frac{\text{gage length}}{\Delta t}\right)^2 \left(\frac{\text{wt.}}{386 \text{ vol.}}\right)$$

$$\text{or } \left(\frac{\text{inches}}{\text{sec.}}\right)^2 \left(\frac{\text{lbs. sec.}^2}{\text{inches}^4}\right) = \text{psi}$$

Then, in the foregoing units:

$$E_d = \left(\frac{\text{gage length}}{\Delta t}\right)^2 \frac{\text{wt.}}{(386)\ (\text{vol.})}$$

With equipment available, it was more convenient to measure the weight of each strip in grams than in pounds. Since volume was standard-

[1]The authors appreciatively acknowledge the assistance of Roy Pellerin and Gary Gunning of Washington State University, Pullman, Washington, in determining the dynamic MOE of the laminae used in this research.

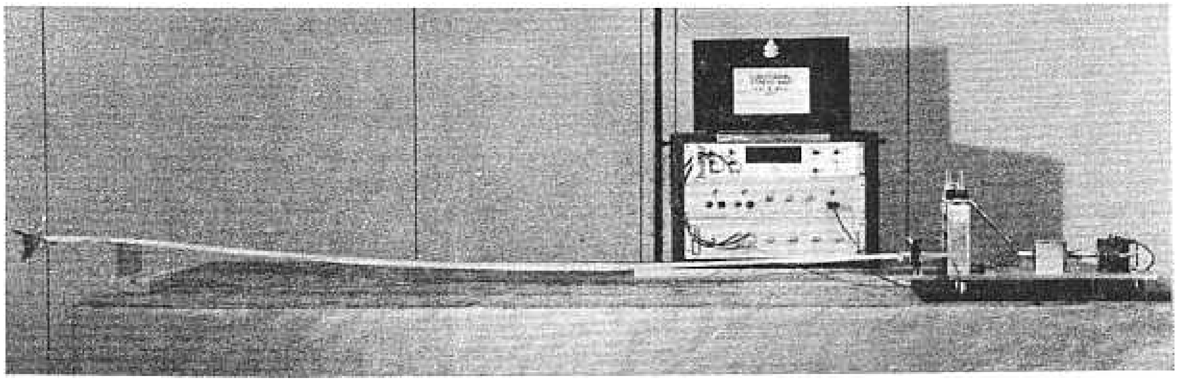

Figure 2. — Apparatus for measuring dynamic MOE over a 92-inch gage length. Solenoid-operated hammer for initiating longitudinal stress wave is at right. Accelerometers for sensing passage of the stress wave are attached to the two plier-type grips spaced 92 inches apart. Readout in timer window (top) was in microseconds.

ized at 40.386 cubic inches and Δt was in microseconds, the expression was simplified to:

$$E_d = K \left(\frac{\text{weight of strip in grams}}{(\Delta t \text{ in microseconds})} \right)$$

Where:

$$K = \frac{(92)^2}{(386)\ (40.386)\ (453.6)\ (10^{-12})}$$

$$\approx (1.197)\ (10^9)$$

Example:

Assume:

weight of strip

$= 440.1$ grams

$\Delta t = 521$ microseconds

Then:

$$E_d = (1.197)\ (10^9) \left(\frac{440.1}{(521)^2} \right)$$

$$= (1.94)\ (10^6) \text{ psi}$$

Correlation with Static MOE

For a check of the dynamic MOE values, the static MOE of every fiftieth strip was measured in full-length tension by means of a 100-pound preload followed by a 300-pound proof load (400-pound total load). A 120,000-pound Riehle universal testing machine was used (set on the 1,200-pound range). Strain was measured to the nearest 0.001 inch by dial gages on both sides of the veneer.

Gage length was 70 inches. The 92-inch length used in the dynamic determinations would have been preferable, but the tension grips of the testing device required considerable space at each end of the veneer.

Dial gages were zeroed under the preload and read under the proof load. Rate of crosshead travel was 0.15 inch per minute. Strain was recorded at 100-pound intervals. The series of observations was replicated 3 times for each veneer and the deflections averaged. MOE was calculated from the usual formula. Thirty veneers broke during test.

The correlation coefficient of the 177 pairs of observations was calculated and a regression line drawn.

