

OSB panel as substrate for engineered wood flooring

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Abstract

The purpose of this study was to develop a special oriented strands board (OSB) formulation to be used as a substrate for engineered wood flooring (EWF). Three-layers oriented strands boards were manufactured from two types of strands: a mixture of 90% aspen (*Populus tremuloides*) and 10% paper birch (*Betula papyrifera*), and 100% of ponderosa pine (*Pinus ponderosa*). The parallel modulus of elasticity (MOE) for both types of specialty OSB was 8192 MPa (aspen/birch OSB) and 9049 MPa (pine ponderosa OSB), comparatively to the 11395 MPa minimum requirement of *Handbook of Finnish Plywood* for birch plywood, a product widely used in EWF. Prototypes of EWF were made using five types of substrates: Baltic plywood, sheathing OSB, web stock OSB and the two prototypes of specialty OSB panels. The tests in conditioning rooms showed that the Baltic birch plywood (BBP) core constructions present the lowest distortion between humid and dry conditions. There were no significant differences in the distortion measured for BBP and aspen/birch OSB substrates. The construction with OSB sheathing, OSB web stock and ponderosa pine OSB substrates showed the greatest distortion. The results of this study demonstrate the possibility to use the OSB panels as EWF substrate.

Introduction

Since the introduction of EWF to the market in the 1970s, the popularity of these products has grown steadily. According to the *Floor Covering Weekly* (Anonymous 2008), in 2007, 37.5% of the wood flooring installed in the

United States was EWF. In this period, the North American EWF market has been negatively influenced by the economic decline. The averages square foot price of EWF jumped 6 % from 2006 to 2007. The development of low cost components could be very interesting for the EWF manufactures.

Generally, EWF has 3 components: a surface layer, the substrate and a backing layer. The surface layer is manufactured from high-quality hardwood. Its thickness determines the number of sandings it can tolerate. In EWF, a surface layer thickness of which is greater than 3 mm, are considered to be high-quality products. The substrate is the core layer of EWF. Its function is mechanical in that it counters surface layer deformation. This layer makes it possible to achieve the desired flooring strip thickness. Generally, the substrate is made of wood composite materials, such as HDF, plywood or wood sticks. The bottom layer enhances the appearance of EWF backing, but it also reduces cupping (Blanchet et al. 2006). Generally, the use of a backing layer is linked to the use of a HDF or a solid wood strip as substrate. Using the French standard NF B54-011 (AFNOR 1980), Blanchet et al. (2003a) developed a method for testing engineered flooring strips adapted to North American climate conditions. Flooring strip assemblies were subjected to alternatively dry and wet cycles. It was assumed that, in North America, a dry environment of 20°C and 20% RH corresponds to winter conditions and a humid environment of 20°C and 80% RH corresponds to summer conditions. Engineered wood flooring strips are unbalanced composite constructions. Their deformation is caused by the specific reaction of each layer to changes in moisture content and temperature near the top surface. Blanchet et al. (2006) used a finite-

element analysis to study the hygromechanical behaviour of EWF. The analysis showed that the mechanical properties of the substrate and its thickness have a significant impact on EWF deformation. Furthermore, they concluded that enhancing the mechanical properties of the core layer does reduce EWF deformation. Blanchet et al. (2006) indicate that the bending modulus of elasticity (MOE) of the substrate affects the cupping deformation. The minimum bending MOE in parallel direction, required by the CSA O437.0 (CSA 1993) standard for OSB class O-2 is 5500 MPa. Blanchet (2008) suggests the necessity to increase OSB bending MOE in one direction to reach a performance level comparable to Baltic Birch (*Betula pendula*) plywood (BBP) currently used for EWF manufacturing in Canada. According to the Handbook of Finnish Plywood (Anonymous 2002), the BBP bending MOE in parallel direction is 11395 MPa.

Oriented strand board (OSB) was introduced into the construction market in the early 1980s. The OSB industry posted a rapid growth and is now well established across North America. Its continuing growth implies that OSB panels are replacing plywood in several applications. For North America, in 1987, OSB production was 29% of the plywood volume; by 1994, it had increased to 55% (Chapman, 2006). APA-The Engineered Wood Association (Merry, 2008) reports that in 2007, the OSB made 62 percent of the total North American structural wood panel (plywood and OSB panels).

OSB panels are manufactured from strands of wood glued together with water-resistant resins (usually a phenol or isocyanate resin) and subjected to a heat-and-pressure process. In general, the oriented strand board industry uses small-diameter, low quality logs.

