Field Study of Hygrothermal Performance of Cross-Laminated Timber Wall Assemblies with Built-in Moisture

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ABSTRACT

Cross-laminated timber (CLT) panels are a type of new engineered wood product being introduced into the North American market. To ensure long-term durability of CLT wall assemblies, their hygrothermal performance needs to be evaluated in terms of drying potential before its widespread adoption in North America. A field test experiment was designed to monitor the drying of wetted CLT panels with different wood species in four wall assemblies with a range of vapour permeances. This paper presents the experimental setup and preliminary test results. It was found that the panels wetted to an extreme level dried very quickly when freely exposed to normal ambient conditions, which was difficult to monitor during wall construction and commissioning of the sensors. By monitoring the moisture content across the depth of the panels, the preliminary data indicated that the wood adjacent to high permeance materials dried quickly enough to reduce potential moisture problems. It also appeared that moisture did not redistribute quickly enough through the thickness of the CLT panels to reduce the moisture content at the panel faces adjacent to low permeance materials. The maximum possible moisture content under typical conditions needs to be examined to determine the suitability of wall materials with medium vapour permeance.

1. Introduction

Cross-laminated timber (CLT) panels have potential market in North America for building mid-rise structures due to their good structural and seismic performance, light weight, and prefabricated nature. Many of these benefits are outlined in the CLT Handbook (Gagnon and Pirvu, 2011). However, prolonged exposure to moisture before and during construction as well as in service can be a durability concern for most wood products including CLT. Specifically, CLT panels stored on unprotected construction sites can be exposed to rain and sitting water, leading to built-in moisture after erection. If this built-in moisture cannot dry out within a reasonable time period, potential damage as a result of excessive moisture may occur. To ensure long-term durability and improve the design of CLT assemblies, the hygrothermal performance of CLT wall assemblies with a variety of configurations and materials needs to be evaluated in terms of drying and wetting potential before their widespread adoption in North America.

The purpose of the experiment is to monitor and analyze the drying behaviour of wetted CLT panels within different wall assemblies. As a result, recommendations may be made regarding the criticality of protecting the panels from moisture sources and the suitability of different wall assemblies to ensure the long-term durability of CLT wall assemblies. The data collected will improve understanding of the effect of adjacent materials in the assemblies and wood species used for CLT manufacturing on drying behaviour, as well as help calibrate CLT material properties to allow for future hygrothermal modelling. By testing multiple samples of different species, the variability between wood species and samples of the same species may be studied to help improve material selection for CLT manufacturing.

This paper presents the methodology used in this field study as well as the drying behaviour of the CLT samples during the first two months of testing.

2. Experimental Setup and Procedure

2.1 Description of Wall Assemblies

In order to evaluate the hygrothermal performance of CLT wall assemblies, a test wall measuring 2.6 m × 2.6 m was constructed in a field exposure building envelope test facility in Waterloo, Ontario. The test wall comprises sixteen 0.6 m × 0.6 m CLT panels, each composed of one of five types of wood species, in combination with two types of water resistant barrier, and two types of insulation.

The drainage planes behind the insulation were created using self adhesive water resistant membranes. A non-vapour permeable (NVP) water resistant membrane was used for the low permeance wall configuration, and a vapour permeable (VP) membrane was chosen for the medium and high permeance wall assemblies. These membranes were chosen since their ability to be fully adhered would reduce potential air leakage adjacent to the wetted CLT panels and focus the experiment on the impact of vapour permeance of the assemblies. Rigid board insulation was used since it encouraged the use of continuous insulation, and its structural properties allowed it to be fastened to the CLT panels via screws through strapping, which also support the cement fibre board siding. Mineral wool insulation board was used as the vapour permeable insulation, and expanded polystyrene (EPS) insulation board was chosen for the rigid semi-vapour permeable insulation. 76 mm thick boards of each type of insulation was used, with the mineral wool providing a thermal resistance of 2.22 m^2K/W, and the EPS providing RSI 2.1 m^2K/W. All assemblies were built with an interior air space and gypsum drywall. The typical wall section is shown in Figure 1.

