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PHYSICAL PROPERTIES OF LAMINATED VENEER LUMBER MADE WITH CAMEROONIAN HARDWOODS AND NEOPRENE CONTACT ADHESIVE

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ABSTRACT

In this work we were interested in the physical properties of wood-adhesives composite materials, specially the case of laminated veneer lumber (LVL). We made samples of laminated veneer lumber using veneer from Ayous and Sapelli and neoprene contact adhesive. Experiments have been carried out enabling us to determine the moisture content of the samples, their densities, their swelling and shrinkage coefficients in all the directions and the hygroscopic point of equilibrium. We found that for a type of species, the ratios of the volume (respectively of the mass) of the lumber saturated in water over the anhydrous volume (respectively of the mass) is constant. Contrary to the phenol-formaldehyde adhesives usually used in developed countries for the manufacture of LVL, the neoprene adhesive used, proved to be interesting for its performance.

Keywords: veneer, LVL, neoprene, wood composite material, Cameroon.

INTRODUCTION

In Cameroon, the sectors of construction and public works largely use materials such as cement (in majority imported), concrete, and metals. Little place is given to wood products. However, compared to other materials, wood presents many advantages:

- Wood is a raw material abundant and inexhaustible for little that the forests are well managed;
- Its exploitation and its implementation consume little energy compared with those of other materials;
- From wood, one can manufacture many composite materials (wood-adhesive, wood-cement, wood-plastic) having mechanical properties, acoustic, thermal and interesting quality/price ratios. Force is to note that in a wood producing country like Cameroon, this material is not widely used in buildings and its local transformation is limited compared to the consumption of wood over the world [1]. It is almost rare to see in the great cities of Cameroon buildings made of wood, or industries specialized in the manufacture of wood composite materials such as particle boards, laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL), Oriented Strand Board (OSB), Medium Density Fiberboard (MDF). Only plywood is manufacture by a few companies, etc.

We have within the framework of this paper, manufactured LVL specimens with veneer from the following Cameroonian hardwood species: Ayous (a very light wood) and Sapelli (a medium-weight wood). They are bonded together with neoprene adhesive. The goal of our work consists of the determination of the moisture content of our samples, their density, their coefficients of volume shrinking and swelling, their hygroscopic point of equilibrium when immerged in water until saturation of the samples.

MATERIALS AND METHODS

In this section, we will present the manufactured samples, the methods used to determine the physical characteristics (moisture content, coefficients of volume withdrawal and swelling, average density), and the material used.

Design and presentation of the samples

With regard to the design of the samples, we used veneers from Ayous and Sapelli.

The veneers used had a thickness of 1mm. The manufacture of the samples began with the cutting of veneers in bands of 16 cm x 5cm.

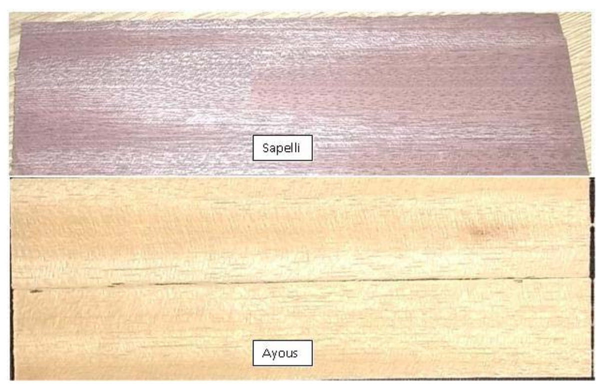

Figure-1. Samples of veneer used.

To glue the bands of veneer between them, we used the Magpow MDP 102 adhesive. According to the manufacturer this adhesive is a fast drying adhesive which resists oil, water, heat, and vibrations. The principal component of this adhesive is the neoprene gum (artificial rubber). Neoprene is a polymer with chloroprene as monomer [2]. The adhesive must be used in a ventilated environment and one must avoid its contact with skin and eyes. Its characteristics are in the following table [3]:

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Figure-2. The Magpow adhesive.