The main objective of this study was to develop a special oriented strands board formulation with high MOE in parallel direction to substitute plywood in specific use such as substrate for engineered wood flooring (EWF). The requisite qualities of OSB panels used as a substrate for EWF are rigidity, internal bond strength and dimensional stability in thickness. The secondary objective was to evaluate the behaviour of EWF made with two specialty OSB (Ponderosa pine and Aspen/Birch strands) and benchmark them with three other construction of EWF (Sheathing OSB, Web stock OSB and BBP).

Materials and methods

OSB panels

Two types of strands were selected to make OSB panels. The first series of panels was made with a mixture of trembling aspen strands (*Populus tremuloides*) (90%) and white birch (*Betula papyrifera*) strands (10%). The strands were provided by Produits Forestiers Arbec – OSB panels Division, located in Sainte-George-de-Champlain, Québec, Canada. The strands used in the production of the second series of panels were prepared at Washington State University’s Wood Material and Engineering Laboratory from small-diameter (100-200 mm) ponderosa pine (*Pinus ponderosa*) logs. Pressing was achieved with two Dieffenbacker presses. The temperature and gas pressure at the core of each panel were measured with a PressMan press monitoring system. Production parameters are presented in Table 1.

Engineered Wood Flooring

The constructions used in this study are presented in Figure 1. The geometry of EWF was 85 mm wide, 12 mm thick, and 610 long. The EWF prototypes were produced using five different materials as substrate. The substrates used were: Baltic plywood, grade sheathing OSB, web stock OSB, specialty aspen/birch OSB and specialty ponderosa pine OSB. A 3 mm-thick sugar maple plank was selected as the surface layer for the production of the EWF. Prior to gluing, all the panels and all the maple planks were stored in a conditioning chamber at 20°C and 50% RH, until a constant mass was obtained. These are the ideal conditions for producing EWF for North America.

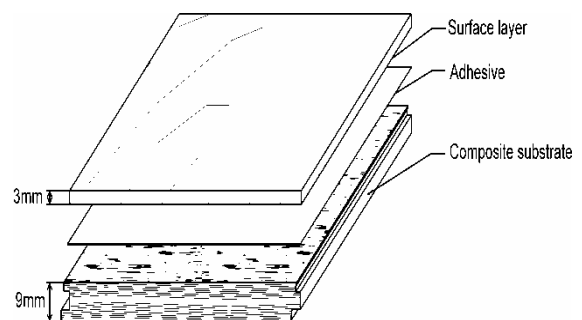


Figure 1 Cross-section diagram of an engineered wood flooring strip

At the end of the conditioning period, the substrates were sanded to ensure uniform thickness and an appropriate gluing surface. Sanding was performed in a three-belt sander with 100, 120 and 150 grit aluminium oxide paper. The production of EWF strips involved cold-press gluing of the surface layer and substrates with a type I PVA (polyvinyl acetate) adhesive provided by Hexion Specialty Chemicals (XB-90K5-LF). Gluing time was 30 minutes at 250 psi. Gluing was achieved in such a way as to ensure that the panel orientation was perpendicular to the grain of the surface layer. Because the PVA adhesive is a water-based product, another conditioning period at 20°C and 50% RH was required to ensure a uniform MC across the product. Following the machining of tongues

and grooves, the surface layer was sanded to final total thickness (12 mm). The flooring strips were glued onto 12.5 mm-thick Duroc cement panels with the Bostik Best urethane adhesive recommended for the installation of EWF. The sides of the 610x1220 mm (2' x 4') assemblies were sealed by a bead of silicone in order to limit the edge effect.

The flooring strips were subjected to a three-week cycle of alternating dry and wet conditions. It was assumed that in North America, a dry environment of 20°C and 20% RH corresponded to winter conditions and that a moist environment of 20°C and 80% RH corresponded to summer conditions (Blanchet, 2008). Distortion measurements on EWF were taken during each cycle at the following intervals: 0, 1, 2, 3, 5, 7, 14 and 21 day(s).

