Technology Profile

Value to Wood

TP–03–02E
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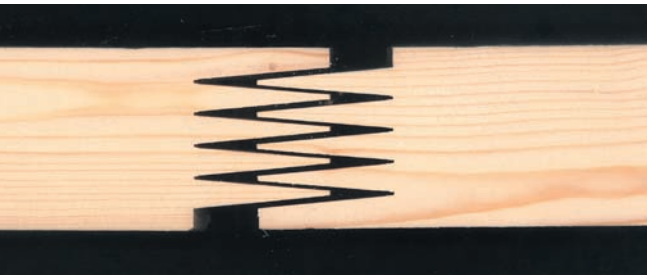

Influence of Moisture Content and Temperature on the Performance of Fingerjointed Lumber

« Manufacturers of fingerjointed wood products need to know how the wood's moisture content and temperature affect the quality of the end product, particularly as new adhesives are being introduced. »

The process of fingerjointing is complex and requires numerous efforts in order to evaluate the various workable and optimum conditions of jointed wood members. Many factors are known to affect the strength of fingerjoints. Some are related to wood, such as species, density, natural defects, moisture content (MC), temperature, and gluability of the species. Others are related to wood machining, including type of adhesive and gluing processes, such as condition of the cutting tools, curing time and applied assembling pressure.

The fingerjointing industry has raised concerns on how moisture content and wood temperature could affect the performance of the end product, especially when new adhesive systems are introduced. Typically, the MC of wood in bonded products should be close to the Equilibrium Moisture Content (EMC) that the product will experience in-service. Average EMC of wood exposed to the outdoors for most of the United-States and Southern Canada is near 12%, and ranges from 7% to 14%. Variability of moisture content between wood pieces in a single assembly should be kept at a minimum. Some researchers have indicated that this variability should not exceed 5%; beyond this limit, further drying and shrinkage in-service could cause stress development in the joint zone, great enough to rupture adhesive bond and wood.

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Seasonal changes in the temperature are also quite common especially in North America. Recommended wood temperature for fingerjointing with typical adhesives used in the industry [i.e., Phenol-Resorcinol-Formaldehyde (PRF), Resorcinol-Formaldehyde (RF)] is around 15°C unless the jointing method employed permits a lower temperature. Although fingerjointed lumber is commonly made from wood that has been seasoned to standard moisture contents (<19% MC) and are grade-stamped "S-DRY" or "KD", different moisture content levels are recommended depending on the type of adhesive used and the curing conditions. According to various studies, the upper and lower limits vary with the adhesive type, formulation and the curing process used.

How Does Moisture and Temperature of Wood Affect the Adhesive Bond?

Big variations in moisture content within individual boards and between boards are not uncommon in a kiln-dried load of lumber, due to the natural variability of wood, the difficulty in controlling the kiln-drying process and changes in the environmental conditions prior to fingerjointing. Boards in the heart of the bundle will experience fewer changes in their MC because of changes in the surrounding environmental conditions compared to those boards located at the top or on the sides.

It is well known that moisture content and temperature of wood at the time of jointing can affect the bond quality. Since end joints usually contain a large proportion of end grain, control of glue penetration becomes quite critical. An optimum penetration depth needs to be achieved to ensure a good structural performance. Two schools of thought exist in explaining why poor performance of an aqueous type of adhesive [i.e., Phenol Formaldehyde (PF), RF, PRF, and Melamine Urea Formaldehyde (MUF)] is associated with high MC of wood.

One study showed that when the wood contains excess amounts of moisture (above fibre saturation point), it absorbs less water and adhesive. This leads to excessive adhesive mobility, followed by squeeze-out when end pressure is applied, producing a thin glue line. Other studies have, on the other hand, concluded that at high MC, adhesive remaining in the glue line after pressing is diluted and, therefore, absorbed by the wood, resulting in a starved joint. At low MC (below 6%), studies have shown that the glue tends to dry out and most of the water from the adhesive

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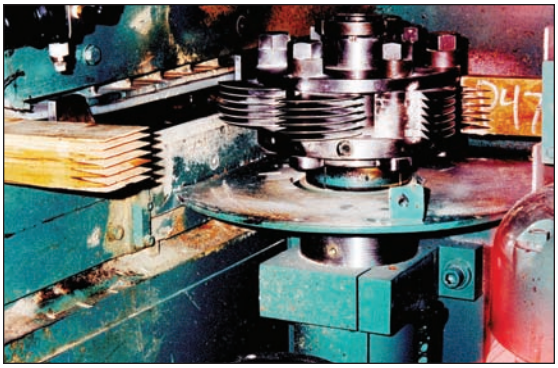

migrates into the wood, leading to a granulose adhesive. A thick joint is produced because of insufficient penetration. Other researchers have also examined the relationship between MC and curing, and determined that the length of time required for the adhesive to cure is extended when using wood that contains high MC. Regardless of the type of explanation given, all sources agree on that fact that poor adhesive bonding performance is associated with high MC.