Table-1. Technical sheet of Magpow MDP 102 adhesive.

Appearance	**blond viscous liquid**
Product code	MPD 102
Percent volatile content (0/0)	(20±2)
Viscosity	(25°C, mPa.s 1) 2000-4000
Utilization	Decoration, architecture, gluing of wood, glass, rubber, etc.

The principle of manufacture of the samples consisted of sticking the pieces two by two by making sure that the fibres of the pieces of veneer are directed in the same direction and that surfaces to be glued are clean and dry [6] [7] [8] [9]. After having stuck two pieces, we press them to optimize the mutual adhesion of the two surfaces. With the bands obtained, we repeat the operation until obtaining the desired thickness.

To press the pieces of veneer at high temperature, we respectively used a screw clamp and a drying oven.

Figure-3. The screw clamp used.

(a)Exterior view (b) Interior view

Figure-4. The dry oven.

To measure the weight of the samples during experiments we used the following balance.

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Figure-5. Balance.

Table-2. Characteristics of the Ayous specimens.

	Number of layers	**length** (cm)	**width** (cm)	**thickness** (cm)	**weight** (g)	**Volume** (cm^3)	**Density** (g/cm^3)
A1	18	15.90	4.75	1.20	40.80	90.63±1.00	0.450±0.005
A2	24	15.89	4.80	1.50	53.80	114.40±1.07	0.470±0.004
A2	36	15.90	4.80	2.10	72.30	160.27±1.19	0.451±.,003

Thus we obtained:
- With veneer of Ayous, three samples A1, A2, A3:

Table-3. Characteristics of the Sapelli specimens.

	Number of layers	**length** (cm)	**width** (cm)	**thickness** (cm)	**weight** (g)	**Volume** (cm^3)	**Density** (g/cm^3)
S1	16	15.90	4.75	0.85	45.10	64.19±0.93	0.702±0.010
S2	32	15.90	4.75	1.65	86.60	124.61±1.09	0.694±0.006

- With veneer of Sapelli, two samples S1, S2:

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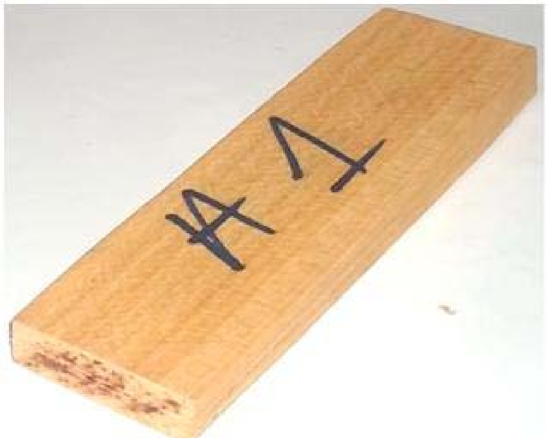

(a) Specimen of Ayous LVL lumber A1.

(b) Specimen of Ayous LVL lumber A2.

(c) Specimen of Ayous LVL lumber A3.

Figure-6. Specimens of Ayous LVL lumber.

(a) Specimen of Sapelli LVL lumber S1

(b) Specimen of Sapelli LVL lumber S2

Figure-7. Specimens of Sapelli LVL lumber.

METHODS

In this section we present the methods used to evaluate the physical characteristics of our LVL samples.

Calculation of the density

To calculate this physical property, we measure the weight of the sample and its dimensions (which enable us to calculate the volume).

The density is given by: $\rho = \frac{m}{V}$ m and V are respectively the weight and the volume of the sample.

