WOOD–ADHESIVE INTERFACE CHARACTERIZATION AND MODELING IN ENGINEERED WOOD FLOORING

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Abstract. Adhesive films used in layered wood-based composites have a significant impact on moisture movement and must be considered in models of such products. The objective of this study was to characterize the wood–adhesive interface and determine its impact on the hygromechanical behavior of engineered wood flooring (EWF). The radial water vapor diffusion coefficient and the coefficients of moisture expansion were determined for sugar maple wood, crosslinked polyvinyl acetate adhesive film (XPVAc), and the wood–adhesive interface. Sugar maple wood had the highest diffusion coefficient at

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1.66×10^{-11} m$^2 \cdot$ s^{-1} followed by the wood–adhesive interface at 5.73×10^{-12} m$^2 \cdot$ s^{-1}, and the free XPVAc film at 4.18×10^{-12} m$^2 \cdot$ s^{-1}. The coefficient of tangential moisture expansion of the sugar maple wood–adhesive interface was found to be 4×10^{-3} (%MC)$^{-1}$ compared with 3×10^{-3} (%MC)$^{-1}$ for sugar maple wood in the tangential direction, and 3×10^{-3} (%MC)$^{-1}$ for the XPVAc film. Finite element modeling of EWF hygromechanical cupping did not show significant differences between hygromechanical cupping calculated with and without interface effects.

INTRODUCTION

The US market sales for hardwood flooring were 96×10^6 m^2 in 2006 according to Floor Covering Weekly (Anon 2007). The same source recently reported growths of hardwood flooring in term of volume (3.0%) and sales (7.1%) over the last 5 yr. Cortelyou (2005) mentioned that engineered wood flooring (EWF) accounts for 34% of the US market in dollars, and it is clearly taking market shares from hardwood flooring. In Europe, a market review performed by the European Federation of the Parquet Industry (Anon 2006) shows that this market represented 110×10^6 m^2 in 2005. An interesting fact compared with North America is the preference of Europeans for EWF (82%) over solid wood (16%). In the competitive global market, the design of innovative and efficient products is now essential. Research and development costs are significant in EWF development. The product designer must ensure that new products meet high-quality standards to maintain the manufacturer's reputation and avoid costly claims. The availability of efficient tools to evaluate the performance of a product could help to select proper components. Numerical approaches such as the finite element (FE) method can help reduce design time and the number of prototypes to manufacture.

Previous work (Blanchet et al 2005) demonstrated that distortion in EWF is the result of a transient phenomenon. A nonhomogeneous moisture transfer in EWF results in cupping distortion. A high moisture content gradient in the surface layer is responsible for cupping distortion caused by shrinkage of the surface layer when the underlying layers do not shrink. The physical properties of most wood species and a few adhesives are available in the literature, but there are limited data for the wood–adhesive interface. It appears that this interface has a significant impact on moisture diffusion inside the composite, acting as a barrier to water vapor diffusion. In this regard, Pizzi and Mittal (2003) mentioned that the adhesive line can be represented as a water vapor diffusion barrier responsible for the development of moisture gradients inside the composite. In EWF, this gradient causes a stress that is essentially located in the hardwood surface layer, which is conditioned by the ambient air, whereas the core and backing layers absorb or desorb water vapor at a much slower rate.

The adhesive film thickness and the type of substrate used determine the properties of the interface obtained. Important properties of both components are modified, notably stiffness in static bending and water vapor diffusion. These interfaces will also become more important as the film thickness decreases (Diebels et al 2005). A complete and satisfying microscopic interpretation of the interface is not available in the literature not only because of the complexity of the interface formation, but also the difficulty to isolate and analyze it. One can assume that the interface properties follow a rule of mixtures between the properties of wood and adhesive as was done by Deteix et al (2008), but this must be verified.

The purposes of this study were to determine the water vapor diffusion and expansion coefficients of the wood–adhesive interface and to use them in an existing model of the hygromechanical behavior of EWF.

