TECHNICAL NOTE: EFFECTS OF NANOCLAY ADDITION TO PHENOL–FORMALDEHYDE RESIN ON THE PERMEABILITY OF ORIENTED STRAND LUMBER

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Abstract. This note examined the effects of adding nanoclays to phenol–formaldehyde resin during the manufacture of oriented strand lumber (OSL) on its in-plane permeability. The panels were made from mountain pine beetle (MPB) attacked lodgepole pine (*Pinus contorta*) strands. Three different montmorillonite nanoclays were mixed with the PF resin: Na^+, hydrophobic organics modified 10A, and hydrophilic organics modified 30B. None of the nanoclays changed the permeability of OSL significantly. The MPB-OSL had higher in-plane permeability than those conventionally made from aspen, which indicated that the pressing time could be shorter for MPB-OSL compared with OSL made from MPB-free strands.

INTRODUCTION

The epidemic of mountain pine beetles (*Dendroctonus ponderosae* [MPB]) beginning in the mid-1990s caused the loss of large quantities of timber in British Columbia. The infestation is projected to be approximately 56 Mm^3 provincially by 2012 (Walton 2009). Many solutions have been tested to utilize this large amount of wood, including conversion to wood plastics, glulam, and biofuel. Oriented strandboard and oriented strand lumber (OSL) have been widely used as structural panels in residential construction in North America. Manufacturing strand-based wood composites with MPB-attacked wood may be a means of utilization. In addition, nanoclays have been used to manufacture various composite materials to improve their properties. Preliminary work on adding nanoclay in phenol–formaldehyde (PF) resin to produce MPB-OSL has been found to increase bonding strength (Kadla et al 2009). Permeability is a key mat property that affects gas flow in a strand mat during hot-pressing. In the last two decades, many studies have investigated the permeability of strand-based wood composites, including the effect of density, strand dimensions (Dai et al 2005; Hood et al 2005), strand orientations (Zhang and Smith 2010a), and fine contents (Fakhri et al 2006).

Little work has been done on OSL with nanoclay addition to the resin. This research is aimed at quantifying the effect of nanoclay type and content in the resin on the in-plane permeability of OSL. Furthermore, as a continuation of the work by Zhang and Smith (2010a, 2010b), this study will permit comparison of permeabilities between MPB-OSL and OSL conventionally made from aspen (*Populus tremuloides*).

MATERIALS AND METHODS

Three commercial montmorillonite nanoclays were chosen in this experiment: Cloisite Na^+ (Na^+), Cloisite 10A modified with hydrophobic organics (10A), and Cloisite 30B modified with

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Table 1. Mean density of permeability and vertical density profile (VDP) specimens for each nanoclay type/content combination.[a]

Samples	Replicates	Oven-dry density (kg/m^3)				
		0%	2% Na^+	5% Na^+	2% 10A	2% 30B
Permeability	3	593 (21)	599 (19)	592 (33)	582 (7)	597 (14)
VDP	12	574 (50)	622 (26)	611 (32)	614 (29)	623 (27)

[a] Standard deviations are given in parentheses.

hydrophilic organics (30B), all manufactured by Southern Clay Products Inc. MPB-attacked lodgepole pine (*Pinus contorta*) strands, 1 mm thick, were supplied by Ainsworth Lumber Co Ltd, Grande Prairie, Alberta, Canada. The resin was liquid PF with a solids content of 59% (Cascophen OSF-59FLM, Hexion Canada). Five combinations of nanoclay type/content as a fraction of resin weight were prepared: 0% nanoclay (control), 2% Na^+, 5% Na^+, 2% 10A, and 2% 30B. Three replicate panels were made with the same target density (600 kg/m^3 at 1% MC) and panel size (406 mm long × 305 mm wide × 25.4 mm thick). The nanoclay and resin were blended for 6 min in a high-speed mixer (Hamilton Beach 730C). The blending and hot-pressing processes were the same as those used by Zhang and Smith (2010a). After pressing, each panel was cut into one 127- × 127-mm specimen for permeability tests and four 51- × 51-mm specimens for vertical density profile (VDP) tests. VDPs were measured with a Quintek Measurement System (Model QDP-01X). Permeability measurements were conducted with the apparatus and procedures described by Zhang and Smith (2010a).

RESULTS AND DISCUSSION

A uniform VDP was found in all the samples and a direct relationship between permeability and density could be established without the confounding effects of different face and core densities. The mean densities for each sample type are listed in Table 1. Because the panel size was relatively small, only two to three times the strand length, it was difficult to achieve a homogeneous in-plane density distribution and these samples may have created a higher variability than would be found in industrially prepared OSL.