Table 1 Production parameters

Physical parameters	
Panel dimensions	635 x 635 x 9.5 mm (width x length x thickness)
Three-layer panels	45%/10%/45%
Target density	675 kg/m ³
Mat target MC	8% in surface layers 6% in the core layer
Resin	
Resin type	Phenol-formaldehyde
Proportion of solids	57%
Resin content	6.5%
Wax	
Proportion of solids	100%
Wax content	1.5% (each layer)
Pressing parameters	
Press platen temperature	210°C – aspen/birch OSB panels 180°C – ponderosa pine OSB panels
Press closing time	15 seconds
Resin curing time	155 seconds
Press opening time	35 seconds – aspen/birch OSB panels 100 seconds – ponderosa pine OSB panels

Because the specialty OSB panels were manufactured at an interval of four months, this test was divided into two parts. First the aspen/birch prototypes were tested and then ponderosa pine prototypes. Considering the fact that the conditions in the conditioning room are not perfectly stable each type of specialty OSB substrate was compared separately with the other substrates. The variations in the conditioning room are the result of the opening of the chamber door for each measurement. (Blanchet et al. 2005). In order to assess long-term delamination of the substrate, 10 samples (50 mm wide x 83 mm long) of each type of substrate were subjected to an oven delamination test. The samples were subjected to four successive 8-hour cycles in a moist environment (20°C and 80% RH), followed by 16 hours in an oven at 70°C. Glueline and substrate delaminations were quantified by a linear measurement of the delamination plane with a vernier calliper. The delaminations length for each sample were added and recorded at the end of each cycle. The Statistical Analysis System (SAS) software 9.1 was used for analysis of variance (ANOVA). In order to determine the performance of EWF strips, an ANOVA focusing on the maximum deformation

amplitude between the two environmental cycles was carried out. This amplitude was determined by calculating the difference between the highest summer cupping value and the lowest winter cupping value. In order to determine the long term delamination of the substrate, an ANOVA on the total values of delamination after four cycles was carried out. Finally, comparisons between substrates were performed in order to classify the specialty OSB panels compared to other substrates.

Results and discussions

Engineered wood flooring distortion

Figure 2 presents the average EWF cupping deformation as a function of conditioning period (days) for substrates made of grade sheathing OSB, web stock OSB, aspen/birch OSB and BBP. The ANOVA results show that at least one type of substrate exhibits properties that are different in relation to the others. The Waller-Duncan multiple comparison test highlighted two different groups (Table 2) at 0.05 probability level. The best average cupping value was obtained for BBP. This type of plywood is made with seven plies of birch.

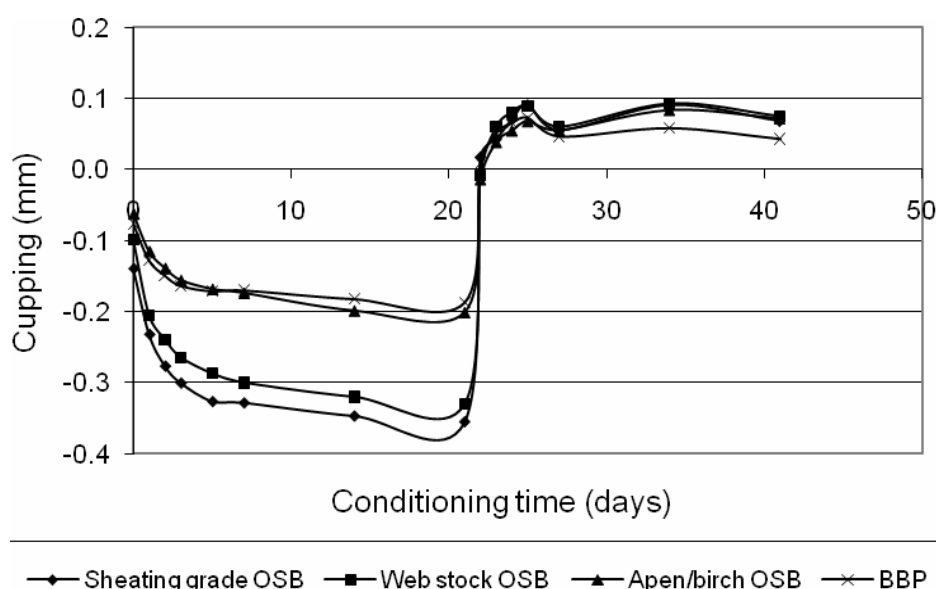


Figure 2 Average EWF distortion as a function of conditioning time (days) and substrate type including aspen/birch specialty OSB