MATERIALS AND METHODS

Specimen Preparation

The adhesive used in this work was a crosslinked polyvinyl acetate (PVA) emulsion (XPVAc, Wonderbond© WB-957H; Hexion Specialty Chemicals, Inc, Saint-Romuald, Québec, Canada). This cold-set adhesive provides good gluing performance at a moderate price and is an interesting option for EWF manufacturing. The reticulation potential of a PVA-type emulsion provides good durability and creep resistance (De Leeuw 1983). This adhesive may be used for cold-set applications in which the temperature of the substrate is above 20°C (Anon 2003). The reticulate agent allows the formation of small units adjacently interconnected to form a 3-D network of macroscopic size. The new network provides better rigidity to the adhesive film after evaporation of water, also reducing the mobility of individual molecules by reducing their sensitivity to the deformations caused by heat or moisture.

Thirty-five EWF strips composed of a 4-mm-thick sugar maple (*Acer saccharum* Marsh.) plain-sawn surface layer, an 8-mm-thick white birch core layer, and a 2-mm-thick yellow birch veneer as a backing layer were built for model validation purposes (Fig 1). All wood components were previously conditioned to 20°C and 50% RH until equilibrium was reached. The flooring strips were bonded by cold-pressing with XPVAc emulsion. The adhesive spread rate was 0.269 kg · m^{-2} as suggested by the manu-

Figure 1.   Structure of the engineered wood flooring considered in this study.

facturer. The pressure applied was 1.72 MPa for 5 min at 20°C. The final dimensions of the EWF strips were 82.5 mm wide and 600 mm long. The strips were placed inside a conditioning room at 20°C and 50% RH until equilibrium was reached. The moisture content (MC) of the conditioned EWF strips was 8.6% (oven-dry basis).

The sample strips were then sealed with silicone and aluminum foil on their edge and backing layer to ensure a restricted moisture transfer from the surface layer only. The strips were then exposed to 20°C and 20% RH. The top surface of each strip was in direct contact with ambient air. Distortion was measured as a function of time at five marked locations on each strip with a dial gauge as described by Blanchet et al (2005).

Experimental Determination of the Diffusion and Expansion Coefficients

Diffusion coefficient. Fick's first law of diffusion applied to moisture diffusion in wood can be rearranged in the following form to determine the water vapor diffusion coefficient (Siau 1995):

$$D = \frac{\Delta wL}{\Delta t A \rho_w G \left(\dfrac{\Delta MC}{100} \right)} \qquad (1)$$

where D = coefficient of moisture diffusion, m^2 · s^{-1}; $\Delta w/\Delta t$ = water vapor flow, kg · s^{-1}; A = cross-sectional area of specimen normal to the direction of flow, m^2; L = length in the flow direction, m; ρ_w = normal density of water (1000 kg · m^{-3}); G = specific gravity of wood at the average moisture content; and ΔMC = moisture content difference across specimen thickness, %. In this equation, the expression $\rho_w G$ can be expressed as the basic density assuming that wood is a stable porous material and that ρ_w and G are constant.

The water vapor diffusion coefficient was determined for three types of material: hardwood sugar maple thin sample (0.3 mm thick), XPVAc adhesive film (0.6 mm thick), and wood–
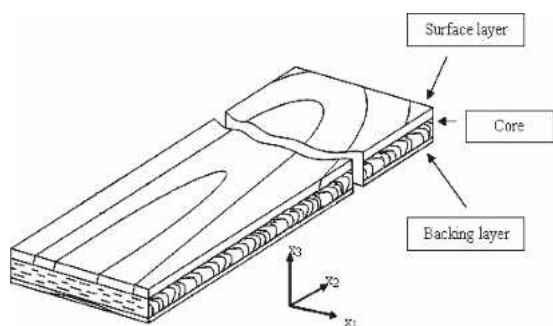
adhesive interface made of sugar maple impregnated with XPVAc (0.3 mm thick). The following procedures were followed to prepare the samples. A representative specimen of the wood–adhesive interface was obtained from a sugar maple strip coated with XPVAc. Strips of sugar maple were flat-sawn as it is the case in EWF manufacturing. The adhesive was applied with a roller coater at 0.135 kg · m^{-2} on top of each strip. Only half of the adhesive application rate used for the EWF strips made for validation purposes was used because there was only one surface of the strip to impregnate in that specific case. The thin sugar maple samples were then placed between two silicone parchment pan liners and pressed under the same conditions as for the EWF strips made for validation purposes. After curing for 24 h, the pure wood side of the strip was sanded with an industrial belt sander (Sandya 20 by SCM) to obtain a 0.3-mm-thick strip measured with a digital micrometer at ±0.01 mm according to standard D 1005-95 (ASTM 1995a). The 0.3-mm dimension was the thinnest that we were able to obtain with this equipment. A three-step grit sanding program (100–120–150) was used to minimize damage to the surface. de Moura (2006) investigated the quality of a sanded sugar maple surface with the same equipment used in this study and demonstrated that crushing or tearing was significantly minimized when using a 120-grit stage or higher. Additional pure sugar maple samples (without XPVAc coating) were prepared following the sanding technique described previously. Films of pure XPVAc were obtained. The adhesive was poured onto an aluminum plate. Once cured, the film was removed from the plate and the thickness was determined according to specifications given in standard D 1005-95 (ASTM 1995a).