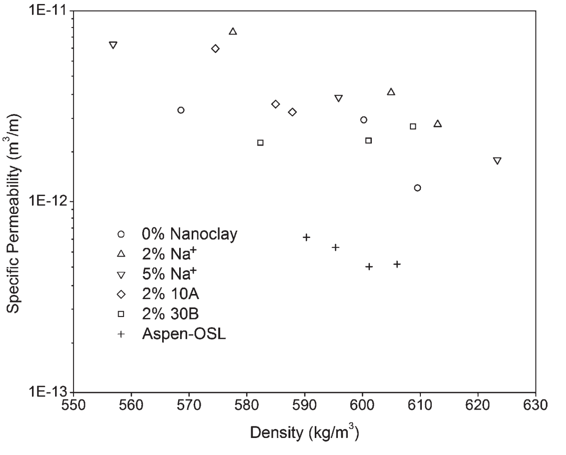

Figure 1. Specific permeability of mountain pine beetle-attached oriented strand lumber (OSL) added with different nanoclay type/content and of aspen-OSL.

The specific permeability was plotted against density in Fig 1, where each point represents one independent measurement. The analysis of variance indicated that density, treated as a covariate, significantly affected permeability ($p < 0.001$), which was in agreement with earlier findings (Dai et al 2005; Hood et al 2005; Zhang and Smith 2010a). The density range in this study (557-625 kg/m^3) was much smaller than that of the previous work and emphasizes the sensitivity of permeability to density.

Pairwise comparison indicated that the addition of nanoclay had no effect on the in-plane permeability of the OSL samples; neither increasing the nanoclay content nor changing nanoclay type had any significant effect over the range of values studied. This is markedly different from what others have found when adding nanoclays to polymer composites, eg Ogasawara et al (2006), where the gas permeability of nanoclay-filled resins was reduced. This difference is thought to be a result of their different compositions and internal structures. Although it is likely that the presence of the nanoclay in the resin will reduce its permeability, ie gases must now follow a more tortuous path around the impermeable nanoparticles, very little flow through the resin takes place. It should be noted that the resin-coated regions of the strands are discontinuous and that Dai et al (2005) showed that the vast majority of gas flow in the transverse direction of strand-based composites occurs through the voids between the strands. As such, the presence of nanoclay in the resin will have very little effect. This conclusion is probably limited to strand- or particle-based wood composites. In the case of plywood, where the resin film between adjacent veneer sheets is continuous, the permeability of plywood would likely be reduced by the addition of nanoclays.

Compared with aspen-OSL measured by Zhang and Smith (2010a), MPB-OSL had a significantly higher permeability at the same target density of 600 kg/m^3 ($p < 0.001$, mean 3.45×10^{-12} to 5.38×10^{-13} m^3/m), as shown in Fig 1. One of the factors resulting in this difference was the higher density of MPB-killed lodgepole pine. With an identical board density and strand size, a higher density of wood elements means fewer strands are required to form the board, leading to a higher porosity from which, according to Dai et al (2005), a higher permeability can be expected. Fewer strands in the transverse cross-section also results in less densified and thicker strands with a correspondingly higher permeability (Dai et al 2005; Hood et al 2005). Other factors may also have played a role in the more permeable MPB-OSL, including the difference in compressive properties and longitudinal permeability of wood elements. Higher permeability in MPB-OSL indicates that a lower internal pressure will accumulate during hot-pressing, reducing the time for steam to escape the panel, resulting in shorter production press times.

CONCLUSIONS

Based on these results, the following conclusions were reached:

1. The nanoclay additions did not change the permeability of OSL, regardless of the nanoclay type or its content. The outcome suggests that manufacturing strand-based panels by adding nanoclay into the resin could use a press cycle similar to that for boards without nanoclay.
2. MPB-OSL had a higher permeability compared with aspen-OSL because of the density difference in the raw materials. This indicated that manufacturing strand-based panels made of MPB-killed wood may require shorter pressing times than conventional boards made from aspen.

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REFERENCES

Dai C, Yu C, Zhou X (2005) Heat and mass transfer in wood composite panels during hot pressing: Part II. Modeling void formation and mat permeability. Wood Fiber Sci 37(2):242-257.

Fakhri H, Semple K, Smith G (2006) Permeability of OSB. Part I. The effects of core fines content and mat density on transverse permeability. Wood Fiber Sci 38(3):450-462.

Hood JP, Kamke FA, Fuller J (2005) Permeability of oriented strandboard mats. Forest Prod J 55(12):194-199.

Kadla JF, Smith G, Lam F, Kim YS, Oudjehane A (2009) Development of high performance MPB wood composites through nanotechnology. Technical Report, Forestry Innovation Investment Ltd., Vancouver, BC, Canada.

Ogasawara T, Ishida Y, Ishikawa T, Aoki T, Ogura T (2006) Helium gas permeability of montmorillonite/epoxy nanocomposites. Compos Part A-Appl S 37 (12):2236-2240.

Walton A (2009) Provincial-level projection of the current mountain pine beetle outbreak. BC Forest Service Research Branch. http://www.for.gov.bc.ca/hre/bcmpb/Year6.htm (19 May 2010).

Zhang C, Smith GD (2010a) In-plane permeability of oriented strand lumber. Part I: The effects of mat density and flow direction. Wood Fiber Sci 42(1):99-106.

Zhang C, Smith GD (2010b) In-plane permeability of oriented strand lumber Part II: Microscopic investigation of void structure during compression. Wood Fiber Sci 42(2):121-129.