The relative density is given by: $d = \frac{\rho_{\square}}{\rho_{eau}}$

Calculation of the moisture content of the samples

To calculate the moisture content of a sample, we first measure its weight. Then, we place it in a drying oven

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at 103°C until stabilization to dry it. It is withdrawn at regular intervals of times to measure the weight. One must repeat the operation until the mass does not vary any more. The values of the wet weight (m_H) and anhydrous wood (m_S) of the wood are consigned in a table.

Calculation of the coefficients of volume shrinkage and swelling and point of saturation of the samples

For these measurements we use: a ruler, a basin of water, a drying oven. To measure the coefficient of swelling, we proceed as follows: we completely immerse the anhydrous specimen in water, after having measured its weight and dimensions. We measure its weight and dimensions at regular intervals of times until its mass does not evolve any more. At this point saturation is reached. We then remove the specimen, wipe water from it, and measure its mass and dimensions at saturation.

Swelling is given by:

$$swelling(\%) = \frac{\text{dimensions of the sample at saturation} - \text{dimensions of the anhydrous sample}}{\text{dimensions of the anhydrous sample}} X100$$

To measure the shrinkage coefficient we used the saturated sample, placed it in the drying oven at 103°C and measured its weight and dimensions at regular intervals of times. It was definitively removed from the drying oven when its weight did not vary any more and his dimensions again were measured. The shrinkage is given by the following relation:

$$shrinkage(\%) = \frac{\text{dimensions of the sample at saturation} - \text{dimensions of the anhydrous sample}}{\text{dimensions of the sampleat saturation}} X100$$

The saturation point (PS) of the samples is given by the relation:

$$PS(\%) = \frac{\text{weight at saturation} - \text{anhydrous weight}}{\text{weight at saturation}} X100$$

Determination of the hygroscopic point of equilibrium

To measure the hygroscopic point of equilibrium, the anhydrous sample is put in the environment of our laboratory. Its weight will vary as it gains moisture from the surrounding air until a limit value corresponding to the time when the sample reached hygroscopic equilibrium with the ambient air. The hygroscopic point of equilibrium (EH) is given by:

$$EH(\%) = \frac{\text{weight at equilibrium} - \text{anhydrous weight}}{\text{anhydrous weight}} X100$$

Calculation of uncertainties

In the relations below:

L = length of the sample;

L = width of the sample;

E = thickness of the sample;

V = L×l×e is the volume of the sample;

m = weight of the sample;

ρ = density. Various uncertainties are given by:

$\Delta L = \Delta l = \Delta e = 0,\ 01$cm; $\Delta m = 0,\ 01$g.

$$\Delta V = V.\Delta l\ [\frac{1}{L} + \frac{1}{l} + \frac{1}{e}]$$

$$\Delta\rho = \rho\ [\frac{\Delta m}{m} + \frac{\Delta V}{V}]$$

RESULTS AND DISCUSSIONS

In this section we present the results of the measurements taken, the calculations made, and give an interpretation and discussion of these results. The results which we present are obtained by supposing specimens are homogeneous.

Calculation of the moisture content of the specimens used

The drying of the veneer samples of Ayous and Sapelli enabled us to have the following results:

Table-3. Initial moisture content of the wood veneer used.

	m_H (g)	m_S (g)	**Moisture content** (%)
Sample of Ayous veneer 16 ×15cm^2	1.1	1.0	10.0
Sample of Sapelli veneer 16×15cm^2	2.4	2.2	9.0

Results obtained during drying

The process of drying of the samples enabled us to follow the evolution of their weight and to obtain the following graph:

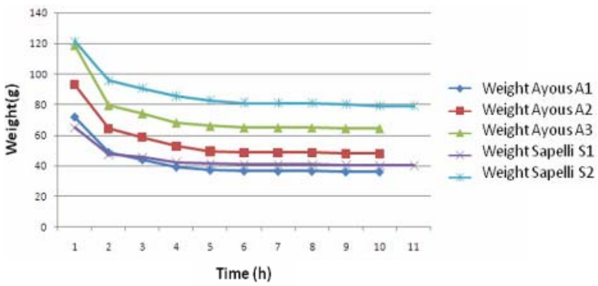

Figure-8. Evolutions of the weights of the sample during drying.