The method used to determine the diffusion coefficient under steady state was inspired from Siau (1995), standard E 96-95 (ASTM 1995b), and the coating diffusion cup, called a "Payne cup." The water vapor flux was determined from the linear part of the curve of the cup mass as a function of time, which corresponds to steady state. The cup contained distilled water and a 100% RH was assumed. The edge of the specimen was sealed with epoxy glue. A Teflon ribbon was also placed around the cup rim to ensure that water vapor diffused only through the specimen. The assembled cup was then placed in a cabinet under climate control (Fig 2).

Twenty-two diffusion cups were prepared for the determination of the wood–adhesive interface diffusion coefficient. Sixteen of the 22 cups were sealed with the wood surface of the wood–adhesive thin sample in contact with ambient air, and the wood–adhesive interface was exposed to 100% RH inside the diffusion cup. The remaining diffusion cups were sealed with the wood–adhesive surface exposed to the ambient air, and the wood surface was exposed to 100% RH inside the diffusion cup. This was done in the event that the adhesive penetrated into wood to a smaller depth than the 0.3-mm strip thickness. The diffusion coefficients of 14 pure

Figure 2. Cabinet with assembled diffusion cups during diffusion tests.

XPVAc film specimens and 7 pure wood strips were also determined.

The RH inside the cabinet was controlled by a saturated salt solution. A saturated potassium acetate solution at 20°C provided and maintained a constant 30% RH and a partial vapor pressure of 0.45 kPa in the cabinet. Distilled water was used in the vapor cups to provide 100% RH, thus creating a substantial vapor pressure gradient across the wood-adhesive strip. This resulted in significant and easily measurable weight losses of the diffusion cups. The cabinet was placed in a conditioning room under identical hygrothermal conditions to reduce changes in hygrothermal conditions around the diffusion cups during weighing. Moisture flux through the specimen was monitored by periodic weighing of the vapor cups. The establishment of steady-state conditions was confirmed when the moisture flux remained constant over a period of 69 h. The initial moisture content measured by the oven-drying method was 8.6%, which is in agreement with data obtained by Djolani (1970) for sugar maple. Basic density was obtained for each component by the gravimetric method.

Coefficient of moisture expansion. For the determination of the coefficient of moisture expansion (CME), wood–adhesive interface thin samples were cut to obtain specimens 50×100 mm in the tangential and longitudinal directions. The thin samples were conditioned first to 20°C and 27% RH and then to 20°C and 80% RH. The CME was obtained by comparing specimen size in both hygrometric conditions. The measurements were obtained with a Multicheck PC 500 Blickle (Gammertingen, Germany), which consists of a microscope mounted on a two-axis roller-supported system that can determine the distance between two points with an accuracy of 0.001 mm. To avoid errors resulting from cupping distortion during the measurement, the thin sample was placed between Plexiglas and metal plates. A total of 15 wood–adhesive thin samples were prepared to determine the CME of the composite. Fifteen pure XPVAc films and 14 pure sugar maple thin samples were also prepared to determine their respective expansion

coefficients in the same hygrometric conditions. The XPVAc was considered an isotropic and homogeneous material. Its expansion coefficient was then assumed to be the same in all directions, and the CME was measured in only one direction.

The CME was obtained from the following relation:

$$CME = \frac{L - L_0}{L_0 \Delta MC} \qquad (2)$$

where CME = coefficient of moisture expansion, $(\%MC)^{-1}$; L = length at 80% RH, mm; L_0 = length at 27% RH, mm; and ΔMC = difference in moisture content of the specimen, %.

