Use of Brazilian eucalyptus to produce LVL panels

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Abstract

Brazil stands out on the international eucalyptus pulp market, with large areas planted with this species, approximately 3,000,000 ha, mainly to supply the demands of this industrial sector. Several species are perfectly adapted to the country's environmental and climatic conditions, constituting a raw material with excellent silvicultural productivity, with trees reaching diameters of up to 30 cm at the base in a period of 8 years. Recent research has evaluated the diversification of the final use of this wood with the idea of obtaining other products from it, such as sawn planks and panels. The purpose of this study is to evaluate the potential of this raw material in the production of LVL panels, to characterize eucalyptus-based LVL, and to spark the interest of Brazilian companies (particularly plywood manufacturers) in this product, which is still nonexistent in Brazil's domestic market. LVL panels of structural dimensions were built in the laboratory using 3-mm-thick sheets. The panels were evaluated through static flexure tests, showing satisfactory results compared to technical information on LVL panels made of other raw materials and sold on the international market. Eucalyptus showed good potential for the manufacture of panels.

Several initiatives are currently ongoing in Brazil to diversify the use of eucalyptus forests cultivated for the production of wood pulp. Some species have adapted very successfully to the country's environmental conditions, producing high quality wood in quite short harvesting cycles of 8, 10, 12, or 15 years, depending on the application.

In response to the growing demand for solid wood and wood-based products, eucalyptus has become an important alternative for other segments of the lumber market besides the paper and pulp industry. Today, blanks and plywood are produced from this raw material, as well as sawn planks and boards. Most of these products are destined for export.

Structural panels known on the international market as laminated veneer lumber (LVL) constitute a product with a high potential to gradually replace structural elements of wood from native species that are still widely utilized in civil construction in Brazil. Some pioneering companies are already using eucalyptus as raw material for the production of sawn planks and boards for both civil construction and the furniture industry. However, the sawing process of this wood is tricky, involving several problems, especially splitting and warping of the final product.

No LVL manufacturer exists in Brazil so far, but LVL has been produced on a laboratory scale at some research institutions. The author of the first Brazilian paper on the subject, published in 1997 (9), used *Pinus taeda* wood as a raw material, which is commonly utilized by sawmills in southern Brazil. His work reported on the gains attained in the strength of LVL panels, based on their classification according to modulus of elasticity (MOE), for which he employed the technique of acoustic wave propagation.

In the present study, we sought to evaluate some characteristics of strength of LVL panels produced on a laboratory scale from a genetic eucalyptus material

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Figure 1. — Eucalyptus grandis Hill ex Maiden and Eucalyptus urophylla S.T. Blake hybrid tree used as raw material.

Figure 2. — Lamination process of the logs on a laminating lathe.

very popular in commercial silviculture in Brazil.

Materials and methods

Materials

The raw material used for the production of the LVL panels was a hybrid of *Eucalyptus grandis* Hill ex Maiden and *Eucalyptus urophylla* S.T. Blake. This hybrid has been planted extensively in southeastern Brazil and today is one of the main genetic materials consumed by the pulp and paper industry in this country. Its wood has a basic density of about 0.5 g/cm^2. **Figure 1** shows a detailed picture of one of the trees selected to supply raw material. Ten logs were selected through random sampling from a commercial plantation cultivated by cloning, with 3.5 m by 1.7 m spacing between trees, close to the city of Mogi-Guaçu in the state of São Paulo, southeastern Brazil. At the time of the sampling and collection of the material, the stand was 10 years old.

Methods

Collection of the logs. — The 10 logs used as raw material for the panels were taken from 10 different trees in the stand. The first log was taken from each tree starting at the base in order to take advantage of the largest diameter of this part of the trunk. The trees had a diameter of approximately 35 cm at a height of 1.30 m from the base.

Immediately after felling, 2-m-long sections were measured from the base of the trunk upwards and sawed off. The two ends of each log were then coated with a waterproofing product to reduce the drastic loss of moisture and subsequent splitting and cracking.

Two rings were then sawn around the entire circumference of each log, at a depth of one-third of their diameter and at 30 cm from each end of the log. The purpose of these rings was to reduce the effect of growth stresses, which cause cracking deleterious to lamination.