Sorting of Veneer Strips

A total of 8,280 veneers (namely, 10,350 less broken veneers and all veneers numbered 5, 10, 15 . . . 10,350, which were used in another study) were computer-ranged by dynamic MOE from high to low and then divided into 54 groups (because each 18-inch-deep beam was 108 laminae thick) containing equal numbers of veneers. In other words, the high 153 veneers were put into group 1 for use as tension and compression skins. The next 153 veneers were put into group 2 for use in the laminae next to the tension and compression skins — and so on until group 54 contained the 153 veneers of lowest MOE, which were used in the central 2 laminae of the beams. Since 8,280 is not exactly divisible by 54, some groups contained 154 veneers.

Veneers were identified by dynamic MOE and placed in the proper slot of a 54-pocket sorting rack.

Assembly of Beams

Because the beams were to be 300 inches (25 feet) long, each lamina required 3 veneers. Butt joints were carefully staggered in the 108 laminae in a pattern estimated to minimize their effect on the net section and hence on the modulus of rupture (MOR). Each 25-foot lamina contained 3 butt joints, with the exception of the tension skin, which contained only 2. That is, all butt joints were (25) (12) / (3) (108) = 25/27 inch from the closest butt joint measured along the length of the beam. In other words, in the 25-foot length of each beam there was one butt joint for every 25/27 of an inch of beam length. Obviously, locating each butt joint correctly required cross-cutting one veneer in each lamina and placing one portion of the cut veneer at one end of the beam and the other portion at the opposite end.

For each pair of laminae in each beam, six veneers were randomly drawn from the proper pocket of the sorting rack and randomly assigned a position in the compression and tension sides of the beam.

Each of the 20 beams was preassembled in order to space the butt joints properly prior to glue application and pressing. All veneers were placed with the tight side outermost, that is, the glueline on the neutral axis of the beam had a loose-to-loose bond (Fig. 3).

A phenol resorcinol adhesive was applied with a double mechanical spreader at a rate of about 60 pounds per 1,000 square feet of glue line. This amount was divided equally between mating surfaces. The beams were laminated in a 25-foot press constructed for the purpose. Presure was applied to achieve fairly uniform glue squeeze-out. No longer than 60 minutes elapsed between spreading of the first veneer and application of pressure to the assembled beam.

A temperature of 72° F. was maintained in the press room, and the beams were allowed to cure approximately 24 hours under pressure. Beams aged at least 7 days after removal from the press and before testing.

Testing Procedure

The Riehle testing machine was modified to permit loading of the beams with 24 feet 4 inches between supports (Fig. 4). Load was applied at 2 points 20 inches apart and symmetrically about midlength of the beam. Rocker-type end supports were used, and roller nests were placed under one head to insure that loading was vertical. Rate of vertical movement of the loading heads was 0.6 inch per minute. The apparatus and speed of loading follow recommendations in ASTM D198-27, Static Tests of Timber.

Prior to test, beams were scraped free of squeezed-out adhesive, jointed on one side, and planed to 2-inch thickness. The dimensions, weight, and volume of each beam were then measured. Deflections between supports were measured to the nearest 0.01 inch with a taut wire and scale (simultaneously read with telescope on both sides of the beam). Tests were carried to destruction.

After each beam failed, a 1-inch cross-sectional slice was cut approximately 12 inches from one end and ovendried to determine moisture content. This moisture content was assumed to represent the average for the beam.

Fabrication of Two Additional Beams

In addition to the 20 beams assembled and tested as previously described, 2 additional beams of the same size were made. The first was comprised entirely of veneers that averaged 1,800,000 psi in dynamic MOE; they ranged from 1,675,000 to 1,925,000 psi. The veneers did not have an ordered placement in the beam but were located in a random fashion.