Modeling Approach

The FE model of EWF hygromechanical cupping used was developed by Blanchet et al (2005) and Deteix et al (2008). The modeling approach used in the current study was similar except for the mesh. Two layers of elements were used in the current study for the adhesive layer instead of one in Blanchet et al (2005). Two layers of elements were also added in each interface section. Figure 3 presents a schematic comparison of the mesh with interfaces used in the current study and the mesh without interfaces used by Blanchet et al (2005). A linear interpolation was used to calculate the diffusion properties of the interfaces other than sugar maple. The calculated cupping was validated against experimental data.

Deformation was assumed to be caused by asymmetric shrinkage induced by water vapor desorption from 8.6 to 5.8% MC occurring by convection from the top surface only. All other edges and the bottom surface were assumed impervious. Each wood layer of the composite was assumed orthotropic and elastic. The EWF strip was assumed to be initially free of stress because the components were conditioned before and after assembly.
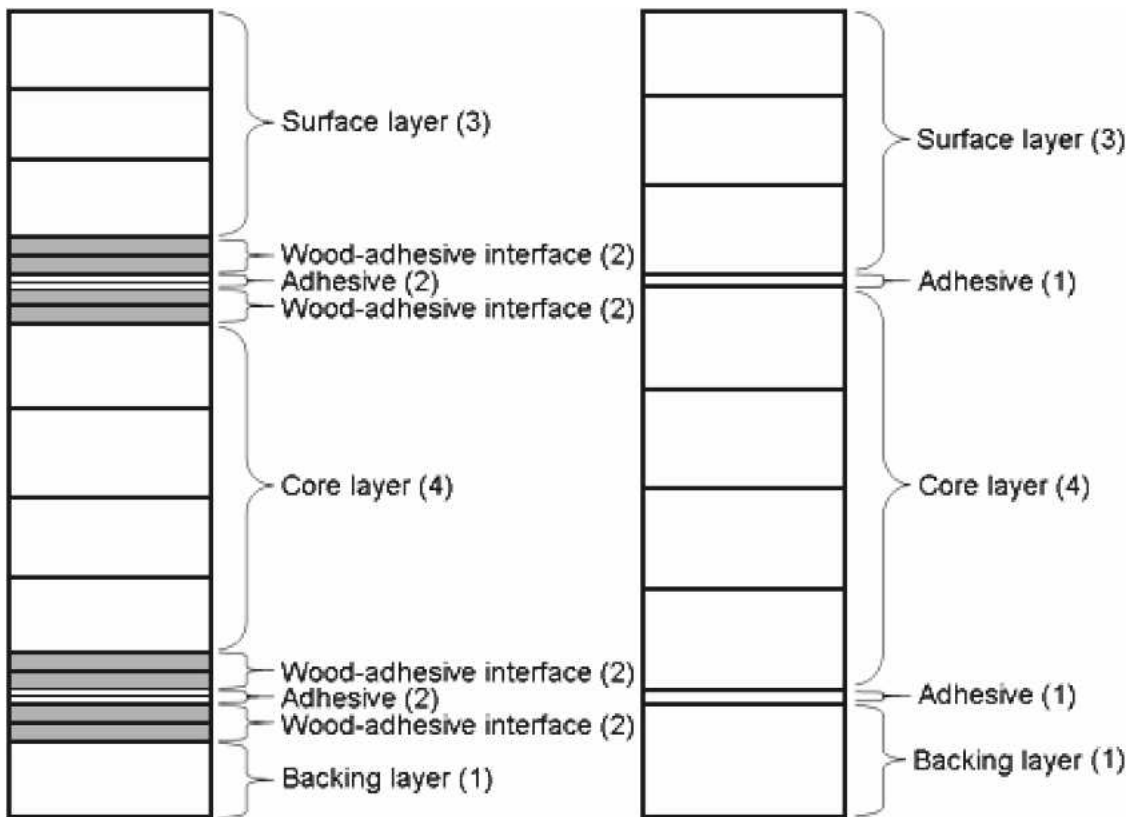
Figure 3. Schematic of the mesh used for the model including interfaces (gray) (left) and the original model from Blanchet et al (2005) (right). The mesh with interfaces from the surface layer to the backing layer with the number of layers of elements in parentheses is presented as follows: surface layer of sugar maple (3), sugar maple–XPVAc interface (2), XPVAc adhesive (2), XPVAc–white birch interface (2), core layer of white birch (4), white birch–XPVAc interface (2), XPVAc adhesive (2), XPVAc–yellow birch interface (2), and the backing layer of yellow birch (1).