Interpretation

The analysis of the curves shows that during the first two hours of drying, the weight of the samples significantly lowers. The specimens of Ayous and Sapelli have a good speed of drying.

Calculation of the moisture content of the samples

The moisture content of the samples is given in the following table.

Table-4. Moisture content of the specimens.

Specimens	m_i (g)	m_S (g)	Moisture content (%)
A1	40.80	36.80	10.86
A2	53.80	48.80	10.24
A3	72.30	65.80	09.87
S1	45.10	41.22	09.41
S2	86.60	80.01	08.23

m_i = weight of the specimen before drying
m_s = weight of the specimen after drying

Average relative density of LVL specimens of Ayous and Sapelli

We used measurements of dimensions of the anhydrous samples, which enabled us to calculate their average relative density. The results are consigned in the following table.

Table-5. Average relative density of LVL specimens.

Specimen	m(g)	L(cm)	l(cm)	e(cm)	V(cm^3)	Anhydrous density (g/cm^3)	Anhydrous relative density
A1	36.80	15.85	4.70	1.10	81.94±0.97	0.449±0.005	0.449±0.005
A2	48.80	1575	4.75	1.45	108.47±1.04	0.449±0.004	0.449±0.004
A3	65.80	15.80	4.70	2.00	148.52±1.15	0.443±0.003	0.443±0.003
S1	41.22	15.85	4.70	0.80	59.59±0.90	0.691±0.010	0.691±0.010
S2	80.01	15.85	4.70	1.55	115.46±1.06	0.693±0.006	0.693±0.006

$\rho_{water} = 1 g.cm^{-3}$: density of water
d = relative density

Interpretation

With the preceding results, we can calculate the average values of the relative densities of the specimens.
-Average relative density of Ayous specimens:

$$d_{Ayous} = \frac{dA1 + dA2 + dA3}{3} = (0.447 \pm 0.004)\ g.cm^{-3}$$

- Average relative density of Sapelli specimens:

$$d_{Sapelli} = \frac{dS1 + dS2}{2} = (0.692 \pm 0.008)\ g.cm^{-3}$$

We can thus say that the specimens of LVL in Ayous and Sapelli have a density higher than that of the solid wood of Ayous and Sapelli at 12% of moisture content (respectively 0.38 and 0.69 [4]). This result is explained by the nature of the composite material (compound of veneer and adhesive) due to the pressure exerted on the veneers. Moreover we can also notes that the density also depends on the moisture content of the sample.

Results of the saturation point of equilibrium and the swelling coefficient

Measurements were taken until stabilization of the weights. The experiment of humidification of the samples gave the following results:

Calculation of the saturation point of equilibrium

The results can be found in the following table:

Table-6. Saturation point of equilibrium.

	A1	A2	A3	S1	S2
m_S (g)	36.80	48.80	65.80	41.22	80.01
m_{Sat} (g)	71.76	93.09	118.68	64.83	121.57
Saturation point PS (%)	48.717±0.020	47.577±0.014	44.556±0.010	36.418±0.010	34.186±0.007
m_{Sat}/m_S	1.9	1.9	1.8	1.5	1.5

m_S = weight of the anhydrous sample and m_{Sat} = weight of the sample saturated with water.

The calculation of the uncertainty on the saturation point of equilibrium is given by:

$$\Delta (PS) = PS x \Delta m \left[1/ms + 1/msat\right]$$

From the preceding results, we obtain an average value of the saturation point of equilibrium of the LVL specimens of Ayous and Sapelli:
PS_{Ayous} = (46.950±0.014) % and $PS_{Sapelli}$ = (35.302±0.008) %.