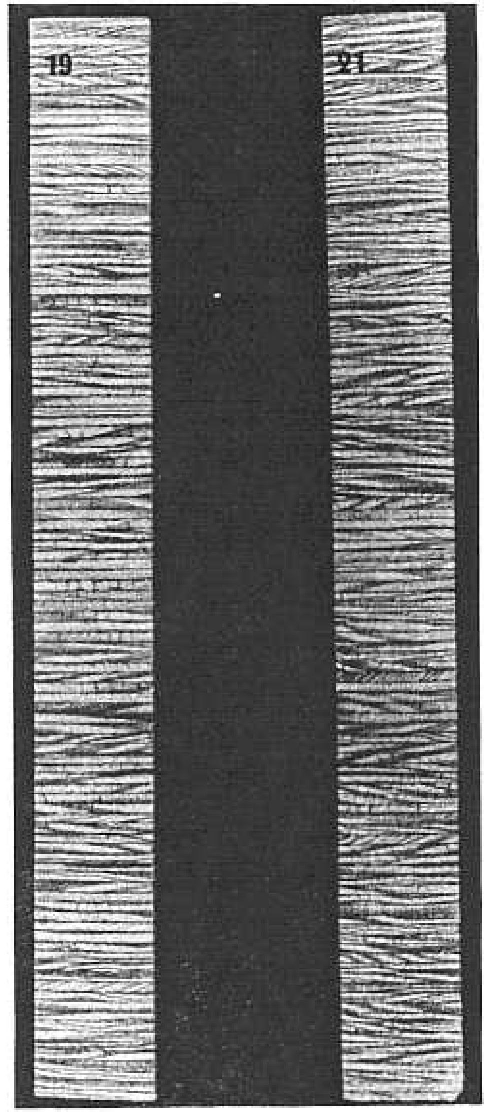

Figure 3. — Beam cross sections. All beams contained 108 laminae, each 1/6-inch thick and arranged with the tight side outermost. Lathe checks are visible. The beams were 18 inches deep and 2 inches wide, with tension side on the bottom.

In the second beam veneers for each lamina were chosen to be approximately 260,000 psi higher in dynamic MOE than the corresponding laminae in the previously described 20 beams. The intention was to simulate the probable distribution of MOE values in a random population of slash pine veneers, for in slash pine the average MOE is 260,000 psi higher than in loblolly. As will be seen, insufficient stiff veneers were located to accomplish accurately this shift in MOE.

Results

Specific Gravity and MOE of Veneers

Specific gravity of veneers numbered 50, 100, 150, . . . 10,350 averaged 0.536 (based on oven-dry weight and volume at 7.6 percent M.C.). Figure 5 shows the regression of static MOE on dynamic MOE for these same veneers.