Wood component properties. The material properties used in the current study are listed in Table 1. Some parameters were taken from the literature and previous studies, and others were determined experimentally. The properties of the core material and backing layer were taken from the literature and were the same as those used by Blanchet et al (2005). Shear and elastic moduli and Poisson's ratios of sugar maple were obtained from Bodig and Jayne (1993). Shrinkage and swelling coefficients were obtained from Goulet and Fortin (1975) except for the tangential direction, which was determined in the laboratory. The CMEs in the longitudinal direction were not sufficiently high to be detected by our apparatus. The basic density and transverse water vapor diffusion coefficients of sugar maple

were also determined experimentally. The water vapor diffusion coefficients in longitudinal direction were taken from Siau (1995).

Wood–adhesive interface properties. Basic density and radial water vapor diffusion coefficient of the wood–adhesive interface were determined experimentally. For technical reasons related to the thickness of the wood–adhesive interface, longitudinal and radial water vapor diffusion coefficients were estimated from our results in the tangential direction. The CMEs of the wood–adhesive interface in the tangential direction were determined experimentally. The experimental results showed that the shrinkage and swelling coefficients were relatively similar for wood and the wood–adhesive interface.

Table 1. *Parameters used in the model.*

Parameter	Material Surface Sugar maple	Material core White Birch	Material Backing Yellow Birch	Binder XPVAc	Interface Sugar maple & XPVAc
d_b (kg·m^{-3})	[7]634	[1]506	[1]559	[7]1178	[7]782
D (m^2·s^{-1})				[4]4.18×10^{-12}	
D_L (m^2·s^{-1})	[2]2.2×10^{-9}	[2]2.2×10^{-9}	[2]2.2×10^{-9}		[5]5.73×10^{-12}
D_R (m^2·s^{-1})	[5]1.66×10^{-11}	[2]4×10^{-11}	[2]4×10^{-11}		[5]5.73×10^{-12}
D_T (m^2·s^{-1})	[7]1.66×10^{-11}	[2]4×10^{-11}	[2]4×10^{-11}		[7]5.73×10^{-12}
M_0 (%)	8.6	8.6	8.6	8.6	8.6
M_∞ (%)	5.8	5.8	5.8	5.8	5.8
h (kg·m^{-2}·s^{-1}·%$^{-1}$)	[2]3.2×10^{-4}	[2]3.2×10^{-4}	[2]3.2×10^{-4}	[2]3.2×10^{-4}	[2]3.2×10^{-4}
$\beta_{Effective}$ (mm·mm^{-1}·%$^{-1}$)				[7]3×10^{-3}	
β_L (mm·mm^{-1}·%$^{-1}$)	[6]1.8×10^{-4}	[1]1.5×10^{-4}	[1]1.5×10^{-4}		[5]4×10^{-3}
β_R (mm·mm^{-1}·%$^{-1}$)	[6]1.9×10^{-3}	[1]1.7×10^{-3}	[1]1.9×10^{-3}		[5]4×10^{-3}
β_T (mm·mm^{-1}·%$^{-1}$)	[7]3×10^{-3}	[1]2.4×10^{-3}	[1]2.3×10^{-3}		[7]4×10^{-3}
$\alpha_{Effective}$ (mm·mm^{-1}·%$^{-1}$)				[7]3×10^{-3}	
α_L (mm·mm^{-1}·%$^{-1}$)	[6]1.5×10^{-4}				[5]4×10^{-3}
α_R (mm·mm^{-1}·%$^{-1}$)	[6]2.1×10^{-3}				[5]4×10^{-3}
α_T (mm·mm^{-1}·%$^{-1}$)	[7]4×10^{-3}				[7]4×10^{-3}
E (GPa)				[4]12.740	
E_L (GPa)	[3]13.810	[3]12.045	[3]15.251		[5]13.810
E_R (GPa)	[3]1.311	[3]1.069	[3]1.251		[5]1.311
E_T (GPa)	[3]0.678	[3]0.516	[3]0.641		[5]0.678
G_{LR} (GPa)	[3]1.013	[3]0.829	[3]0.971	[9]4.718	[5]1.013
G_{RT} (GPa)	[3]0.255	[3]0.200	[3]0.242	[9]4.718	[5]0.255
G_{LT} (GPa)	[3]0.753	[3]0.607	[3]0.721	[9]4.718	[5]0.753
ν				[8]0.035	
ν_{LT}	[3]0.50	[3]0.43	[3]0.45		[5]0.50
ν_{RT}	[3]0.82	[3]0.78	[3]0.70		[5]0.82
ν_{TL}	[3]0.025	[3]0.018	[3]0.018		[5]0.025
ν_{RL}	[3]0.044	[3]0.043	[3]0.035		[5]0.044
ν_{TR}	[3]0.42	[3]0.38	[3]0.36		[5]0.42
ν_{LR}	[3]0.46	[3]0.49	[3]0.43		[5]0.46