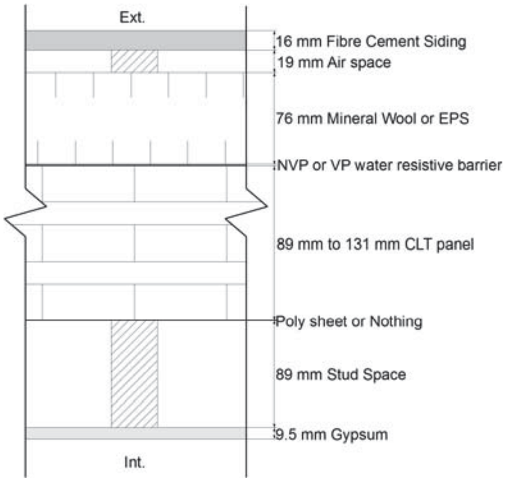

Fig. 1. Typical CLT Wall Assembly Cross-section

As a result four categories of wall assemblies were studied: three having high, medium, or low vapour permeance materials outside of the CLT panels, respectively, but all having an unobstructed wall cavity to the interior of the panels and allowing them to freely dry to the interior. The fourth category had the medium permeance construction on the exterior but with a polyethylene sheet on the interior of the panels, creating a low interior permeance condition. The vapour permeance variations are created with the following material combinations, chosen to give three orders of magnitude of vapour permeance:

1. Low Exterior – NVP membrane and mineral wool (1.6 ng/Pa.s.m^2 combined)
2. High Exterior – VP membrane and mineral wool (1670 ng/Pa.s.m^2 combined)
3. Medium Exterior – VP membrane and EPS (64.4 ng/Pa.s.m^2 combined)
4. Medium Exterior and Low Interior – VP membrane and EPS (64.4 ng/Pa.s.m^2 combined) plus 0.15 mm polyethylene sheet on interior (3 ng/Pa.s.m^2)

2.2 Description of Wood Species

The four Canadian wood species or species groups included are Western SPF, black spruce, Eastern SPF, and hem-fir. The test also included a European CLT product with European spruce as a reference. Four samples each for Western SPF, European spruce, and black spruce were tested, one for each wall permeance category. Two hem-fir samples were tested with the low and medium exterior permeance wall assemblies, and two Eastern SPF panels were tested with the high exterior and low interior permeance wall assemblies. The Eastern SPF species group was composed largely of black spruce, although the manufacturing methods differ so they are treated as a separate category for this experiment.

The Western SPF, Eastern SPF, and hem-fir CLT panels were manufactured in a Vancouver laboratory specifically for this test wall, and included five laminations totalling 130 mm in thickness. The European spruce CLT panels were a commercial product from Europe, made of three layers and totalled 89 mm in thickness. The black spruce CLT panels were commercially made in Quebec and consisted of three layers, totalling 102 mm in thickness.

2.3 Wetting Protocol

2.3.1 *Wetting Period*

Since this study aimed to investigate the wetting and drying behaviour of CLT, one of the key experimental parameters that should be defined was the level of moisture to be introduced to the panels before construction of the test wall. Hygrothermal simulations using WUFI 4.2 were conducted to determine the moisture content (MC) profiles developing in the panels, using the preset 3-ply cross-laminated panel material properties, when they were directly exposed to, or enclosed in a high humidity environment, such as covered with a tarp with sitting water on a construction site. The simulations indicated that riskier MC profiles could occur when the panels were enclosed with a moisture source rather than exposed to normal exterior weather conditions, including the rainy season in Vancouver.

Parallel laboratory testing of the same types of CLT panels was also being conducted, monitoring the wetting and drying behaviour of the panels alone. The results of these tests showed that hygrothermal modelling for CLT based on the existing model and knowledge drastically underestimated both the rate of water uptake and the drying speed. Since the purpose of this field test was to investigate the drying potential of the CLT wall assemblies, it was imperative that the panels started in a sufficiently wetted state so that differentiation between wall assemblies or wood species could be detected. Since there would be a period of about three days between the start of panel installation and the connection of all the sensors to the datalogger, and the laboratory testing showed significant drying would occur in this timeframe for the CLT panel, a decision was made to wet the panels to an extreme level in an attempt to ensure the panels would still be wet when the data collection commenced. A period of one week, with the panels immersed in water, was chosen.

2.3.2 *Wetting Method*

The edges of each CLT panel were sealed in advance with polyurethane paint in order to ensure water adsorption in the thickness direction. The paint was allowed to dry for at least two weeks before submersion. The original plan was to wet both sides of CLT for seven days to study the impact of the assembly permeance on both the exterior and interior of CLT assemblies. Data could be collected from the exterior faces, where the permeance of the wall materials is varied, and from the interior faces, where the panels are relatively free drying to the interior air space, and the variation in behaviour between the different species, and the samples of the same species may be analyzed.

A large children's swimming pool was used for wetting. The panels were placed in the pool in five stacks, with spacers between the pool floor, and each of the panels. Bricks were then stacked on top of the panels to act as ballast as the pool was filled with water. Unfortunately, the advertised depth of the pool could not be obtained. The panels on the tops of the stacks were initially covered in water when wetting began, but the pool leaked water overnight until the water level stabilised about halfway up the top panel of each stack. As the pool was set up in the test facility, which has no plumbing, the amount of water available for wetting was limited. Consequently the top of some panels were left exposed to the air with only the bottom faces immersed. These panels were marked, and the dry faces were placed where their drying conditions were closely replicated elsewhere, usually as the interior freely drying face of the assemblies.