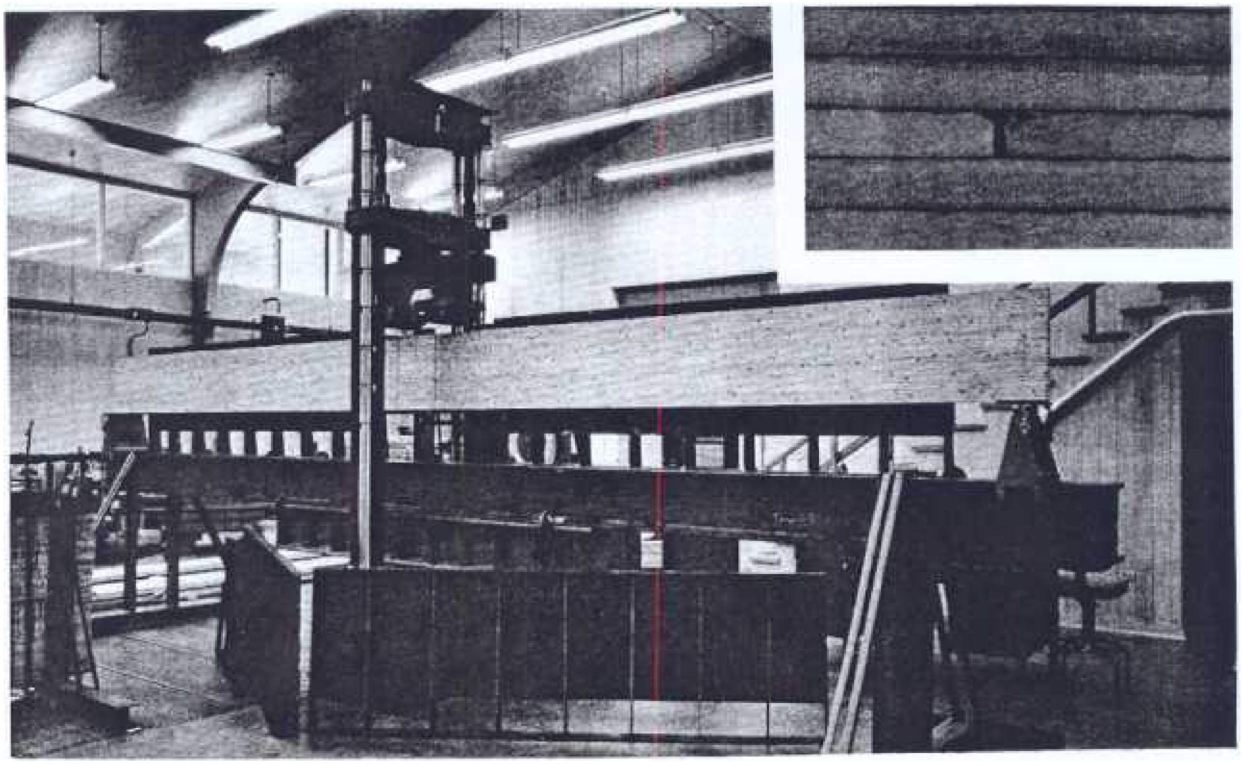

Figure 4. — Setup of testing machine for evaluating beams. Jigs providing lateral restraint on the near side of the beam were removed for purposes of illustration. Black circles on beam mark butt joints. The inset—upper right corner—shows a typical butt joint.

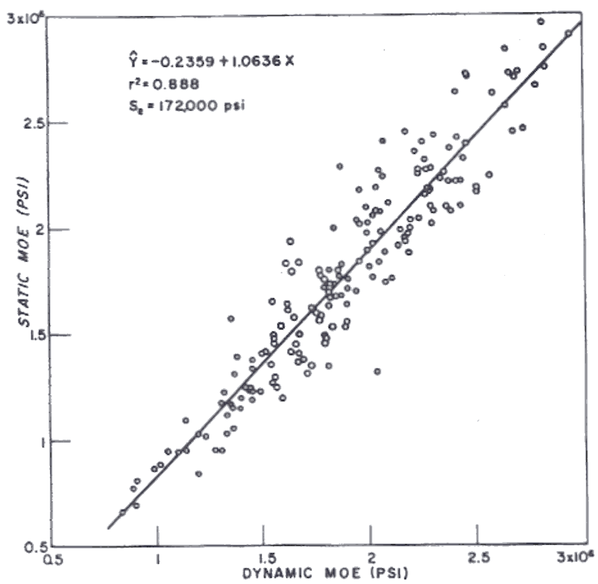

Figure 5. — Regression of static MOE on dynamic MOE, 177 observations.

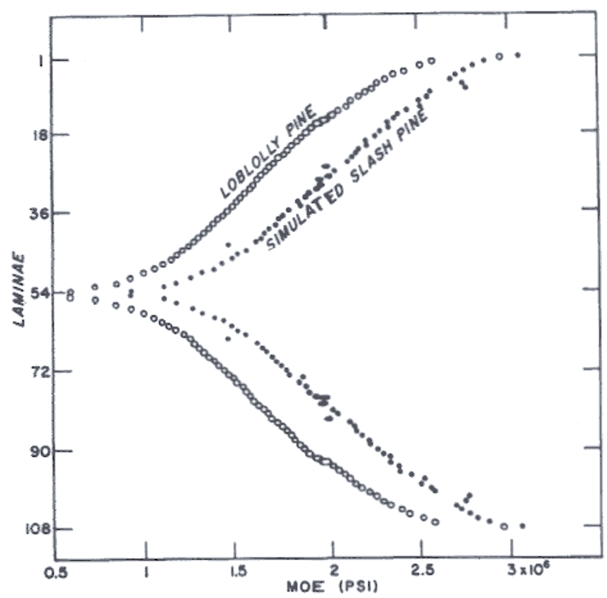

Figure 6. — Average calculated static MOE values for individual laminae comprising loblolly beams in main group of 20 (circles), and single beam simulating slash pine (solid dots).