Interpretation

The saturation point of equilibrium of LVL specimens of Ayous is higher than that of specimens of Sapelli. This is explained by the fact that Ayous is a light wood [4] thus very absorbent of moisture (low density of fibres), contrary to Sapelli which is a medium-weight wood. We also notice that within the same species of a given LVL specimen, the ratio mSat/m_S practically constant.

Calculation of the swelling coefficients

G is the swelling coefficient calculated according to the length (L), the width (l) and the thickness (e), as well as the volume swelling coefficient. The indices sat and S refers respectively to the characteristics of the saturated samples and the anhydrous samples. The results can be found in the following tables.

- **According to the length**

Table-7. Swelling coefficient according to the length.

	A1	A2	A3	S1	S2
L_{Sat} (cm)	15.88	15.79	15.85	15.90	15.87
L_S (cm)	15.85	15.75	15.80	15.85	15.85
$G_L = \frac{Lsat - Ls}{Ls} x100$	0.18	0.25	0.31	0.31	0.12

Interpretation

The variation of the length of the LVL samples is very weak. These results find their explanation in the design of the specimens. The veneers are stuck the ones to the others along the grain, which attenuates the variation of their lengths. Moreover, the coefficient depends on the number of layers constituting the specimen.

- **According to the width**

Table-8. Swelling coefficient according to the width.

	A1	A2	A3	S1	S2
l_{Sat} (cm)	4.85	4.95	4.97	4.95	4.96
l_S (cm)	4.70	4.75	4.70	4.70	4.70
$G_l = \frac{lsat - ls}{ls} x100$	3.19	4.21	5.74	5.31	5.53

Interpretation

The swelling coefficient according to the width is more important than that according to the length. It grows with the number of layers.

- **According to the thickness**

Table-9. Swelling coefficient according to the thickness.

	A1	A2	A3	S1	S2
e_{Sat} (cm)	1.37	1.67	2.30	1.00	1.90
e_S (cm)	1.10	1.45	2.00	0.80	1.55
$G_e = \frac{esat - es}{es} x100$	24.54	15.17	15.00	25.00	35.00

Interpretation

The swelling coefficient following the thickness is more important than those according to the length and the width. Moreover it is more important in the case of Sapelli than in the case of Ayous. Sapelli being a wood denser than the ayous, the impregnation of the veneers in Sapelli by the adhesive is less deep than in the case of the ayous (mechanical model of gluing [5]). Consequently, the joints of adhesive are less strong in the case of the specimens in Sapelli. During humidification, water infiltrates more easily in the specimens of Sapelli than in the ones of Ayous.

- **Volume swelling coefficient**

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Table-10. Volume swelling coefficient.

	A1	A2	A3	S1	S2
V_{Sat} (cm^3)	105.51	130.52	181.18	78.70	149.55
V_S (cm^3)	81.94	108.47	148.52	59.59	115.46
GV = $\frac{Vsat - Vs}{Vs} x100$	28.76	20.32	22.00	32.06	29.52
V_{Sat}/V_s	1.2	1.2	1.2	1.3	1.3

Interpretation

The calculation of the various swelling coefficients emphasizes the following observations:

- they depend on the direction (length, width, thickness), of the number of layers of which the specimen is made up;
- swelling following the length is very weak;
- they are not constant for a type of given species;
- they depend on the moisture content of the specimen;
- for a given species, the ratio of the volume of the specimens saturated with water to the anhydrous volume is quite constant.

The humidification has affected the initial color of the samples. The joints of adhesive were still strong in spite of the 9 days of humidification and high temperature of the drying oven. This means that the neoprene adhesive used can have good structural properties.