2.4 Test Wall Layout

The test wall was located on the eastern side of the building envelope testing facility as shown in Figure 2. Viewed from the exterior, the panels are arranged as shown in Figure 3.

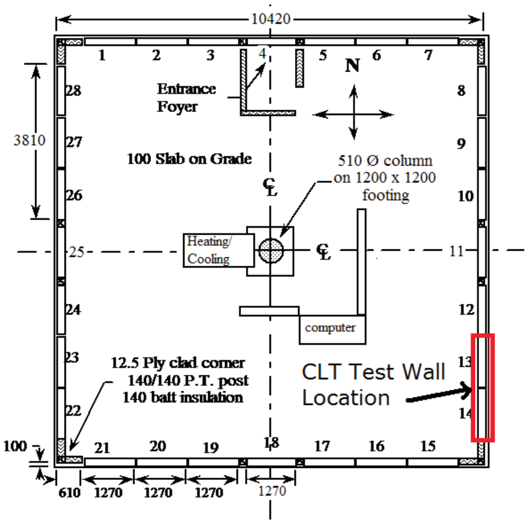

Fig. 2. CLT Wall Location in Building Envelope Test Facility

<table>
<tr><td rowspan="4">CLT Panel Species Type
All panels wetted on both sides except as indicated</td><td>A: European</td><td>A1
Int Dry</td><td>A2</td><td>A3</td><td>A4</td></tr>
<tr><td>B: Black Spruce</td><td>B1</td><td>B2
Int Dry</td><td>B3</td><td>B4</td></tr>
<tr><td>C: Western SPF</td><td>C1</td><td>C2
Int Dry</td><td>C3</td><td>C4
Ext Dry</td></tr>
<tr><td>D: Hem-fir/
E: Eastern SPF</td><td>D1</td><td>E2</td><td>D3
Int Dry</td><td>E4</td></tr>
<tr><td rowspan="8">Wall Assembly</td><td>Type</td><td>1: Low</td><td>2: High</td><td>3: Medium</td><td>4: Low Int</td></tr>
<tr><td rowspan="3">Interior Materials</td><td colspan="4">9.5 mm Gypsum</td></tr>
<tr><td colspan="4">Minimum 89 mm Air Space</td></tr>
<tr><td colspan="3">-</td><td>Poly Sheet</td></tr>
<tr><td rowspan="4">Exterior Materials</td><td>NVP WRB</td><td colspan="3">VP WRB</td></tr>
<tr><td colspan="2">76 mm Mineral Wool</td><td colspan="2">76 mm EPS</td></tr>
<tr><td colspan="4">19 mm Vented Cavity</td></tr>
<tr><td colspan="4">16 mm Fibre Cement Board</td></tr>
</table>

Fig. 3. CLT Wall Panel Layout

The Western SPF, Eastern SPF, and Hem-fir panels were mounted directly onto a stud frame. The black spruce panels and the European spruce panels were less thick, and therefore were mounted onto the frame with spacers at the screw locations, allowing the exterior faces of all the CLT panels to align. This arrangement created interior vertical cavities for each of the four wall assemblies, which were relatively open to each other at the top. While the stud frame was necessary for this unconventional test wall made of many smaller panels, in typical construction this cavity may not be necessary or can be used to accommodate services within the wall.

The panels are separated from each other by a layer of spray polyurethane foam with a thickness of about 13 mm, in addition to the polyurethane paint used to seal the edges during wetting. The wall opening of the test facility for accommodating the entire CLT test wall was lined with a layer of polyisocyanurate foam board insulation and plywood, wrapped in the NVP water resistant membrane.

2.5 Sensor Layout

Moisture content pins, thermistors, and relative humidity (RH) sensors were installed across the wall assemblies to monitor the behaviour of the CLT panels. RH and temperature were measured in each of the four exterior vented cavities and interior air spaces, and between the weather resistant barriers and insulation for each of the CLT panels. In total 24 combined RH and T sensors were used. Seven moisture content pins were placed in each CLT panel, located in the middle of the panels, 19 mm in from each face, 13 mm in from each face, and 6 mm in from the exterior face, except for the low interior permeance panels, where the 6 mm depth moisture measurement was taken at the interior face. Three additional thermistors per panel were inserted in the middle of each panel and 13 mm from each face. There were three more thermistors for the whole wall, two on the back of the fibre cement board sheathing, and one inserted 3mm into the interior side of the gypsum board. All the sensors were monitored via a Campbell Scientific CR1000 data logging system. The typical panel sensor layout is shown in Figure 4.