The logs were left in the field for 24 hours, avoiding the loss of moisture. Twenty-four hours after felling, the material was transported to the testing site. In the laboratory, the logs were kept submerged in water in a metal tank to maintain a high level of moisture until they were laminated.

Lamination. — Lamination was carried out using a rotary-peeled lathe adjusted to produce 3-mm thick, 1.25-m wide sheets. For this operation, the logs were preheated in a heating tank. The heating time of 11 hours and temperature of 71°C were based on the wood's basic density and the diameter of the logs, as recommended in the studies of Lutz (8) and Feihl and Godin (4). **Figure 2** shows a detail of the lamination process.

After leaving the lathe, the sheets were clipped into 1.25-m by 0.96-m pieces and left in the open air to dry under a roof. The sheets were placed to dry in a horizontal position with separators between them, to allow air to circulate freely over each one. Twenty days after lamination, the sheets had reached a moisture content of about 12 percent.

Preparation of the panels. — LVL panels differ from traditional plywood, particularly insofar as their assembly is concerned. In LVL panels, the sheets are always oriented in the same direction, the number of sheets may exceed 20, their thickness may vary from 2.5 mm to 12.7 mm, and the panels' dimensions may reach up to 70 mm of thickness and more than 20 m in length (7,9,11).

Six panels were produced in the laboratory, each having a thickness of 54 mm, composed of 18 sheets, with a final width of 17 cm and length of 1.25 m. The panels were produced using phenol-formaldehyde resin, and the process stages were: pre-pressing for 1 hour and hot-pressing at 145°C for 40 minutes under a pressure of 1.3 MPa.

The formulation of the adhesive followed the work carried out at the Federal University of Paraná (9), which involved the production of *Pinus*-based LVL panels. Several modifications were introduced in the formulation used in those earlier studies, owing to the different raw material.

The amount of adhesive used per area of sheet (weight) was 360 g/m^2. **Table 1** lists the proportion of each ingredient utilized.

Testing. — To evaluate the LVL, two bending specimens, 5 cm wide, 5 cm thick, and 115 cm long, for each panel, were prepared and tested by center-point

Table 1. — Formulation of the ingredients by parts in weight.

Material	Parts
Phenol-formaldehyde resin (commercial name: Cascophen HL 2080)	100
No. 9 powdered coconut shell (commercial name: Albex no. 9)	5
Wheat flour	5
Water	10

Table 2. — Dimensions of the logs, initial and final volumes (rest of the log) and lamination yields.

Log	Length	Largest diam.[a]	Smallest diam.[a]	Cylindrical diam.[b]	Rest of log diam.[c]	Initial volume	Volume of rounded log	Rest of log volume	Laminated volume[d]	Volume of each sheet[e]	No. of sheets obtained	Volume in sheets	Lamination yield (green)
	(m)	- - - - - - - - (cm)	- - - - - - - -			- - - - - - - -	- - - - - - - - (m³)	- - - - - - - -				(m³)	(%)
1	1.25	29.8	28.5	26.4	13.6	0.083	0.068	0.018	0.050	0.004	13	0.047	56.1
2	1.25	29.1	28.5	25.7	14.0	0.081	0.065	0.019	0.046	0.004	12	0.043	53.1
3	1.25	27.8	26.6	24.4	12.8	0.073	0.058	0.016	0.042	0.004	11	0.040	54.6
4	1.25	29.2	27.9	25.4	13.0	0.080	0.063	0.017	0.047	0.004	12	0.043	54.0
5	1.25	29.4	28.3	25.7	17.6	0.082	0.065	0.030	0.034	0.004	9	0.032	39.7
6	1.25	26.5	24.5	24.6	14.2	0.064	0.059	0.020	0.040	0.004	10	0.036	56.3
7	1.25	30.9	29.3	25.8	12.5	0.089	0.065	0.015	0.050	0.004	13	0.047	52.8
8	1.25	31.1	29.9	25.5	19.3	0.091	0.064	0.037	0.027	0.004	7	0.025	27.6
9	1.25	29.5	28.7	25.1	12.2	0.083	0.062	0.015	0.047	0.004	12	0.043	52.0
10	1.25	31.5	29.9	27.0	13.7	0.093	0.072	0.018	0.053	0.004	14	0.050	54.4

[a] Without bark.
[b] Diameter of the rounded log, corresponding to the point during lamination at which a whole sheet corresponding to the log's total length is obtained.
[c] Diameter of the rest of the log at the end of the lamination process.
[d] Volume of the rounded log minus volume of the rest of the log.
[e] Obtained by the final dimension of the sheet after slicing: 0.96 m by 1.25 m by 0.003 m.