Evolution of the volume during humidification

The analysis of the preceding results enabled us to plot the following curves:

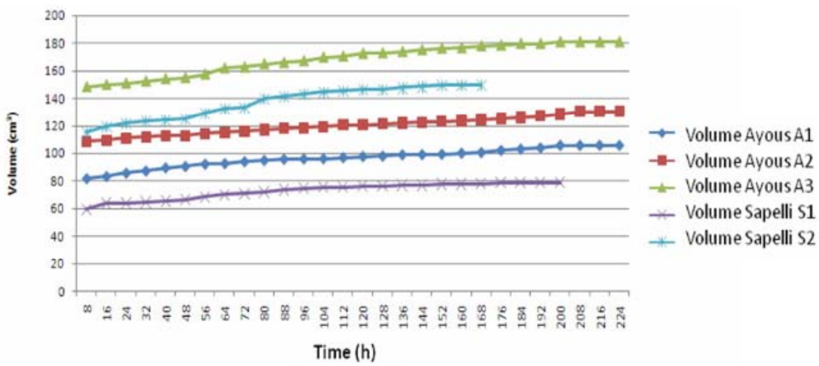

Figure-9. Evolution of the volume of the specimens during humidification.

Interpretation

The analysis of the curves shows that the samples of Sapelli reach more quickly their point of saturation than the samples of Ayous. This is explained by the fact why Ayous is a wood less dense than Sapelli. Consequently, Ayous absorbs more water than Sapelli.

Calculation of the shrinkage coefficients

The follow-up of the drying of the samples saturated with water enabled us to obtain the data hereafter where R is the shrinkage coefficient. We calculated the coefficients of volume shrinkage according to the length, the width and the thickness. The indices Sat and S respectively refer to the characteristics of the samples saturated with water and the anhydrous samples.

- **According to the width**

Table-11. Swelling coefficients according to the width.

	A1	A2	A3	S1	S2
l_{Sat} (cm)	4.85	4.95	4.97	4.95	4.96
l_S (cm)	4.71	4.74	4.72	4.73	4.69
R_l= $\frac{Lsat - Ls}{Lsst} x100$	2.88	4.24	5.03	4.44	5.44

- **According to the length**

Table-12. Swelling coefficients according to the length.

	A1	A2	A3	S1	S2
L_{Sat} (cm)	15.88	15.79	15.85	15.90	15.87
L_S (cm)	18.85	15.75	15.79	15.87	15.78
R_L = $\frac{Lsat - Ls}{Lsst} x100$	0.18	0.25	0.37	0.18	0.56

- **According to the thickness**

Table-13. Swelling coefficients according to the thickness.

	A1	A2	A3	S1	S2
e*Sat* (cm)	1.37	1.67	2.30	1.00	1.90
e*S* (cm)	1.12	1.44	1.93	0.78	1.55
R*e* = $\frac{esat - es}{esst} x100$	18.24	13.77	16.08	22.00	18.42

- **Coefficients of volume shrinking**

Table-14. Coefficients of volume shrinking.

	A1	A2	A3	S1	S2
V_{Sat}(cm)	105.51	130.52	181.18	78.7	149.55
V_S(cm)	83.56	110.48	143.84	58.55	114.71
m_{Sat} (g)	71.76	93.09	118.68	64.83	121.57
m_S (g)	36.16	48.07	64.48	40.51	79.19
$R_v = \frac{V_{Sat}-V_S}{V_{Sat}} x100$	20.80	17.63	20.60	25.60	23.29
V_{Sat}/V_S	1.2	1.2	1.2	1.3	1.3
m_{Sat}/m_S	1.9	1.9	1.9	1.6	1.5

Interpretation

The calculation of the various shrinkage coefficients emphasizes the following observations:

- they depend on the direction (length, width, thickness), of the number of layers of which the panel is made up;
- the withdrawal following the length is very weak;
- they are not constant for a type of panel of plating given;
- they depend on the water content of the panel of plating;
- for a type of given species, the ratio of the volume (respectively of the mass) of the saturated specimen with water to the anhydrous volume (respectively of the mass) is constant.

Moreover, we find the same values of the constants as those found in the case of swelling. This is shown in the literature[11] [12].