The MC pins on the interior and exterior faces of the CLT panels were hammered directly into the wood, using a spacer to control the depth of penetration. Holes were pre-drilled to 12 mm less than the final penetration depth of the MC pins monitoring the middle of the panels, which were then hammered in to the correct location. Holes for the thermistors were also pre-drilled, and were sealed with silicone caulking after insertion. The RH sensors were taped in place on the CLT panels, as well as in the cavity spaces.

The sensor leads were passed through the CLT wall from the exterior in the gaps between the panels. The wires were draped and fastened angling up into the gap to ensure the drainage plane remained robust. Care was taken to spray insulation around the wires to reduce air leakage.

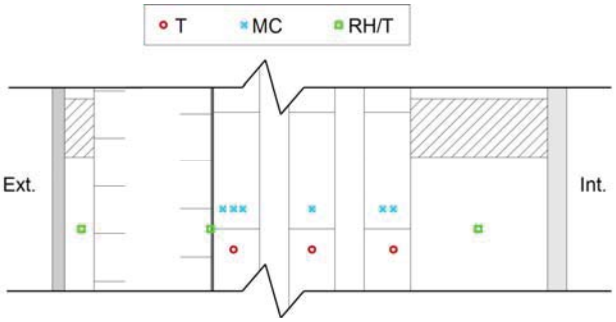

Fig. 4. Typical CLT Panel Sensor Configuration

2.6 Test Wall Construction

Figures 5 through 8 show several stages during the construction of the test wall. The large CLT panel and stud wall section above it are not discussed in this paper. The low exterior and low interior permeance panels had Blueskin and polyethylene sheeting, respectively, applied to them several hours after the wetting pool was drained. The insulation was installed approximately 30 hours after the wetting pool was drained, enclosing the panels in their final drying environments. 12 hours were required to attach all the sensors to the logging system, and data collection began on August 20, 2011, approximately 80 hours after the wetting pool was drained.

Data is collected and stored on-site and can be retrieved remotely. However, remote access to the data logger was delayed and therefore on-site downloading was done during the first several weeks. Unfortunately data of a few periods were found missing when the data was collected. This was likely caused by a faulty outlet being used in combination with a failure of the datalogger's power supply batteries. Fortunately four full days' data was collected at the beginning of the experiment, when the wood was drying quickly, showing the major differences between the panels, in addition to the majority of the data after the initial quick drying phase, when the panel moisture content continued to change.

Fig. 5. Soaking of CLT panels in pool

Fig. 6. After installation of water resistive barriers

Fig. 7. CLT test wall with insulation, strapping and cladding.

Fig. 8. Interior of wall before drywall installation

3. Preliminary Results and Discussion

3.1 Moisture Content Calculations

The panels were monitored to assess drying behaviour and to test for the presence of moisture contents above 26%, the threshold for wood decay initiation (Wang and Morris 2011). The moisture content pins in the CLT samples were used to measure the electrical resistance of the wood. These resistance values were converted to wood moisture content percentage values using Eq. (1) described by Straube (2002) to convert wood resistance to a Delmhorst meter reading for Douglas-fir:

$$Log_{10}(MC_u) = 2.99 - 2.113(\log_{10}(\log_{10}(R_W))) \qquad (1)$$

where MC_u is the moisture content (%), uncorrected for species and temperature, and R_W is the measured resistance (Ω) of the wood.

The moisture content was then corrected for species and temperature using the Garrahan (1988) correction factors for moisture meter reading. Eq. (2) was used, as follows:

$$MC_c = [\frac{MC_u + 0.567 - 0.0260t + 0.000051t^2}{0.881(1.0056)^t} - b] + a \qquad (2)$$

where MC_c is the corrected moisture content (%), MC_u is the uncorrected moisture content (%), t is the temperature at the location of the MC reading (°C), and a and b are constant correction factors for difference species. The values used for a and b are outlined in Table 1.

Table 1. Garrahan (1988) species correction factors

CLT Panels	Species	a	b
A: European	Norway Spruce	0.702	0.818
B: Black Spruce	Black Spruce	0.820	-0.378
C: Western SPF	Lodgepole Pine	0.835	-0.545
D: Hem-fir	Eastern Hemlock	0.904	-0.051
E: Eastern SPF*	Black Spruce	0.820	-0.378