Average observed dynamic MOE for the 8,280 veneers from which beam laminae were drawn was 1,810,000 psi. By the regression equation from Figure 5, average static MOE for these strips (at 7.6 percent M.C.) was calculated to be 1,690,000 psi. This is 110,000 psi less than the Wood Handbook's (9) value for loblolly pine at 12-percent moisture content. Figure 6 is a plot of the calculated average static MOE for each lamina in the 20-beam main test. Static MOE ranged from 510,000 psi for veneers at the neutral axis to 2,960,000 for those in the tension and compression skins.

Strength and Stiffness of Beams

In a beam with a gradient in elastic modulus from the neutral axis to the outer laminae there is no definitive elastic modulus of the wood as such, but there is a definite bending stiffness (EI). Hence the term MOE, as it is here applied to specific beams, should be interpreted as the effective or apparent MOE of the beam, rather than as a definitive MOE of any particular layer.

Detailed results of the bending tests are given in Table 1. The average specific gravity (volume at 12.2 percent M.C. and ovendry weight) for the 20 beams was 0.59.

For all beams, stress at proportional limit (column 7) and MOR (column 8) were calculated from the standard flexure formula, $f = Mc/I$, where f is the calculated stress, M is the applied moment, c is the distance from the neutral axis to the outer face of the beam, and I is the moment of inertia of the cross section.

The MOE's in column 9 were calculated from the deflection formula,

$$\Delta = (Pa/48EI)\ (3L^2 - 4a^2) + (3Pa/5GA)$$

where: Δ is midspan deflection, inches
- P = total load on beam, pounds
- a = distance from support to load point, inches
- E = MOE, psi
- I = moment of inertia of cross section, inches^4
- L = span length, inches
- A = cross-sectional area, square inches
- G = modulus of rigidity or shear modulus, psi

This formula accounts for deflections caused by both bending and sheer stresses. The shear modulus (G) was assumed to equal 1/16 the MOE (9, p. 78).

In general, the beams first developed compression wrinkles, about 5 laminae deep, under one or both loading heads, but final failure was in tension. Most of the tension failures occurred in the central 20 inches between loading heads, and the break progressed through some of the butt joints as the fracture developed toward the neutral axis. In 4 of the beams, the tension failure was initiated at one of the two butt joints in the tension skin. These joints were 100 inches from each beam end.

The average MOE was 2,110,000 psi, with little variation among beams (range 2,070,000 to 2,200,000 psi). Standard deviation was 30,000 psi. Theory predicted this with considerable accuracy. Thus, when the product (EI) of the static MOE and moment of inertia of each matching pair of laminae was calculated, summed with the product of all other pairs, and then divided by the moment of inertia of the entire beam, a calculated beam MOE of 2,118,000 psi was predicted. The butt joints in these 20 beams did not appear to affect beam MOE adversely.

Table 1. — RESULTS OF BENDING TESTS OF 20 SOUTHERN PINE BEAMS.

Beam No.	Height	Width	M.C.	Specific gravity[1]	Maximum load	Stress at proportional limit	MOR	MOE[2]	Type of failure[3]
		(3)	(4)		(6)	(7)		(9) 1000	(10)
	In.	In.	Pct.		Lbs.	P.s.i.	P.s.i.	P.s.i.	
1	18.29	2.03	12.0	0.60	15,700	6,020	9,450	2,120	C-T
2	18.35	2.03	11.6	.60	14,250	5,500	8,710	2,080	C-T
3	18.40	2.01	11.7	.61	15,725	5,690	9,420	2,100	C-T
4	18.27	2.01	11.8	.57	14,650	5,170	8,920	2,200	C-T
5	18.41	2.02	11.8	.59	15,325	5,670	9,150	2,160	T
6	18.44	2.02	12.8	.59	16,150	5,650	9,610	2,140	C-T
7	18.43	2.02	12.6	.59	14,930	5,360	8,880	2,110	C-T
8	18.40	2.02	12.8	.59	16,450	5,670	9,820	2,090	C-T
9	18.44	2.02	12.7	.59	16,650	5,940	9,890	2,110	C-T
10	18.35	2.01	12.8	.59	15,950	5,420	9,610	2,110	C-T
11	18.47	2.01	12.2	.59	12,750	5,050	7,570	2,090	T
12	18.55	2.02	12.9	.59	12,300	5,290	7,230	2,100	C-T
13	18.46	2.01	12.7	.60	12,900	5,050	7,670	2,130	T
14	18.46	2.01	12.5	.59	14,925	5,370	8,900	2,120	C-T
15	18.42	2.01	12.4	.58	16,750	5,370	10,000	2,110	C-T
16	18.50	2.01	12.7	.59	16,400	5,040	9,730	2,120	C-T
17	18.52	2.01	11.3	.60	14,950	5,030	8,850	2,070	T
18	18.50	2.01	11.3	.60	14,875	5,630	8,810	2,080	C-T
19	18.37	2.01	11.3	.60	15,400	4,800	9,250	2,080	C-T
20	18.39	2.01	11.3	.60	14,850	5,100	8,910	2,110	C-T
Avg.	18.42	2.02	12.2	0.59	15,090	5,390	9,020	2,110	

