Effect of moisture content and temperature on tension strength of fingerjointed black spruce lumber

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Abstract

To optimize product performance, the various parameters which can influence the complex fingerjointing process must be evaluated. Among key variables are the conditions of the lumber blanks including moisture content (MC) and temperature. Black spruce (Picea mariana (Mill) B.S.P.) 2- by 3-inch blocks at different MCs (12%, 16%, 20%, and green) were conditioned at several temperatures (–5°, 5°, 12°, and 20°C) prior to fingerjointing. Two types of adhesives were used in this study: polymer emulsion polyurethane (PEP) and a new fast-curing formulation of phenol-resorcinol-formaldehyde (PRF). All specimens were tested in tension after 24 hours of curing at room temperature to determine their ultimate tensile strength. Microscopic analysis of the adhesive bond was also carried out to explain differences between the various treatments. Results have shown that the operating envelope for PEP adhesive is between 12 percent and 16 percent and between 5°C and 20°C. It was also found that frozen lumber bonded better with PRF compared to PEP. Optimum MC for the PRF adhesive was found to be 16 percent. High wood failure and a uniform glue penetration profile were generally observed with green lumber.

Fingerjoints are important for engineered wood products (EWP), including glued laminated beams (glulam) and I- and open-web joists. EWPs are gaining market share in North America. For example, more than 40 percent of the wood floor area was built with wood I-joists in 2002. This market is expected to grow to as much as 80 percent in the next 10 years. There are two key driving forces behind the demand for EWPs in North America: the prevalence of wood-frame construction and the changing nature of the softwood fiber supply (Shuler 1999). Also, market drivers include the need of builders for more predictable product performance, price stability, and the need to reduce labor content and cycle time on the building site. Another important factor is the reduction of waste volumes at building sites (Tissari 2001).

This study is an extension of previous fingerjointing process optimization studies carried out by Bustos et al. (2003a, 2003b, 2004). Many factors such as joint configuration, end pressure, curing time, and machining parameters were studied by these authors using polymer emulsion polyurethane (PEP) adhesive. There is a need to expand on that study in order to include the effect of a range of moisture content (MC) and temperature on the performance of fingerjointed lumber. A newly developed...
phenol-resorcinol-formaldehyde (PRF) with a short curing time adhesive was also evaluated.

**Process variables: MC and temperature**

Usually, the MC of lumber in bonded products should be targeted to the equilibrium moisture content (EMC) the product will experience in-service. EMC of lumber exposed outdoors for most of the United States and the southern parts of Canada is near 12 percent and generally ranges from 7 to 14 percent (Simpson 1999). Additionally, Kennedy (1951) states that the range in MC between pieces in a single glued assembly should not exceed 5 percent. Beyond these limits, drying and shrinkage in-service could induce stress in the joint zone large enough to cause a rupture at the interface between the adhesive and the wood.

Published research and technical data given by adhesive manufacturers provide specific recommendations as to the MC range suitable for the fingerjointing of lumber (Selbo 1975, Jokerst 1981, Raknes 1982, Troughton 1984, Vick 1999). Fingerjointed flanges are usually manufactured with lumber that has been seasoned to a standard MC (≈ 20%) and are graded-stamped “S-DRY” or “KD”. Nevertheless, depending on the adhesive type and heating method used, lumber can be fingerjointed at a higher MC than recommended. High variations in MC between boards and within boards in a kiln load are usually observed due to the natural variability of wood and due to the difficulty in controlling the process of kiln-drying. Also, high seasonal variations in relative humidity (RH) and temperature in North America are common and can induce MC and temperature variations of lumber prior to fingerjointing. Recommended temperatures of lumber for fingerjointing with PRF and resorcinol-formaldehyde (RF) adhesives are around 15°C unless the jointing method employed permits a lower temperature (Fröblom 1975, Raknes 1982).

Traditional PRF adhesives used in fingerjointing have a long gel time, and fingerjoints must be heated to cure quickly in order to meet process requirements. A radio-frequency (RF) tunnel is commonly used in the industry to cure the adhesive within a few seconds. High frequency waves set water molecules into rapid motion, causing their temperature to rise. One of the major limitations for the use of RF is related to the MC variation of lumber in production. RF energy and feed speed are normally set for the use of kiln-dried lumber at a very narrow range (generally around 16% MC). If lumber contains moisture above this range, RF energy can dissipate away from the adhesive, producing improperly cured joints. On the other hand, if the MC is much below this range, sparks are produced in the joints resulting in burned joints (Ngangué 1999). Moreover, RF tunnels consume a great deal of energy and are costly when it comes to maintenance. Better processes and adhesive systems, not requiring RF curing and providing more flexibility, would be an improvement.