Table 3. — Modulus of rupture and modulus of elasticity determined from static bending tests (mean of six tested panels for each position).[a]

Specimen	MOR	MOE
	- - - - - - (MPa)	- - - - - -
A: flatwise	59 (5.0)	13,792 (4.9)
B: edgewise	55 (4.4)	12,917 (8.1)

[a]Values in parentheses are coeffecients of variation; 1 MPa = 145 psi.

loading on edge over a span of 105 cm. The equipment was regulated to insure failure with a 10 MPa/min. loading rate. Destined for predominantly structural purposes and applications similar to those of solid wood elements, in this work the panels were evaluated following the same methodology described in the Brazilian NBR 7190:1997 code (2) for non-laminated panels.

Results and discussion

Table 2 presents the initial and final dimensions of the logs and the performance results of the lamination process.

Lamination of the wood yielded up to 56 percent, which represents a good yield for this wood. The behavior of eucalyptus in sheet production is still in the study and development phase. A few plywood manufacturers in southern Brazil have been working with eucalyptus species, but data on their yields are still unknown.

Compared to the yield resulting from the production of eucalyptus planks and boards, which usually lies in the range of 40 percent (3), lamination undoubtedly represents a significant gain in terms of utilization of raw material.

During lamination of log numbers 5 and 8, whose yields were rather low (39% and 27%), slipping of the claws of the lathe occurred, causing premature interruption of the laminating process.

Table 3 lists the mean values of the modulus of rupture (MOR) and MOE obtained from the static bending tests on the six LVL panels produced from the sheets. The samples displayed a mean moisture content of 10.5 percent and a mean specific gravity of 0.66 g/cm³. The letters A and B indicate the position of the tested specimen, flatwise or edgewise (**Fig. 3**).

The MOR and MOE values for test position A (flatwise) were slightly higher than those for position B (edgewise). The slightly increased values for the A position can be explained by the densification of the surfaces from the pressing process.

Kunesh (7) also presents slightly higher results for flat bending stiffness (16,138 MPa) compared to edge bending stiffness (15,931 MPa) for LVL made from Douglas-fir (*Pseudotsuga menziesii*) veneer.