[1]Based on volume at test M.C. (column 4) and ovendry weight.

[2]Corrected for shear on assumption that ratio of MOE to modulus of rigidity is 16/1 (9,p.78).

[3]C = compression; T = tension. Sequence indicated when failure was multiple.

Those designers who do not bother to compute the shear-free value of MOE may be interested to know that the average uncorrected MOE of the 20 beams was 1,970,000 psi.

Stress at proportional limit averaged 5,390 psi and ranged from 4,800 to 6,020 psi.

MOR of the 20 beams averaged 9,020 psi and ranged from 7,230 to 10,000 psi. Depending on the method chosen, at least 3 MOR values can be derived as a lower limit on which to base an allowable working stress.

1. By the procedure outlined on page 47 of Steel and Torrie (8), a value of 7,650 psi can be calculated. The probability is 95 percent that a given future beam will have an MOR higher than 7,650 psi.

2. Table 1 shows that 95 percent of the beams tested, that is, 19 out of 20, had an MOR of 7,570 psi or higher.

3. The most conservative procedure requires the use of the tabulated K for one-sided statistical tolerance limits as given, for example, in Table A-7 of Natrella (7). By this procedure, the probability is 95 percent that at least 95 percent of the MOR values in the distribution from which the sample was drawn will exceed the average MOR less K times the standard deviation, namely, $\bar{x} - Ks$. From Table 1, $\bar{x} = 9{,}020$ psi and the standard deviation (s) is 772 psi. The appropriate K (for $n = 20$) is 2.396. The lower 5-percent exclusion limit for MOR then is 7,170 psi, with an associated probability of 95 percent.

A recognized allowable working bending stress for a specific population of beams can be calculated by breaking a random sample of beams, computing the 95-percent exclusion limit for MOR, and multiplying this value by 1/2.1 (4). The overall factor 1/2.1 is the product of three components: 9/16 for duration of load, 11/10 for normal loading, and 10/13 for factor of safety.

Application of this procedure to the 20 beams tested resulted in an allowable bending stress of 3,370 psi, that is, 7,170/2.1.

Consider now the two additional beams. Beam 22 was constructed of randomly placed veneers ranging in dynamic MOE from 1,675,000 to 1,925,000 psi. The average dynamic MOE of 1,800,000 psi corresponds to an average static MOE of 1,680,000 psi (Fig. 5).

The beam first developed compression wrinkles, then failed in tension at a maximum load of 14,600 pounds. Beam MOE (assuming a ratio of MOE to modulus of rigidity of 16/1) was 1,700,000 psi. This value agrees well with the average static MOE of the veneers comprising the beam. MOE uncorrected for shear deflection was 1,590,000 psi.

Stress at proportional limit was 4,710 psi, and MOR was 8,600 psi. The beam measured 2.03 by 18.49 inches, was tested at 13.0 percent M.C., and had a specific gravity of 0.60.

Beam 21 was constructed in an effort to simulate distribution of MOE values in a random population of slash pine veneers. That the effort was not entirely successful can be seen from Figure 6. Each lamina should have been comprised of veneers 370,000 psi higher than corresponding laminae in the 20-beam series, that is, the Wood Handbook's (9) value for slash pine MOE (2,060,000 psi) less the average static MOE of the veneer in the 20-beam series (1,690,000 psi). Thus, the average static MOE for veneer in beam 21 should have been 2,060,000 psi, and the range should have been from 880,000 to 3,330,000 psi. Figure 6 shows that the average was actually 2,040,000, with a range from 940,000 to 3,070,000 psi.