**Effect of MC and temperature on adhesive penetration and gluebond performance**

MC and temperature at the time of jointing can affect bonding quality. Since the joints are usually exposed to a large proportion of end grain, control of glue penetration becomes a critical factor in bonding quality (Currier 1960). Optimum depth of penetration has to be achieved in order to obtain good structural performances. When wood contains excessive amounts of moisture (above fiber saturation point), less water and adhesive is absorbed by wood. This leads to a squeeze-out when end pressure is applied (Vick 1999). In contrast, Jokerst (1981) and Ménard (1993) mention that at high MC the adhesive remaining in the glueline after pressing is diluted and, therefore, is absorbed by the wood, resulting in a starved joint. Also, aqueous adhesives tend to dry-out when applied to wood with a MC below 6 percent. In this case, wood absorbs water from the adhesive so quickly that the adhesive flow is drastically inhibited, thus resulting in a thick joint with insufficient penetration (Ménard 1993, Vick 1999). Finally, MC variation will normally affect curing time. Low MC can cause premature thickening and curing of the adhesive. At a high MC, the time required for the glue to cure is extended (Bailey et al. 1998).

Increasing the temperature of lumber by heating the fingerjoint accelerates polymerization of thermoset adhesives. Heating increases the viscosity of the adhesive, thus reducing excessive penetration into the wet wood and leading to a reduction in the MC of the lumber (Troughton 1986). Very high temperatures can pre-cure the glue and cause insufficient penetration. On the other hand, cold lumber will decelerate the polymerization reaction, keeping low viscosity adhesive for a longer time, which may lead to excessive penetration.

**Development of adhesive systems**

The wood industry is in need of new adhesive systems that can cure quickly and are simpler to use, highly performant, and more economical than those currently available (Pagel and Luckman 1981). Although new adhesive systems have been developed, the dominant types of adhesives used in the fingerjointing industry are RF and PRF. There is a need to develop new adhesive systems for the fingerjointing industry that would enable an efficient and robust process that would be more tolerant to MC and temperature variations in lumber. The usability of such new adhesives are not well-known in Canada’s industry because until recently the production of structural lumber jointed according to SPS-1 (NLGA 2002a) was limited to the RF and PRF adhesives (CSA 1977). A new performance-based standard has been developed by the National Lumber Grading Authority of Canada (NLGA) with the objective of establishing performance criteria and evaluation methods to verify the compliance with such criteria (NLGA 2002b). This development from the standard’s perspective allows the Canadian industry to consider using new adhesive systems.

Two new types of adhesives have been developed for fingerjointing structural lumber that polymerize quickly at room temperature:

1. Cascothen AG-5695™ a liquid PRF resin for use in gluing structural lumber members when short curing time is desirable. It is usually mixed with Cascozet FM-6210 , a powder formaldehyde hardener with use with PRF and resorcinol resins.
2. ISOSET® adhesive based on PUP as the main component (ISOSET UX-100) combined with an AEP as the minor component (ISOSET WD3-A322). Since PUP is principally moisture curable, the curing speed depends on the mix ratio.

These new adhesive systems sustain high production flow and decrease the amount of energy needed to cure the adhesive. None of them require a RF tunnel for curing in-process. Both types of adhesives are water-based. From a penetration per-
spective, water-based adhesives are generally desirable for wood bonding since wood is capable of absorbing a large amount of water in cell lumens and within cell walls. Water is used as the carrier for these wood adhesives (Vick 1999).

**Objectives**

The objectives of this study were to:

1. Evaluate the influence of MC and temperature at the time of jointing on the tension strength of fingerjointed black spruce.

2. Compare the tension strength of fingerjointed black spruce lumber made with an isocyanate adhesive and a newly developed, fast-curing PRF adhesive.