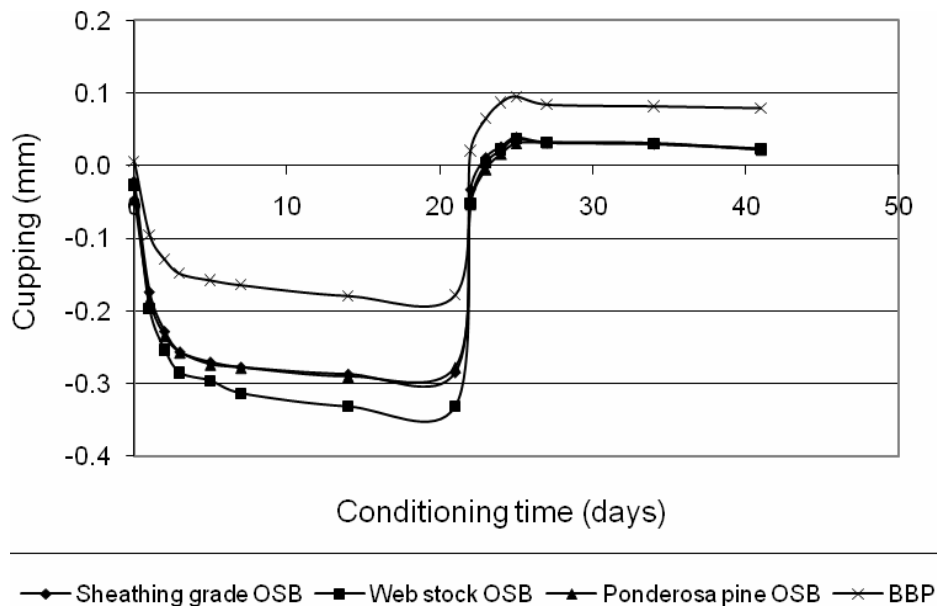


Figure 3 Average EWF distortion as a function of conditioning time (days) and substrate type including ponderosa pine specialty OSB

Table 2 Average cupping distortion values as a function of substrate type

Type of substrate	Average	Group
Grade sheathing OSB	0.453	A
Web stock OSB	0.430	A
Aspen/Birch OSB	0.287	B
BBP	0.263	B

According with Waller-Duncan test the means with the same letter are not significantly different at 5% probability level.

Table 3 Average values of mechanical properties of OSB panels

Type of OSB panel	MOE II MPa	IB MPa	TS %
Aspen/birch OSB	8192	0.476	11.1
Ponderosa pine OSB	9049	0.946	14.5

Table 4 Average cupping values as a function of substrate type

Type of substrate	Average	Group
Web stock OSB	0.369	A
Grade sheathing OSB	0.322	B
Ponderosa pine OSB	0.321	B
BBP	0.273	C

According with Waller-Duncan test the means with the same letter are not significantly different at 5% probability level.

This slow-growth species produces wood of an excellent quality. According to the Handbook of Finnish Plywood (Anonymous, 2002), the parallel modulus of elasticity for this type of plywood is 11395 MPa, whereas the average measured value for OSB produced with a mixture of aspen and birch strands is 8192

MPa (Table 3). Despite these values, no significant difference between the measured cupping values for the BBP substrate and those for the OSB substrate made with a mixture of aspen and birch strands was noted (0.263 and 0.287 mm, respectively). These constituted the best substrate group in terms of cupping. In the

second group, the grade sheathing OSB and web stock OSB exhibit average cupping values of 0.453 and 0.430 mm respectively. Figure 3 presents the average cupping deformation as a function of conditioning period for substrates made of grade sheathing OSB, web stock OSB, ponderosa pine speciality OSB and BBP. The ANOVA indicates that at least one type of substrate is significantly different than the others. In order to classify flooring strips in terms of substrate, a multiple comparison test was carried out. The Waller-Duncan test (Table 4) highlighted three different groups. As in the preceding case, the BBP substrate exhibits the best average value for cupping (Figure 3). Although the average measured MOE value for OSB produced with ponderosa pine strands was 9049 MPa (Table 3), there are significant differences between the measured amplitude of cupping values for this type of substrate and the BPP substrate. This may be due to the poor dimensional stability of panels made with ponderosa pine strands. This dimensional instability is tied to the use of small-diameter ponderosa pine logs (100-200 mm) with a high proportion of juvenile wood. Heebink et al. (1964) have shown that the linear expansion of oriented strand board panels is strongly influenced by the linear expansion of solid wood. Juvenile wood presents anatomical and chemical properties that are different from those of mature wood.