Evolution of the volume and the weights of the specimens during shrinkage

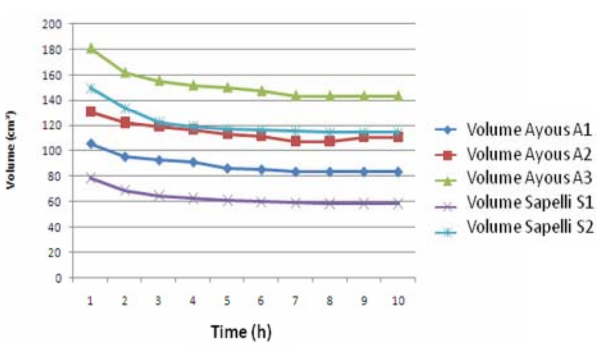

Figure-10. Evolution of the volume of the specimens during shrinkage.

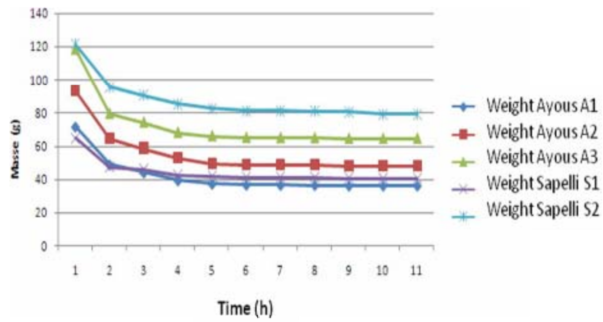

Figure-11. Evolution of the weights of the specimens during shrinkage.

Calculation of the hygroscopic point of equilibrium (EH) in the lab environment

We used the anhydrous samples obtained at the end of the study of the shrinkage. We obtained the following values:

Table-15. Results of the hygroscopic point of equilibrium.

	A1	A2	A3	A4	A5
m_{EH} *(g)*	38.03	50.45	67.63	42.08	81.61
M*i (g)*	36.16	48.07	64.48	40.51	79.19
EH (%)	5.17	4.95	4.88	3.87	3.05

m_{EH} = weight of the specimen at the hygroscopic point of equilibrium
m_i = initial weight of the specimen

Interpretation

The analysis of the results shows that:

- the hygroscopic point of balance depends on the number of layers of which the specimen is made up;
- the specimen of Ayous fix more moisture than those of Sapelli. This is due to the density of the two species (Ayous is light and Sapelli is medium-weight). A species of low density of fibres will more easily fix the moisture of the air than a species of high density[13] [14] [15].

CONCLUSIONS

The purpose of this work was to manufacture LVL samples of Ayous and Sapelli and to determine some their physical properties (the moisture content of the manufactured samples, relative density, the point of saturation of fibres and coefficients of swelling and shrinking). We manufactured five LVL samples including three in Ayous and two in Sapelli. The drying controlled in a drying oven at 103°C provided us to obtain data (weight and dimensions of the dried samples) making it possible to calculate the moisture content of the samples and the relative density of the specimens. The results obtained showed that the LVL specimens in Ayous and Sapelli were denser than the wood of Ayous and Sapelli.

The study of the humidification of the samples made it possible to calculate the coefficients of swelling

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and shrinkage of the LVL specimens of Ayous and Sapelli, as well as their point of saturation in water.

We found that for a type of species, the ratio of the volume (respectively of the mass) of the panels saturated with water with volume (respectively of the mass) is constant.

Contrary to the phenol-formaldehyde adhesives usually used in developed countries for the manufacture of LVL, we used neoprene adhesive, a synthetic rubber, which proved to be interesting for its performances as phenol-formaldehyde. For the development of the wood-composite industry in Cameroon, it is important to encourage the manufacture of that adhesive locally to reduce the production costs of LVL. As perspectives for this work, we expect to continue our research for the determination of the mechanical properties and the influence of techniques of treatment of wood on the various characteristics of the lumber.

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