Beam 21 first developed compression wrinkles and then failed in tension at a maximum load of 16,950 pounds. Stress at proportional limit was 6,540 psi and MOR was 10,080 psi. The beam measured 2.03 by 18.40 inches, was tested at 11.3 percent M.C., and had a specific gravity of 0.63.

MOE uncorrected for shear deflection was 2,200,000 psi. If it is assumed that the ratio of true MOE to modulus of rigidity was 16/1, then beam MOE was 2,360,000 psi.

In order to apply the deflection formula given in the procedure section, it is necessary to know the modulus of rigidity with some accuracy. To improve the estimate of the modulus of rigidity of beam 21, the procedure described in ASTM D805, Plate Shear (Forest Products Laboratory Test), was applied to 2 undamaged, 18-1/4-inch lengths of beam 21. The test plates measured 18-1/4 inches square and contained veneer graded in MOE from 940,000 psi at the center to 3,070,000 at the edges. Prior to the plate shear test, the lengths were planed to 1/2-inch thickness.

The average modulus of rigidity of the beam lengths was 117,361 psi. This value, when inserted into the formula for beam deflection, gives a beam MOE of 2,400,000 psi.

Theory closely predicted this MOE for beam 21. When the EI of each of the matching pairs of laminae was calculated, summed with the EI of all other pairs, and divided by the moment of inertia of the entire beam, a calculated MOE of 2,470,000 psi was predicted. Evidently the butt joints did not greatly reduce the MOE of this beam.

Discussion

It would appear from this experiment that the hypothesis drawn in the previous publication (5) is correct. Uniformly strong, long, 18-inch-deep, southern pine beams can be fabricated from rotary-cut, log-run, butt-jointed laminae.

Slash pine probably offers the best opportunity. It has been widely planted throughout the South and, with loblolly, is the favored plantation species.

If it can be assumed that static MOE values for individual veneers range from approximately 880,000 to 3,330,000 psi, average 2,060,000 psi, and have the same distribution pattern as the loblolly pine curve of Figure 6, then a beam MOE of 2,400,000 psi should be assured. This is a one-third increase over the existing maximum design value. Furthermore, the MOR for such beams should average approximately 10,000 psi. Under these conditions, the 95-percent exclusion limit should justify an allowable bending stress of at least 3,470 psi. This is a one-third increase over the present maximum allowable (2,600 psi) for a beam 12 inches deep, and a 45-percent increase over the present maximum allowable (2,390 psi) for a beam 18 inches deep (2).

Although the beams in this experiment were only 18 inches deep, the good results achieved with log-run wood cause the authors to wonder if the system would be equally successful on beams 30 inches or more in depth. The system appears to offer one approach to the problem of low MOR observed in very deep structural beams assembled in the usual way (1).

A discussion of manufacturing costs is beyond the scope of this paper, but a few comments may be in order. First it is recognized that glue consumption (assuming no waste) per cubic foot of beam will be 4.32 pounds for 1/6-inch laminae as contrasted to 0.96 pound for 3/4-inch laminae. If glue is $0.30 a pound, this represents an additional material cost of $1.01 per cubic foot of the superstrength beam. Second, a beam 32 feet long and 18 inches deep requires 432 pieces when made from veneers 1/6-inch thick and 8 feet long. If the same beam is manufactured from 3/4-inch laminae 16 feet long it will contain only 54 pieces. Finally, there is a considerable cost in stress-rating the individual veneers, but it should be possible to design a production machine to measure dynamic MOE of veneers on a grading chain at a cost not much in excess of a double-end trim.

Offsetting these disadvantages are several gains. First, the superbeams are 1/3 stiffer and justify an allowable bending stress at least 1/3 higher than conventional beams. They therefore require only three-fourths as much wood. Buttjointing the laminae eliminates the expensive step of fabricating scarf or finger joints. Hopper-feeding of the 8-foot veneer strips should be feasible. Finally it may be observed that most producers of southern pine veneer now chip strips narrower than 6 inches and thus realize only $6.30 per green ton ($0.20 per cubic foot) on this material. These low-value strips could be diverted into a laminating plant. Most such strips are cut from the outer portion of the log during round-up and therefore should have a higher MOE than the average for the species being cut.

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