**Material and methods**

**Preparation of the lumber material**

A volume of 76.5 m³ of black spruce lumber from the Chibougamau-Lake-Saint-Jean region in the Province of Quebec, Canada, was shipped to Forintek Canada Corp., Eastern Laboratory. The sample material consisted of rough/green 38 by 64 mm (2 by 3 in) 2440 mm (8 ft) long No. 2 and Better grade lumber. Some of the lumber was kiln-dried at 12 percent MC with a conventional schedule and the rest of the lumber was air-dried at either 16 percent or 20 percent during summer conditions for gluing with the PEP adhesive. For fingerjointing with the PRF adhesive, some of the lumber was kiln-dried at either 12 percent or 16 percent MC with a conventional schedule and some of the lumber was air-dried at 20 percent MC in summer conditions. For both adhesives, lumber in the green condition was selected to range from 30 to 35 percent MC. A 50-cm block cut from the center of each green board was used to measure MC. Defects were trimmed out to produce blocks between 20 cm (8 in) and 91 cm (36 in) according to NLGA-SPS-1 specifications (NLGA 2002a). The defecting yield reached almost 75 percent for the green lumber and 65 percent for the kiln-dried lumber to produce fingerjointing blocks from grade No. 2 and Better. Following trimming, blocks were conditioned in three groups at 20°C and 65 percent relative humidity (RH), 20°C and 80 percent RH, and 5°C and 90 percent RH to reach 12, 16, and 20 percent EMC, respectively. Green blocks were wrapped in plastic sheets and kept in a conditioning chamber set at 5°C and 90 percent RH prior to jointing. Blocks were conditioned to their respective temperatures 24 hours prior to fingerjointing.

**Experimental design**

Sixteen combinations were selected to cover a range of conditions usually found in fingerjointing plants (Table 1). Extreme conditions (green lumber at 30% to 35% MC and temperatures below zero) were selected to test the limits of the two studied adhesives. A three-level factorial experiment design (four MCs; four temperatures; two adhesives) was used to evaluate the main effects and the interactions (SAS GLM procedure). Analysis of variation (ANOVA) was performed to evaluate the data (SAS Institute 1998). When a source of variation was significant, multiple comparison tests were made using Least Squares Means statement from the SAS General Linear Models to determine which factor levels differed from the others. These comparisons were done at the comparison-wise error rate of 0.05. Normality assumption was verified using Shapiro-Wilk test, while the homogeneity of variances was analyzed by Levene and Bartlett tests.

**Fingerjointing**

A Conception RP 2000 machine with a lateral feed system, commonly used in the North American fingerjointing industry, was used. Blocks at various conditions were machined in such a manner that the fingers were cut parallel to the wide face to produce horizontal joints. “Feather” profile was selected due to its good performance (Bustos et al. 2003a). The machining parameters as well as geometric characteristics are given in Table 2. Glue was applied manually on one end using finger-profiled pieces of lumber cut to appropriate dimensions. A balance was used to verify the quantity of glue for the PEP adhesive. However, since a shorter assembly time was necessary for PRF adhesive, the quantity of glue applied was estimated following enough trials to ensure consistency in glue application. Once glued, the blocks were jointed together. An end pressure of 3.79 MPa (550 psi) was applied for about 20 seconds. The fingerjointed lumber was cut off at 2.44 m (8 ft) long. Specimens were mechanically tested after 24 hours of curing at room temperature (20°C and 65% RH). Other process parameters

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Table 1. — Experimental design to assess the effect of MC and temperature on the performance of fingerjointed black spruce.

<table>
<thead>
<tr>
<th>Moisture content (%)</th>
<th>Lumber temperature at the time of jointing (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PEP adhesive</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>–5, 5, 12, 20</td>
</tr>
<tr>
<td>16</td>
<td>–5, 5, 12, 20</td>
</tr>
<tr>
<td>20</td>
<td>–5, 5, 12, 20</td>
</tr>
<tr>
<td>Green</td>
<td>–5, 5, 12, 20</td>
</tr>
<tr>
<td>PRF adhesive</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>–5, 5, 12, 20</td>
</tr>
<tr>
<td>16</td>
<td>–5, 5, 12, 20</td>
</tr>
<tr>
<td>20</td>
<td>–5, 5, 12, 20</td>
</tr>
<tr>
<td>Green</td>
<td>–5, 5, 12, 20</td>
</tr>
</tbody>
</table>

4 Conditions in bold were those identified for microscopic examination.

Table 2. — Joint geometry and fingerjointing process characteristics.