Juvenile wood is characterized by low density, short fibres, thin cell walls, high lignin content and a high microfibrillar angle. The microfibrillar angle has a significant impact on dimensional stability - the greater the angle, the greater the dimensional instability of the wood. Fahey et al. (1986) demonstrated that ponderosa pine juvenile wood exhibits a significant longitudinal shrinkage compared to mature wood.

The different reaction of each EWF layer to changes in humidity generates tensile, compression and shear stresses. When these stresses become too high, substrate delamination can occur. Observation of ponderosa pine OSB and aspen/birch OSB substrates in climatic chamber highlighted this type of delamination. The number of delaminations and their depth negatively impact EWF cupping values. The presence of delaminations in the OSB substrate made with ponderosa pine strands as well as their relatively high number explains the non-significant differences between this type of substrate and the grade sheathing OSB substrate which was not consistent with MOE of the boards.

Oven-generated delamination

Figure 4 presents the average length of delamination as a function of substrate and conditioning cycles.

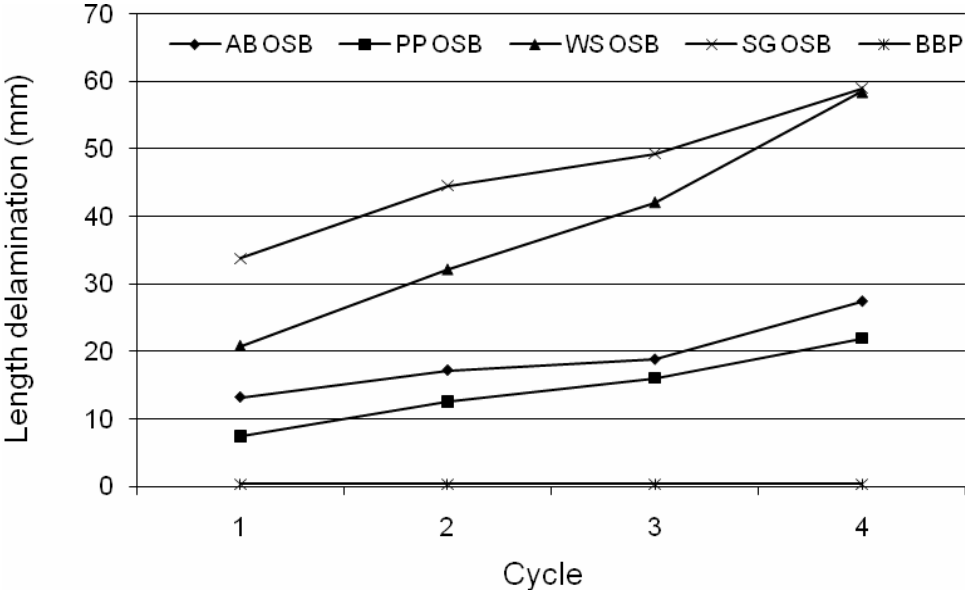


Figure 4 Substrate delamination as a function of substrate and conditioning cycles

(AB OSB – aspen/birch OSB, PP OSB – ponderosa pine OSB, WS OSB – web stock OSB, SG OSB – sheathing grade OSB and BBP – Baltic birch plywood)