[1]Jessome (2000), [2]Siau (1995), [3]Bodig and Jayne (1993), [4]Bandrup et al (1999), [5]Estimated value, [6]Goulet and Fortin (1975), [7]Experimental value, [8]Urayama et al (1993), [9]Baïlon and Dorlot (2000). d_b = basic density; D_i = diffusion coefficient in direction i; M_0 = Initial moisture content; M_∞ = Final moisture content; h = convective mass transfer coefficient; β_i = shrinkage coefficient in direction i; α_i = swelling coefficient in direction i; E_i = elastic modulus in direction i; G_{ij} = shear modulus in plane ij; ν_{ij} = Poisson's ratio in plane ij.

From this perspective, shrinkage and swelling in the radial and longitudinal directions as well as the shear and elastic moduli and the Poisson's ratio were then assumed to be the same for both materials.

Polyvinyl acetate adhesive properties. Polyvinyl acetate adhesive can be considered as an isotropic material. The modulus of elasticity (E) and Poisson's ratio (υ) were obtained from Bandrup et al (1999) and Urayama et al (1993), respectively. The shear modulus (G) was obtained from Eq 3 from Baïlon and Dorlot (2000):

$$G = \frac{E}{2(1 + \upsilon)} \qquad (3)$$

Basic density, shrinkage, and swelling coefficients and diffusion coefficient of XPVAc were obtained experimentally following the technique described previously.

RESULTS AND DISCUSSION

Diffusion Coefficient

No splits or other types of damage of the specimens were detected during the diffusion experiment. This was a concern for the wood–adhesive interface samples for which the wood side of the specimen was in contact with a 100% RH environment. An analysis of variance was

performed on the average diffusion coefficients obtained using the SAS statistical software (SAS Institute, Cary, NC). A very significant difference was found between sugar maple, XPVAc, and the wood–adhesive interface. The Duncan multiple comparison test results presented in Table 2 show that the mean diffusion coefficient obtained for sugar maple, XPVAc, and the wood–adhesive interface were significantly different. The mean diffusion coefficients obtained for XPVAc-sugar maple and sugar maple-XPVAc were not significantly different.

Sugar maple had the highest diffusion coefficient at 1.66×10^{-11} $m^2 \cdot s^{-1}$ and the free film of XPVAc had the lowest at 4.18×10^{-12} $m^2 \cdot s^{-1}$. The sugar maple diffusion coefficient obtained in the current study is similar to that obtained by Blanchet et al (2005) (1.80×10^{-11} $m^2 \cdot s^{-1}$). The mean diffusion coefficient obtained for the wood–adhesive interface is slightly higher than for pure XPVAc film at 5.73×10^{-12} $m^2 \cdot s^{-1}$, which is in agreement with our expectations. These results confirm the information found in the literature that the adhesive layer acts as a barrier for moisture diffusion. In addition, the wood–adhesive interface results suggest that the diffusion coefficient of the wood–adhesive interface is an average of each component of the composite. These results confirm that the interface between the wood substrate and the adhesive line presents an additional barrier to water vapor diffusion. The solid adhesive clearly becomes an integral part of the composite structure, creating an interface having its own properties.

Coefficient of Moisture Expansion

The tangential CMEs for the wood–adhesive interface were found to be 4×10^{-3} $(\%MC)^{-1}$ (Table 3). Even during shrinkage or swelling, the coefficients obtained for the wood–adhesive interface were very similar. The results obtained suggest that impregnation of XPVAc in sugar maple does not have a significant impact on the expansion coefficient of the resulting composite material.