| Fingerjoint geometry                                          |                                              |
|---------------------------------------------------------------|                                              |
| Finger length                                                | 28.27 mm                                     |
| Tip width                                                     | 0.76 mm                                      |
| Pitch                                                        | 6.69 mm                                      |

| Characteristics of the fingerjoint process                    |                                              |
|---------------------------------------------------------------|                                              |
| Rotation speed of knives                                      | 3,500 rpm (six knife bolts per tool)         |
| Feed speed of blocks                                         | 18.3 m/min                                   |
| Chip-load                                                    | 0.84 mm                                      |
| Assembly time (before pressure)                              | < 5 min (PEP)                                |
| Pressure time                                                 | ~ 20 s                                       |
| Adhesive quantity                                            | 90 to 113 g/m² (PEP)                         |
| Adhesive quantity                                            | 181 to 207 g/m² (PRF)                       |

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used in this study (Table 2) were those optimized by Bustos et al. (2003a, 2003b, 2004). The knives were sharpened once every 4 hours of machining (2,500 board feet); it is reported that in this range of operation, no significant effect of knife wear could be observed (Pitcher 2003).

**Tension tests and microscopy analysis**

Tension tests were carried-out in accordance to ASTM D 198-99 (ASTM 2001a) with a Metriguard model 412 testing machine and evaluated according to NLGA-SPS-1 (2002a) for structural fingerjointed lumber. The machine provides a uniform tensile stress over the complete cross section with a gauge length of 815 mm (32 in). Failure modes were classified in accordance with ASTM D 4688 standard (ASTM 2001b). Following tension tests, two samples were cut from each side of the failed joint and MC determined. Effective dimensions and specific gravity (SG) were also determined in accordance with ASTM D 2395-93 (ASTM 2001c). Since the study focused on assessing the strength of joints, only those failures occurring in the joint zone were considered, others were rejected. Thus, failure modes No. 5 and 6 (with mainly wood failure) were not included in the analysis, but they were considered in the discussion.

Microscopic examination using scanning electron microscopy (SEM), with a JEOL 840-A instrument, was used to explain differences in the tension strength and failure mode between the various groups with different conditions. Blocks of about 1.0 cm² (0.16 in²) of transverse area, including the glueline, were cut from the middle of the joint location (Fig. 1). Samples were taken from fingerjoints made with both adhesives and with lumber in various conditions (Table 1). Examined conditions were those which had the highest and lowest tension strength. Prior to SEM examination, a microtome was used to cut a surface across the end grain. The blocks were later desiccated with phosphorus pentoxide (P₂O₅) over two weeks. Then, they were mounted on standard aluminium stuff with silver paint, redissecated, and coated with gold-palladium using a sputter-coater. Electron micrographs of five representative surfaces were taken for each of the ten conditions. In the micrograph images, the area covered by adhesive was colored using Photoshop. The colored surface representing adhesive penetration was measured using Metaphorm Imaging System (Version 4.5r0), an image analysis software. Then, surface areas were divided by the length of the picture in order to calculate an average glueline thickness.

**Results and discussion**

Average (Avg.), minimum values (Min.), and standard deviation (SD) values of the ultimate tensile strength (UTS) as a function of MC and temperature are shown in Table 3, as well as average and SD for SG and MC at the time of testing. Figures 2 and 3 present UTS average and standard error for each group condition, respectively for PEP and PRF. When PEP adhesive was used, the best performance was obtained at 12 percent MC and 20°C (34.1 MPa); the worst performance was found at green and 5°C condition (18.6 MPa). When PRF adhesive was used, the best performance was obtained at 16 percent MC and 12°C (34.8 MPa) and the worst performance at green and –5°C condition (21.0 MPa). ANOVA indicated that MC, temperature, and adhesive type had a significant effect on the UTS (Table 4). Also significant interactions were observed between MC and temperature as well as between MC and adhesive type on one side and temperature and adhesive type on the other.