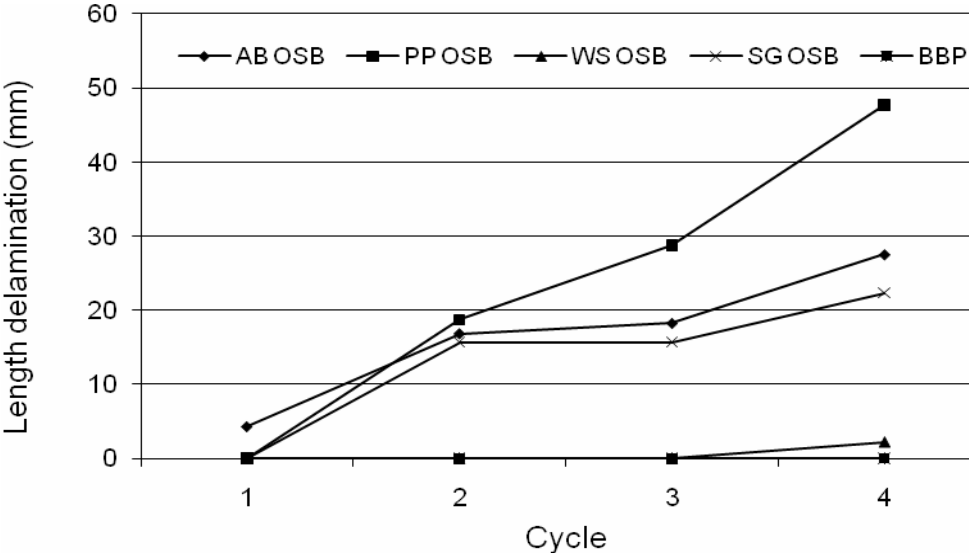


Figure 5 Substrate delamination as a function of substrate and conditioning cycles (AB OSB – aspen/birch OSB, PP OSB – ponderosa pine OSB, WS OSB – web stock OSB, SG OSB – sheathing grade OSB and BBP – Baltic birch plywood)

Table 5 Average substrate delamination as a function of substrate type at the end of four cycles

Type of substrate	Average (mm)	Group*
Sheathing grade OSB	58.90	A
Web stock OSB	58.40	A
Aspen/birch OSB	27.41	B
Ponderosa pine OSB	21.88	B C
BBP	0.34	C

*According with Waller-Duncan test the means with the same letter are not significantly different at 5% probability level

Table 6 Average glue-line delamination as a function of substrate type at the end of four cycles

Type of substrate	Average (mm)	Group*
Ponderosa pine OSB	47.7	A
Aspen/birch OSB	27.5	B
Sheathing grade OSB	22.3	B
Web stock OSB	2.2	C
BBP	0	C

*According with Waller-Duncan test the means with the same letter are not significantly different at 5% probability level

The analysis of variance showed that the effect of the substrate on delamination was highly significant at 0.01 probability level. Waller-

Duncan test results on the substrate delamination after four cycles highlighted three different groups at 0.05 probably level (Table 5). The BBP substrate is the most delamination-resistant in an oven test. Only one sample out of ten exhibited delaminations. No significant differences between BBP and ponderosa pine OSB substrates were noted. In the second group, the ponderosa pine OSB substrate showed a comparable performance to aspen/birch OSB. The delamination values for commercial OSB panels (third group) are nearly twice as high as those of specialty OSB panels. Since the wood strand bonding in an OSB panel is achieved by adhesive droplets, delamination occurs more easily within an OSB panel substrate than in a BBP substrate where the plies are bonded with a continuous glue-line.

Figure 5 presents the average value of the glue-line delamination as a function of substrate and conditioning cycles. All the OSB substrates exhibited glue-line delaminations. BBP substrate behaved as expected with almost no delaminations. The presence of glue-line delamination for OSB substrates suggests incompatibility between the PVA adhesive and the surface layers of the panels or

an inappropriate surface preparation. This incompatibility may be due to the low penetration of the adhesive in the high density panel surface layer. The analysis of variance indicates a highly significant effect of substrates on glueline delamination at 0.01 probability level. The Waller- Duncan test (Table 6) shows that the ponderosa pine OSB substrate exhibits the higher average value for glueline delamination. This lower compatibility between the PVA adhesive type I and ponderosa pine OSB substrate can be explained by the presence of extractives in ponderosa pine. Extractives are soluble in neutral solvents, such as water, alcohol, ether and benzene. They are found in higher concentrations in the bark and heartwood. Anderson (1951) found that the quantity of extractives in the heartwood of ponderosa pine is between 12 % and 15 %. These extractives could negatively interact with the adhesive and affect bonding quality.

Conclusions

In this study, five EWF prototypes were manufactured and evaluated. The five types of substrates were: BBP, grade sheathing OSB, web stock OSB, specialty aspen/birch OSB and specialty ponderosa pine OSB. Results highlighted the influence of substrate mechanical and physical properties on the performance of EWF strips. EWF made with BBP substrate presented the best average cupping values (0.263 and 0.273 mm). However, non-significant differences between the BBP substrate and the aspen/birch OSB substrate (0.287 mm) were noted.

The results for the OSB substrate made from small-diameter ponderosa pine logs were similar to those for the grade sheathing OSB (0.321 and 0.322 mm), but different from those of the BBP substrate..

This work demonstrates the potential of OSB substrate in the EWF constructions. It would be interesting to pursue this study with the characterization of EWF mechanical behaviours to determine the nature and distribution of the stresses. The delaminations observed in OSB panel prototypes are also present in BBP substrates but at a lowest level. It should be suitable to improve internal bond of these speciality OSB to prevent delaminations. The in-depth study of this type of fracture should help to define the relationship between

this type of fracture and the properties of EWF components.

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