*The Black Spruce and Eastern SPF panels differ in manufacturing methods

3.2 Drying on the Interior Face

In order to determine whether wood species has a significant effect on the drying behaviour of CLT, most of the panels were constructed with no vapour barriers impeding drying into the interior wall cavity. The moisture content at 13mm into the interior face of the freely drying panels is plotted in Figure 9. While the panels had different moisture content levels when data collection began, the rate of drying did not appear to vary greatly between the different species, although different wood species, or more precisely, different CLT samples, had different water absorptions. The rates of moisture content change appeared to be relatively constant between these samples, except panels C3 and D3. Both panels had the medium permeance wall materials on the exterior. The readings for panel D3 were likely an error, as the moisture content readings seemed to indicate the panel was behaving as if it had polyethylene sheeting on the interior face, when in fact, not only was there no sheeting, but the interior surface was not even wetted before construction. However, no programming or wiring errors could be found to explain these readings. On the other hand, the panel C3, made of Western SPF, was the panel with the highest MC at the start of data collection and dried at a faster rate than all the other panels, despite being located within the same MC range. In the samples which started with higher MC, especially above 20%, the drying rate appeared to be faster, probably due to the higher proportions of free water in cell lumens than the bound water in cell walls. Since neither all the medium exterior permeance panels, nor all the Western SPF panels dried at a faster rate than the remainder of the panels, it seemed likely that the faster drying rate was caused by special variations and irregularities in the specific wood sample tested, and may not be indicative of significant variations between wood species. The species may have a larger effect on total moisture adsorbed, or the depth of penetration of the elevated moisture content, but not the actual rate of drying of intercellular water molecules.

The relative consistency in behaviour between the freely drying interior CLT faces suggests that wood species is not a significant factor which will affect the choice of which CLT panels to choose for a construction project from a hygrothermal perspective. Also, it appeared that the panels were thick enough that the drying behaviour of the exterior and interior panel faces was not closely connected in the initial drying phases. For example, the interior faces of the panels were not drying more slowly when the exterior face was exposed to a low permeance material or more quickly when the exterior face was exposed to a higher permeance material.

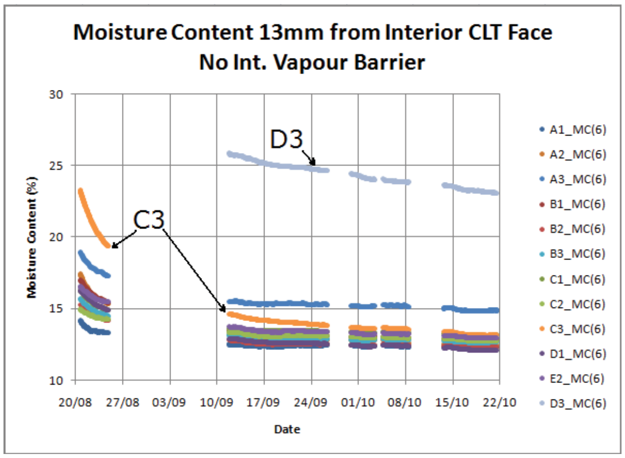

Fig. 9. Moisture Content at 13mm from Interior CLT Face for Freely Drying Panels

The panels with polyethylene sheeting on the interior face showed slightly less uniform behaviour, especially in the first few days of rapid drying, as seen in Figure 10. The European panel, A4, dried more quickly than the others initially, which may indicate that liquid moisture transport occurred more readily, redistributing into the centre of the European panels when drying to the free surface was dramatically slowed. The rate in decline of MC for panel C4, the Western SPF panel, is extremely low compared to the other three panels after the initial drying phase.

The MC in all the low interior permeance panels remained at a very high level, with only two panel dropping significantly below 26% after two months. While it was expected that the low interior permeance panels be the worst performing hygrothermally, with the highest risk of damage due to moisture, this measured data confirms that the moisture content does not redistribute quickly enough to the centre of the panels, sufficiently lowering the MC in the outer layers in a fast enough time frame to safely prevent mould and rot.

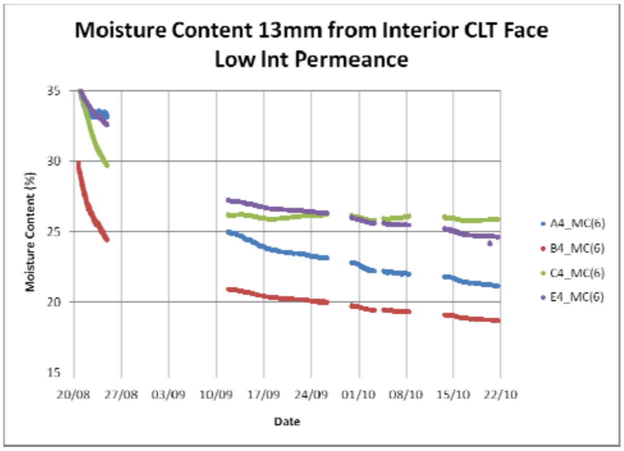

Fig. 10. Moisture Content 13mm from Interior CLT Face for Low Interior Permeance Panels

The MC 19 mm into the interior face are slightly higher than at the 13 mm mark, but the drying patterns are the same, as seen in Figure 11. This trend of higher moisture contents deeper into the face of the panel is mirrored across the entire test wall. The MC in the centre of the panel, in Figure 12, is lower than at the interior face, allowing moisture to redistribute into the centre, and the rate of drying into the centre is much lower than at the face, and in some cases the MC in the centre rises. This indicates that the moisture at the interior face of the panels with polyethylene is drying into the centre of the panel, and the moisture in the centre of the panel is drying further to the exterior CLT face.