Increasing wood temperature by heating the fingerjoint accelerates polymerization of thermosetting adhesives. Heating increases the viscosity, thus reducing excessive penetration of the adhesive into the wet wood. Higher temperature could however pre-cure the glue and cause insufficient penetration. Cold wood, on the other hand, could decelerate the polymerisation reaction, by keeping the adhesive at low viscosity for a longer period of time, and lead to excessive penetration.

« Moisture content and wood temperature can also affect indirectly other variables related to wood, which could in turn affect the bond quality as well. »

It is important to mention that moisture content and wood temperature can also indirectly affect other variables related to wood, which could in turn affect the bond quality. For example, the machining properties of wood and its compression strength (associated with the assembly) can be influenced by MC and wood temperature.

Sensitivity of Traditional Adhesives to Variations in Moisture Content

Traditional PRF and RF adhesives are fairly tolerant to high MC when cured at room temperature. Practical experiences, as well as research, have shown that when using PRF and RF adhesives, MC up to 25% has no adverse effect on adhesion or bond strength. In fact, poor bonding often occurs with very low MC (according to some studies), and MC of 8 ~10% is considered to be the lowest limit for efficient gluing of softwoods. Lower average ultimate tensile strength and modulus of rupture values (MOR) were associated with 8% when compared to 12 and 14% MC. Moreover, with 8% MC, failure in tension and bending occurred mostly in the adhesive (with less wood failure).

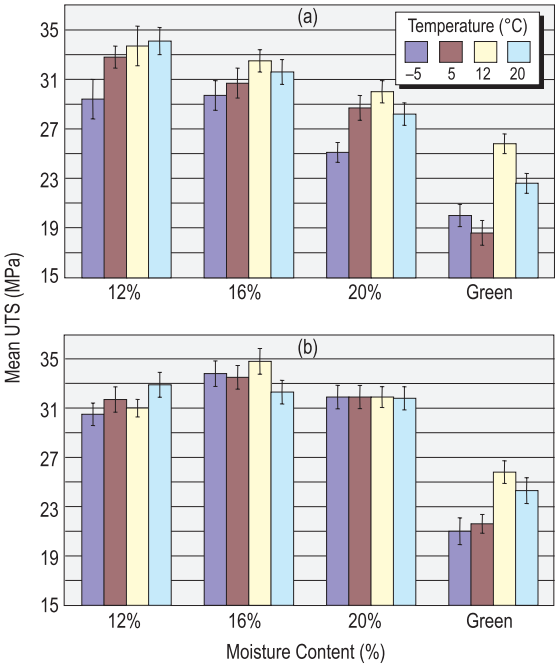

Figure 1. Effect of moisture content and temperature on the UTS for: (a) PEP; (b) PRF adhesives

Comparison Between Polymer Emulsion Polyurethane (PEP) and Phenol Resorcinol Formaldehyde (PRF)

A recent study was carried out by Forintek's Eastern Laboratory and the *Centre de recherche sur le bois* at Laval University dealing with the influence of moisture content and temperature on the performance of fingerjointed black spruce (*Picea mariana*). Blocks of 2 x 3 lumber, both in green condition and at different MCs (12, 16 and 20%) were conditioned at various 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 tension tested after 24 hours of curing at room temperature to determine their ultimate tensile strength (UTS). Microscopic analysis of the adhesive bond was also performed to evaluate the glue penetration into the wood following conditioning.

Findings from this study have indicated that MC of fingerjointed black spruce lumber has more impact on the ultimate tensile strength (UTS) than temperature, for the range of conditions and the type of adhesives studied (PEP and PRF). The effect of temperature was found to be more pronounced for green lumber, using either type of adhesive. Results also show that the best operating envelope for PEP adhesive is between 12 and 16% MC and between 5 and 20°C, while optimum MC for PRF adhesive was found to be around 16%. It was also found that the PRF adhesive performed better at high moisture content (Figure 1) as compared to PEP adhesives.

The study also demonstrated that high wood failure and uniform glue penetration profiles were associated with dry lumber whereas failure in the glue and irregular glue penetration profiles were generally associated with green wood.

The 2003-2004 ***Value to Wood*** research program includes various projects related to finger-jointing. For information, go to www.valuetowood.ca (Research and Development). The partners involved are:

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*Ce **Profil technologique** est également disponible en français.*

Value to Wood

As part of the ***Value to Wood*** program, funded by Natural Resources Canada, Forintek's Industry Advisors are providing technical services to value-added wood product manufacturers in all regions of Canada. If you need information on any technical issue related to wood product manufacturing, you can:

- Send a request via *valuetowood.ca* (Help Desk).
- Contact a *Value to Wood* co-ordinator at one of the following locations:

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