In **Table 4**, the results found for the eucalyptus-based LVLs are placed next

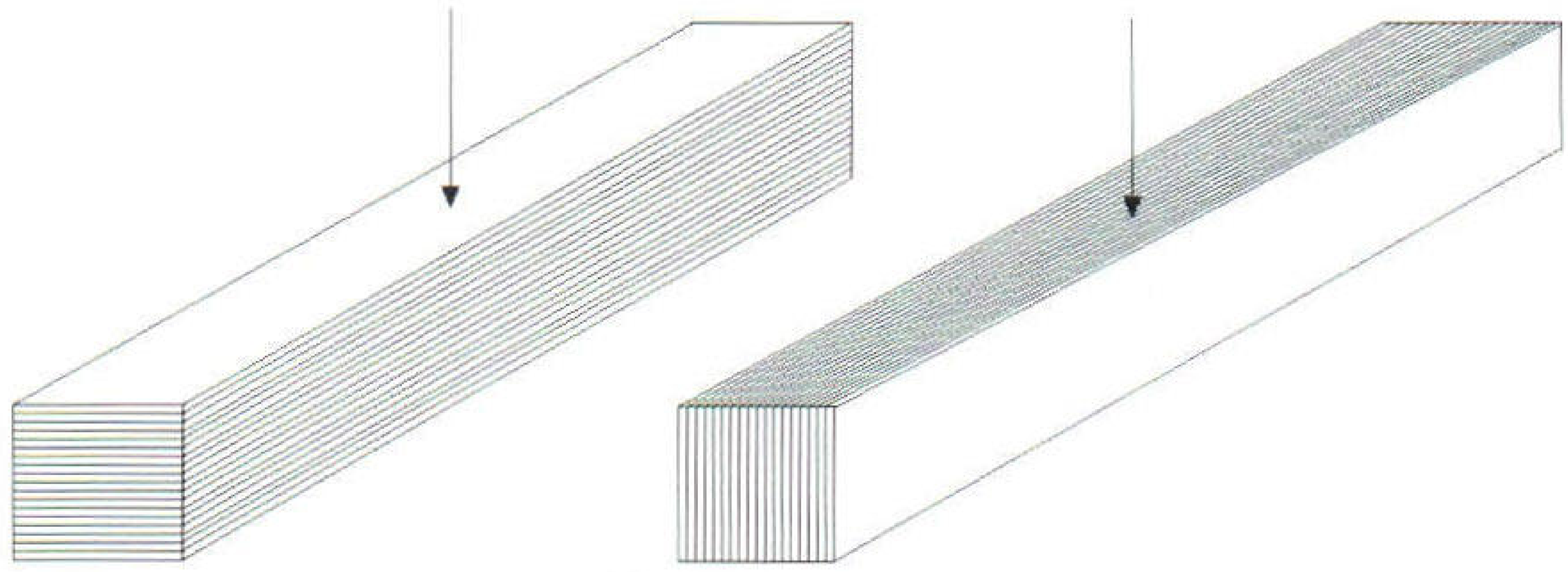

Figure 3. — Positions A and B of the test specimens in the static bending tests.

to some average values calculated from work published in the literature, for which the ASTM D 198 procedures (1) were used to evaluate LVL panels.

The LVLs produced in our study displayed very similar results congruent with other studies found in the literature. Moreover, the eucalyptus panels presented better results than those obtained by Kretschmann et al. (6), who used 2.5-mm- and 3.2-mm-thick Douglas-fir and *Pinus* consecutively. The eucalyptus wood that composed the panels has a specific gravity around 0.64 g/cm^3, MOR varies from 45 to 80 MPa, and MOE varies from 12,000 to 17,000 MPa (10). The results found in LVL tests are coherent with the raw material characteristics.

The results of the LVL produced from the *Eucalyptus grandis* Hill ex Maiden and *Eucalyptus urophylla* S.T. Blake hybrid were also superior to those of Matos (9), who carried out studies in Brazil with *Pinus taeda*.

However, the work of Jung (5), who produced LVL panels using thicker Douglas-fir sheets of 6.3 mm thickness, gave better results than those of the work reported on herein.

Conclusions and recommendations

The following conclusions and recommendations were drawn, based on the results and the methodology utilized here:

- The pilot-scale LVL panel production system proved satisfactory, resulting in a product with quality characteristics comparable to those of panels produced internationally on both pilot and commercial scale.

- In comparison with the production of sawnwood pieces for the same applications, the production of eucalyptus LVL panels offers a very interesting alternative in view of the gains in yield achieved in the lamination process compared to the yield of sawn boards.

- Eucalyptus displayed a great potential for the production of LVL panels. In Brazil, in view of the ample availability of commercial plantations from other industrial sectors, the development of this type of material may be facilitated.

- Other species of eucalyptus, with densities and characteristics unlike the ones studied here, can and should be tested. Studies involving LVL panels should be encouraged, considering the demand of the international market for this type of product.

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Table 4. — Comparison of the properties of LVLs determined from static flexure tests with those of other published data (mean values calculated from the data cited here); the last line refers to the data of the present study.[a]

Source	Species	Thickness of the sheets	MOR	MOE
		(mm)	----- (MPa) -----	
Jung (5)	Douglas-fir	6.3	59	17,053
Kretschmann et al. (6)	Douglas-fir	2.5	51	11,794
Kretschmann et al. (6)	Southern pine	3.2	58	11,229
Matos (9)	*Pinus taeda*	3.2	40	7542
		4.2	38	7721
Eucalyptus grandis Hill ex Maiden and *Eucalyptus urophylla* S.T. Blake hybrid		3.0	57[b]	13,354[b]

[a] 1 MPa = 145 psi
[b] Mean of positions A and B