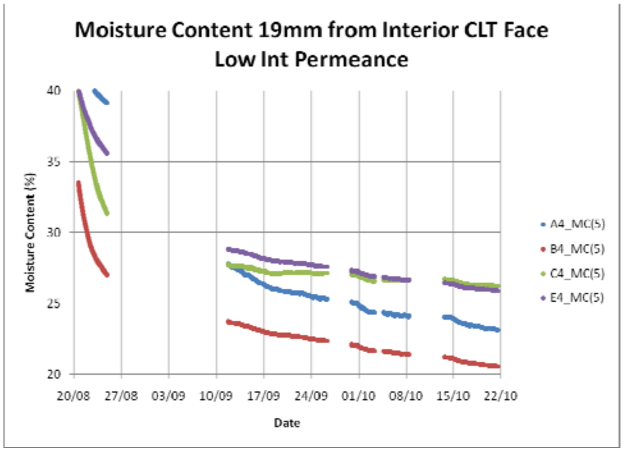

Fig. 11. Moisture Content 19mm from Interior CLT Face for Low Interior Permeance Panels

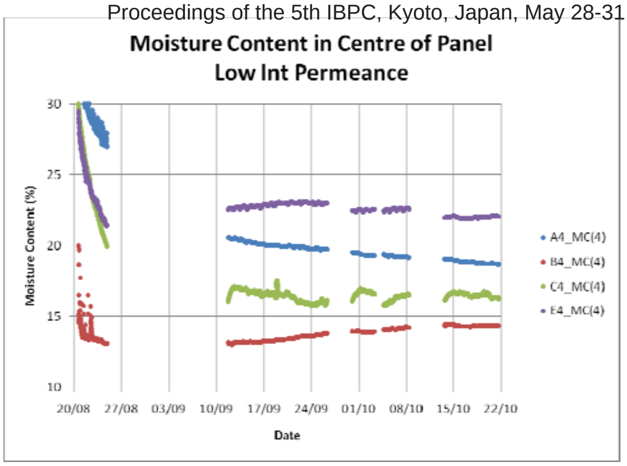

Fig. 12. Moisture Content in Centre of Panel for Low Interior Permeance Panels

An additional point of concern for wood durability is the possibility of mould growth on the surface at a relative humidity above 80%. For the panels with low permeance materials adjacent to them, the RH sensors were not placed directly on the wood surface, they were placed between the non-vapour permeable membrane and the insulation for the exterior low permeance panels, and in the interior cavity for the low interior permeance panels. However, at the time of installation, extensive condensation was present on the inside of the polyethylene sheet on the low interior permeance panels, in Figure 13. Given the slow rate of drying, it is likely that the RH on the surface of the panel remains well above 80%, even after two months. The same is likely the case for the panels with low exterior permeance, though the opaque vapour barrier masks condensation.

Fig. 13. Condensation on Interior of Polyethylene Sheet for Low Interior Permeance Panels

3.3 Drying on the Exterior Face

The MC records for the exterior face of the CLT panels demonstrate that the permeance of the materials adjacent is a principal factor in the drying behaviour of the wetted panels. Due to the drying that occurred during construction, before installation of the insulation, many of the panels with a vapour permeable water resistant barrier had already dried to below 26% MC before the start of data collection. The panels which had the non-vapour permeable water resistant barrier or polyethylene sheeting applied shortly after being removed from the wetting pool all have moisture contents in the covered faces of at least 20%, and usually well above the 26% required to initiate wood decay. Since the application of the vapour control layer is the only difference in the treatment of the panels, it is reasonable to assume that all the panels were wetted to at least 30% in the outer layers in the wetting pool. Comparing this assumed initial moisture content to the moisture contents at the start of data collection, it becomes clear that the majority of drying occurred during the time before the insulation was installed. The majority of the high and medium exterior permeance panels are at MC levels between 15% and 19% at the time when data collection begins.

Figures 14, 16, and 18 show the moisture contents 13mm in from the exterior faces of the high, medium, and low exterior permeance CLT panels, respectively.