The result obtained for sugar maple tangential shrinkage [3×10^{-3} $(\%MC)^{-1}$] is similar to that obtained by Goulet and Fortin (1975) [2.8×10^{-3} $(\%MC)^{-1}$]. In the case of swelling, the tangential CME obtained for sugar maple was slightly higher with 4×10^{-3} $(\%MC)^{-1}$. The tangential shrinkage and swelling CMEs obtained for XPVAc were equal to 3×10^{-3} $(\%MC)^{-1}$. The basic density of the interface (782 $kg \cdot m^{-3}$) was closer to the basic density of sugar maple (634 $kg \cdot m^{-3}$) than that of pure XPVAc (1178 $kg \cdot m^{-3}$). This suggests that XPVAc filled only a fraction of the wood pore space.

Modeling Results

Figure 4 presents the FE model results obtained considering RH variation inside the conditioning room and the corresponding experimental results. Sorption hysteresis and the interaction between moisture content and the diffusion coefficient were taken into account in the model. The initial moisture content of the EWF strip was 8.6% and the equilibrium moisture content was set at 5.8%. The experimental deformation curve

Table 2. *Duncan's multiple comparison test for the diffusion coefficients, experimental diffusion coefficients, and basic density (OD mass/green volume).*

		Water vapor diffusion coefficient	Basic density
	Duncan grouping	$(m^2 \cdot s^{-1})$	$(kg \cdot m^{-3})$
Sugar maple	A	1.66×10^{-11} (1.49×10^{-12})	634 (4)
Sugar maple-XPVAc	B	5.73×10^{-12} (3.02×10^{-13})	782 (5)
XPVAc-sugar maple	B	5.73×10^{-12} (1.37×10^{-13})	782 (5)
XPVAc	C	4.18×10^{-12} (2.91×10^{-13})	1178 (16)

Standard error in parentheses.

Table 3. *Experimental expansion coefficient obtained for each section.[a]*

| | Swelling | | Shrinkage | |
| | From 21°C/27% RH to 21°C/80% RH | | From 21°C/80% RH to 21°C/27% RH | |
	Tangential (%MC)$^{-1}$	Effective (%MC)$^{-1}$	Tangential (%MC)$^{-1}$	Effective (%MC)$^{-1}$
Sugar maple-XPVAc	4×10^{-3}		4×10^{-3}	
Sugar maple	4×10^{-3}		3×10^{-3}	
XPVAc		3×10^{-3}		3×10^{-3}

[a] Effective refers to the expansion coefficient of XPVAc adhesive, which is isotropic.
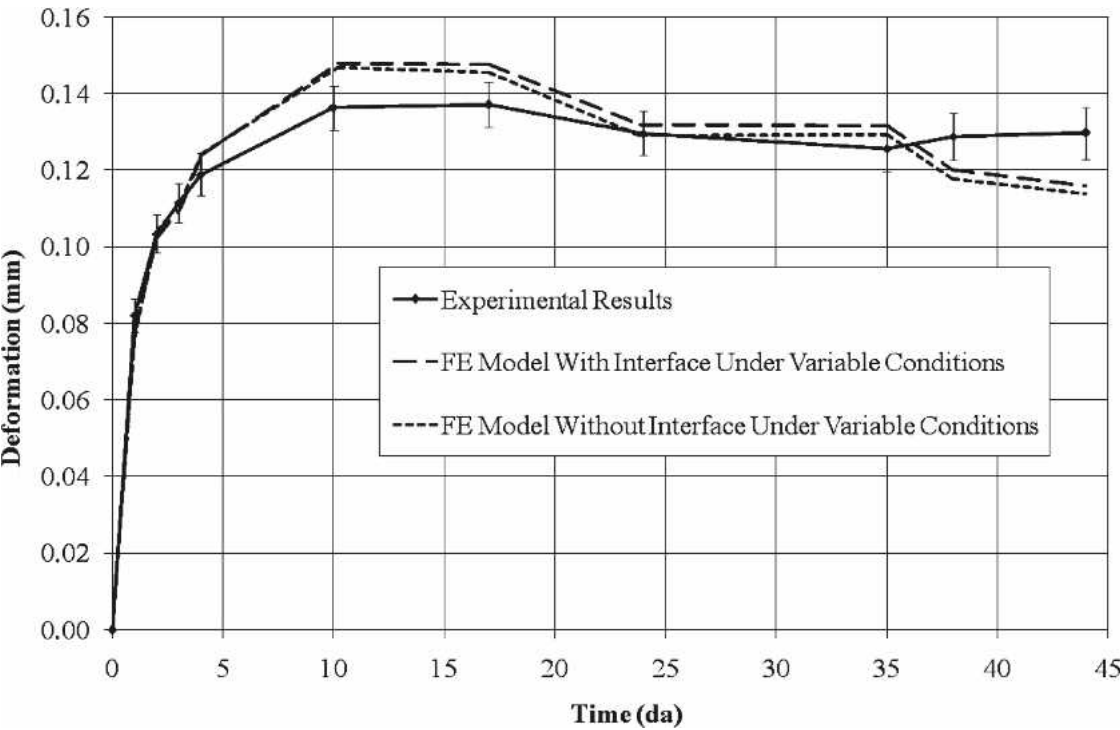RH = relative humidity; MC = moisture content.