**PEP adhesive**

**MC effect.** — Figure 2 shows an increase in UTS average values as MC decreases and an optimum UTS value at 12 percent MC. LSMEANS indicated no significant differences between the various groups with different conditions. Blocks of about 1.0 cm² (0.16 in²) of transverse area, including the glueline, were cut from the middle of the joint location (Fig. 1). Samples were taken from fingerjoints made with both adhesives and with lumber in various conditions (Table 1). Examined conditions were those which had the highest and lowest tension strength. Prior to SEM examination, a microtome was used to cut a surface across the end grain. The blocks were later desiccated with phosphorus pentoxide (P₂O₅) over two weeks. Then, they were mounted on standard aluminium stuff with silver paint, redissecated, and coated with gold-palladium using a sputter-coater. Electron micrographs of five representative surfaces were taken for each of the ten conditions. In the micrograph images, the area covered by adhesive was colored using Photoshop. The colored surface representing adhesive penetration was measured using Metaphorm Imaging System (Version 4.5r0), an image analysis software. Then, surface areas were divided by the length of the picture in order to calculate an average glueline thickness.

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**PEP adhesive**

**MC effect.** — Figure 2 shows an increase in UTS average values as MC decreases and an optimum UTS value at 12 percent MC. LSMEANS indicated no significant differences be-

![Figure 1. — SEM samples cut across the grain.](image1)

![Figure 2. — Effect of MC and Ton UTS for PEP adhesives.](image2)

![Figure 3. — Effect of MC and Ton UTS for PRF adhesives.](image3)
tween 12 percent and 16 percent at any temperature level. Lumber between 12 percent and 16 percent MC produced a good bond quality with the PEP adhesive. On the other hand, green lumber showed poor performances. LSMEANS indicated significant differences between specimens made with various MCs at every temperature level.

Temperature effect. — Figure 2 shows an optimal temperature at 12°C for the green condition. LSMEANS indicated no significant differences between 5°, 12°, and 20°C for 12, 16, and 20 percent MC levels. LSMEANS also indicated that frozen lumber (−5°C) produced the worst performances. Significant differences were found between −5°C and 5°C at 12 and 20 percent MC levels. For the green condition, −5° and 5°C were statistically different, whereas those were statistically significant differences between −5° and 12°C for the green condition. LSMEANS indicated no significant differences between −5°, 5°, and 12°C temperature levels for the PRF adhesive. Results from this study indicate, however, that the lower limit for the fast-curing PRF formulation is even higher.

Temperature effect. — The effect of temperature on the UTS average values for fingerjoints made of PEP and PRF adhesives is shown in Figure 3. LSMEANS indicated that differences were not significant between temperature levels for 12, 16, and 20 percent MCs. However, the factorial experiment confirmed that temperature effects on UTS were more significant with green lumber than with dry lumber. In the green condition, −5° and 5°C were not statistically different; however, those two were statistically different than the 12° and 20°C samples. Similar to the PEP adhesive, the effect of low temperatures on UTS is more detrimental when using green lumber compared to dry lumber.

**PRF adhesive**

**MC effect.** — Figure 3 shows optimum UTS values at 16 percent MC and −5°, 5°, 12°C. LSMEANS indicated significantly higher UTS values at 16 percent compared to 12 percent MC for −5° and 12°C temperature levels. Marra (1992) stated that waterborne adhesives that harden by chemical reaction without heat cannot tolerate rapid water loss, as would be the case if they were used with very dry lumber. A range of 8 to 12 percent MC of lumber was recommended as the lower limit when using these types of adhesives. Moreover, Raknes (1982) indicated that low MC (8% to 10%) is the critical lower limit for traditional PRF adhesive. Results from this study indicate, however, that the lower limit for the fast-curing PRF formulation is even higher.

**Failure modes**

The types of failure that can occur in fingerjointed specimens due to tension stress are classified into six modes according to ASTM D 4688 standard (ASTM 2001b). Generally, wood failure was high for all fingerjoints tested, regardless of the type of adhesive used. On average for both adhesives and various conditions studied, approximately 70 percent of the failure modes were No. 3 and 4. Such failures are the most common in structural fingerjointed material, and they are indicative of a good glue bond. Very few (less than 5%) in groups at 12, 16, and 20 percent MC with both adhesives failed in...
modes No. 1 and 2, this confirms that the gluing process was adequate. In the green condition, however, 28 percent of the specimen failed in modes No. 1 and 2 and were associated mainly with glue failure along the joint profile. Also, no major differences were found in the failure mode between groups fabricated with lumber at different temperatures but with the same MC. Approximately 30 percent of tested fingerjointed specimens fabricated with PEP adhesive and lumber at 12, 16, and 20 percent MC failed in modes No. 5 and 6 and were rejected, while, approximately 10 percent failed with PRF adhesive. No specimens were rejected among groups fabricated with green lumber (Table 3).