All the high exterior permeance panels were below 26% MC when data collection began, and in two months time dried to below 15% MC. The MC in the exterior face of these panels is more responsive to high outdoor relative humidity creating a vapour drive into the CLT panel from outside on several occasions due to the high vapour permeance of the mineral wool insulation. The variation is small in the data collected from the test wall with a well ventilated drainage cavity, but solar driven moisture may be a point of concern for poorly constructed walls. The outdoor vapour pressure is also plotted in Figure 14 to demonstrate the connection.

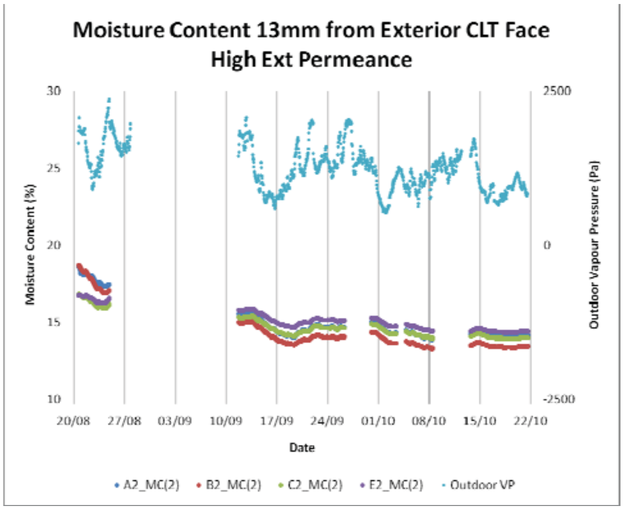

Fig. 14. Moisture Content 13mm from Exterior CLT Face for High Exterior Permeance Panels

The risk of mould growth for the high exterior permeance panels is low, as the highly vapour permeable mineral wool means the RH adjacent to the panel surface closely mirrors the ambient RH, rising above 80% only occasionally, for brief periods, as shown in Figure 15.

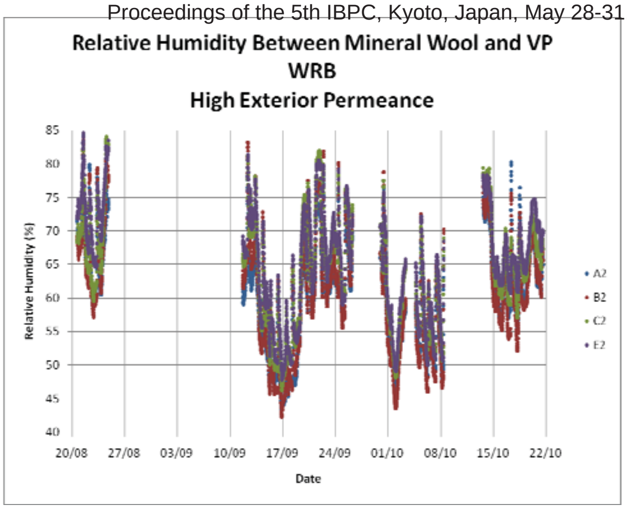

Fig. 15. Relative Humidity Between Mineral Wool and VP WRB for High Exterior Permeance Panels

The panels with medium exterior permeance which started below 20% MC when data collection began, dried at a very slow rate, or remained nearly stable. The few panels with higher MC dried to below 26% quickly, and their rates of drying slowed as they approached 21%. With the exception of panel C4, which increased in MC noticeably due to an unexplained high RH adjacent to the panel's exterior face, the semi-vapour permeable expanded polystyrene insulation appeared to serve as a buffer, removing the immediate impact of high exterior relative humidity on the MC of the exterior face of the CLT. The source of the moisture being driven into panel C4 from the exterior is unknown, but is consistently present in all the panel's sensors in the exterior face. Overall, since the MC is very stable, the initial MC becomes a point of concern for long term durability of the panel, since the drying period will be extended.

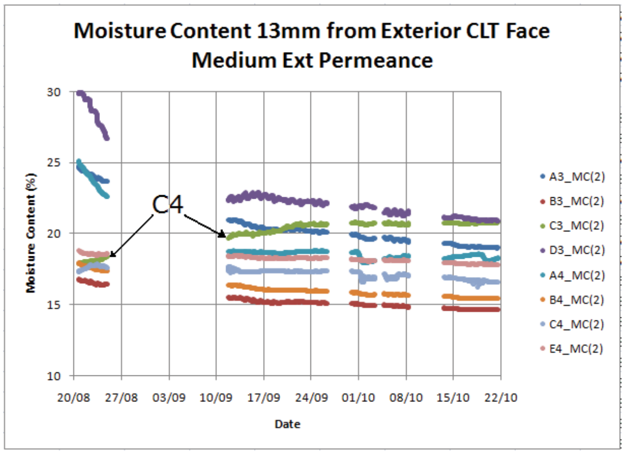

Fig. 16. Moisture Content 13mm from Exterior CLT Face for Medium Exterior Permeance Panels