Figure 4. Experimental and calculated cupping deformation as a function of time considering actual relative humidity variation in the conditioning room. Error bars represent the 95% confidence intervals from the experimental data points.

with its 95% confidence intervals was compared with model results obtained by Blanchet et al (2005) without considering the effect of the interface and with the current model, which considers this effect.

The cupping deformation can be divided into two parts. The first one represents the transient section occurring during the first 10 da of conditioning followed by a plateau, which is more stable in terms of cupping. The current model considering interface effects does not have a sig-

nificant impact on the deformation compared with the model without an interface. This can be observed from the slope of the calculated cupping in the transient section where both models remain close to each other and slightly above the experimental curve. The deformation calculated from both models remains close to the 95% confidence intervals from the experimental curve during the entire timespan. Both models slightly overestimate the deformation until day 35. After this time, both models slightly underestimate the deformation. The two models used are based on

the hypothesis of elastic behavior of wood and the adhesive. Cupping is a mechanosorptive phenomenon that most likely affects the drying rate. This could explain the difference between experimental and calculated deformation curves. It would be interesting to consider mechanosorption and creep in future models. On the methodological aspect, an appropriate process to provide thinner samples of the interface would certainly offer more accurate interface properties.

CONCLUSIONS

The main objective of this study was to provide additional information about engineered wood flooring behavior through the determination of the water vapor diffusion coefficients and moisture expansion coefficients of the wood–adhesive interface. The model proposed by Blanchet et al (2005) implemented with these parameters does not offer more accurate results. The current model considering interface effects is not closer to the experimental curve than the model without interface effects.

Sugar maple had the highest diffusion coefficient at 1.66×10^{-11} m$^2 \cdot$ s^{-1} and the free film of XPVAc had the lowest at 4.18×10^{-12} m$^2 \cdot$ s^{-1}. The diffusion coefficient obtained for the wood–adhesive interface was slightly higher than that of pure XPVAc film but lower than for solid wood at 5.73×10^{-12} m$^2 \cdot$ s^{-1}. The investigation of the moisture movement in the wood–adhesive interface confirmed that there was not a significant difference between the mean diffusion coefficients of sugar maple-XPVAc and XPVAc-sugar maple samples.

The tangential coefficients of moisture expansion for the wood–adhesive interface were found to be 4×10^{-3} (%MC)$^{-1}$ and 3×10^{-3} (%MC)$^{-1}$ for XPVAc. In the case of sugar maple, the results obtained for tangential shrinkage at 3×10^{-3} (%MC)$^{-1}$ are slightly lower than those of the tangential expansion coefficient at 4×10^{-3} (%MC)$^{-1}$. The moisture expansion properties for the wood–adhesive interface were

relatively similar to those of solid wood in the composite structure.

The results obtained in this study confirm that the wood–polyvinyl acetate adhesive interface has no significant influence on the cupping deformation resulting from moisture movement through laminated composites such as engineered wood flooring. However, the lower diffusion coefficient obtained for polyvinyl acetate compared with maple wood shows that the impact of the wood–polymer interface acting as a moisture barrier should still be considered in FE models dealing with adhesive and wood composites. It is also clear that the solid adhesive becomes an integral part of the composite structure, creating an interface with its own specific properties.

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