Adhesive comparison

Table 3 shows the UTS performance comparison between the two types of adhesives. From LSMEANS comparisons, it can be observed that the two adhesives did not show any difference for all MC conditions at the temperature of 12°C. At 20°C, the adhesives did not show significant differences for any MC level, except for the 20 percent MC samples where PEP showed a significantly lower performance. At 5°C, the two adhesives had a similar performance at 12 percent and 16 percent MC, but PEP had a significantly lower UTS performance than PRF for the 20 percent MC and green conditions. Below 0 (–5°C), PEP showed significantly lower UTS performance than PRF for 16 percent and 20 percent MC while there was no significant difference between the two for 12 percent MC and the green condition. These results point to a more robust UTS performance of the PRF adhesive when used outside the conditions recommended by the suppliers. When comparing the samples for each adhesive, no significant differences were found for MC; however significant differences ($p = 0.0002$) were found for SGs (Table 3). On the other hand, no relation between SG and UTS ($r^2 = 0.05$) was found over the total range of SG studied. In any case, for all tested temperature and MC conditions (Table 3), all samples performed better than the proof load requirement according to NLGA-SPS-1 specifications (NLGA 2002a) which is 6.8 MPa.

SEM analysis of transverse glueline section

Two micrograph images are shown in Figures 4 and 5 for green and dry conditions, respectively. When studying the glueline and penetration pattern, it is evident that the glueline thickness profile is less uniform for fingerjoints made with green lumber compared to those made with dry lumber. This trend was confirmed for both types of adhesive. The type of glueline profile associated with green lumber with very thin glueline spots could produce stress concentrations large enough to weaken the joint.

It was noticed that occasionally there was more penetration on one side of the glueline compared to the other when gluing green lumber. In Figure 4, there is less penetration in the upper side than the lower side. This could be due to the variation of MC between the two pieces fingerjointed with green lumber. In green groups, MCs ranged from 30 to 35 percent. Lumber at high MC inhibits adhesive penetration at the time of pressing.

Using these SEM images and the Photoshop glueline identification procedure, the glueline thickness was measured as indicated in Figure 4. According to the average glueline thickness values given in Table 5, the 12 percent and 20°C condition produces the highest penetration for both types of adhesives. No significant differences were found between specimens at 12 percent and 20°C and those in green and at –5°C conditions; LSMEANS indicated, however, significant differences between –5°C and 20°C at the 12 percent level for both adhesives.

![Figure 4](image-url)
Moreover, the PEP adhesive produced deeper penetration compared to the PRF adhesive. Significant differences were found between the two types of adhesive for the various conditions. A glueline thickness of around 108 µm when using PEP adhesive and around 75 µm when using PRF adhesive appears to maximize the UTS performances. This good difference in the glueline thickness between the two types of adhesive can be explained by the longer gel time associated with PEP adhesive compared to PRF adhesive. An adhesive with a long gel time allows the adhesive to flow into the lumber resulting in deep penetration.

**Conclusion**

MC of fingerjointed black spruce lumber has more influence on the UTS than temperature for the range of conditions and the type of adhesives studied (PEP and PRF) and tested after full curing adhesive. The effect of temperature was found to be more pronounced for lumber in the green condition than with dried lumber using both types of adhesives. Findings from this study have indicated that optimum operating conditions for the PEP adhesive were from 12 to 16 percent MC and 5°C to 20°C.

These conclusions were supported by SEM analysis of glueline in fingerjoints, which indicated that the condition 12 percent and 20°C produces the deepest penetration thickness. With the PRF adhesive, the cold temperature only had a negative effect on green lumber. Optimum MC for PRF was found to be at 16 percent. No difference was found between the performance of the two adhesives within the MC and temperature conditions recommended by the manufacturers. However, in extreme conditions of MC and temperature, the PRF performed better, and it was observed that in these conditions the PEP adhesive showed deeper penetration in the wood. For all of the lumber conditions, including green lumber, all specimens exhibited higher minimum tensile strength than the specified SPS-1 tensile value (NLGA 2002a) for spruce-pine-fir, Grade No. 2. There would be a need to assess the PEP adhesive called UX-200 that has recently been commercialized by Ashland Inc. The producer’s claim is that this adhesive specifically formulated for fingerjointing would withstand the process requirement for curing at room temperature within 30 minutes.

**Literature cited**


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