Although the MC in the panels with medium exterior permeance may be low enough to prevent wood decay, the relative humidity on the exterior panel face remains above 80% for the majority of the panels, shown in Figure 17. The two panels with the highest RH levels are both made of Western SPF, which may indicate a different in behaviour between CLT panel wood species groups. Due to the medium vapour permeance of the EPS insulation, the relative humidity adjacent to the panel is very stable, which prevents the RH from decreasing during each day, when the ambient

RH is low, as occurs for the panels with high exterior vapour permeance. These sustained, elevated RH levels present a serious risk of mould growth.

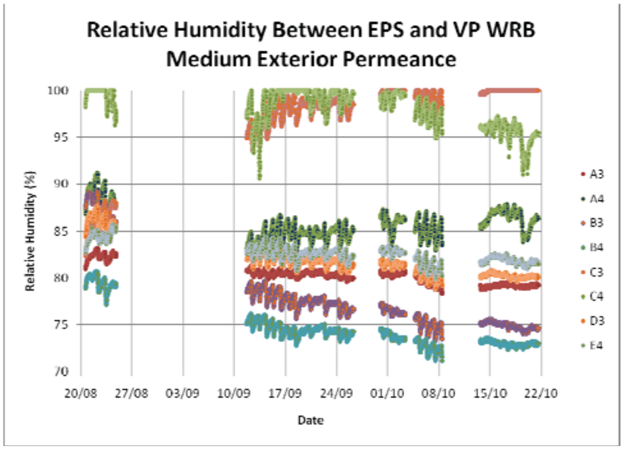

Fig. 17. Relative Humidity Between EPS and VP WRB for Medium Exterior Permeance Panels

The panels with low exterior vapour permeance were again expected to perform very poorly. They appear to be reaching equilibrium between 20% and 25% MC, just below the danger zone for wood products. This again indicates that moisture redistribution into the centre of the panel may occur too slowly to safely prevent moisture related durability issues.

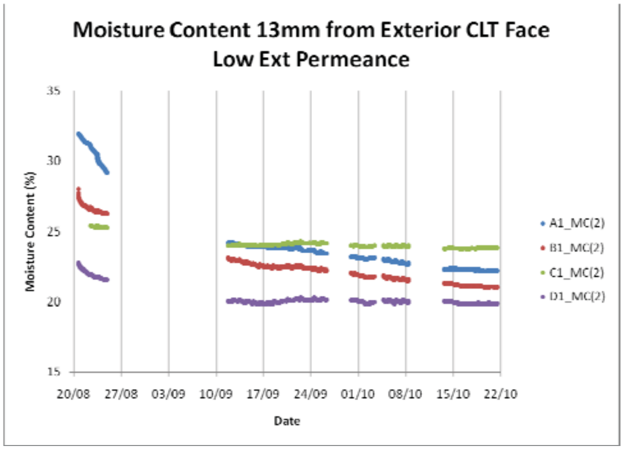

Fig. 18. Moisture Content 13mm from Exterior CLT Face for Low Exterior Permeance Panels

4. Conclusions

The preliminary data analysis from this field test experiment indicated three key aspects of the hygrothermal behaviour of cross-laminated timber.

First, during construction, wetted panels dry very quickly under typical Southern Ontario Summer conditions. While for this field test, this behaviour made it difficult to capture the initial drying phase, it does indicate that during a typical construction project, where efforts are not made to purposely build with wetted panels, the highest possible initial moisture content at the time of enclosure of the CLT panels due to accidental moisture exposure may be low enough to reduce potential durability problems under normal operating conditions. The drying may be slower under cooler and more humid conditions, such as in the rainy winter conditions in Vancouver. Second, the use of high permeance envelope materials can effectively promote drying of CLT panels. The impact of assemblies with medium permeance, including the use of EPS, should be further investigated before any firm recommendations can be made.

Low permeance materials should not be used, not only because they prolong the time period required for wetted panels to dry to a safe level, also because of the evidence of slow moisture redistribution into the centre of the panel, which further indicated that the CLT panel itself was a good vapour retarder. Therefore any additional vapour barrier should not be used in a CLT assembly.

Finally, the wood species does not appear to have a significant effect on the drying behaviour of the CLT panels.

The test wall will continue to be monitored for at least a year, and the data will be further analysed to study the drying behaviour of CLT assemblies, and also to calibrate hygrothermal simulation software allowing modelling of different types of CLT wall assemblies under various climates.

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