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Hygrothermal Performance of Cross-Laminated Timber Wall Assemblies with Built-in Moisture: field measurements and simulations

KEYWORDS: Hygrothermal performance; Cross laminated timber; Built-in moisture

OVERVIEW OF PROJECT

Prolonged exposure to moisture during construction and in service could be a durability concern for most wood products including cross-laminated timber (CLT). Specifically, CLT panels at unprotected construction sites can be exposed to rain and sitting water, which could lead to undesirably high levels of built-in moisture once assembled. If this built-in moisture cannot dry out within a reasonable time period, potential damage resulting from excessive moisture may occur. To ensure long-term durability performance, 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 to improve the design of CLT-based building enclosures. This study aims to assess i) whether wetted CLT panels are capable of drying within a reasonable time period; ii) how the wall assembly configurations influence the drying behaviour of CLT panels; and iii) whether the hygrothermal simulation program WUFI is able to predict such hygrothermal behaviour with reasonable accuracy.

A test wall measuring 2.6 m × 2.6 m and incorporating sixteen 0.6 m × 0.6 m CLT panels with five types of wood species or species groups from Canada and Europe in combination with two types of water resistive barrier and two types of insulation was constructed. The hygrothermal performance of these CLT wall assemblies was monitored over a one-year period in a building envelope test facility located in Waterloo, Ontario. Four categories of wall assemblies were studied: three having high, medium or low vapour permeance materials outside the CLT panels, respectively, but all having an unobstructed wall cavity to the interior of the panels and allowing them to freely dry to indoor. 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 were created with the following combinations of materials:

1. Low Exterior – non-vapour permeable membrane and mineral wool insulation (with a combined permeance of 1.6 ng/Pa.s.m^2)
2. High Exterior – vapour permeable membrane and mineral wool insulation (with a combined permeance of 975 ng/Pa.s.m^2)
3. Medium Exterior – vapour permeable membrane and expanded polystyrene (EPS) insulation (with a combined permeance of 64.4 ng/Pa.s.m^2)
4. Medium Exterior and Low Interior – As 3, plus 0.15 mm polyethylene sheet on the interior (3 ng/Pa.s.m^2)

The test wall was located on the eastern side of the building envelope testing facility. The CLT panels were wetted by submersion in water for one week, achieving over 30% MC in a depth of 25 mm. The CLT panels were immediately built into wall assemblies after the initial wetting. Moisture content pins, thermistors, and relative humidity sensors were installed across the wall assemblies to monitor the hygrothermal behaviour of the CLT panels. The interior condition was maintained at 21°C ±1°C and about 50% ±3% RH, and the test walls were exposed to the natural environmental conditions. The measurements were taken from August 2011 to August 2012.

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The field test data was analysed to evaluate the drying potential of the tested wall assemblies, and compared to hygrothermal simulation results using WFUI to assess the accuracy of modelling and identify areas for improvement.

KEY RESULTS

The field study has provided an opportunity to determine the behaviour of wetted CLT panels within a variety of wall assemblies, and to verify the hygrothermal model, WFUI, in these extreme cases. The main findings of this study were:

- The wetted CLT panels dried quickly under the southern Ontario summer/fall conditions. The tests were started at the end of August, although different drying behaviours were observed among different CLT wall assemblies, most of the CLT panels dried to below 26% within one month except for CLT walls with low-permeance interior membrane;
- Elevated MCs which would allow for potential decay initiation were not highly likely to be developed in CLT of building enclosures resulting from typical exposure to moisture in a southern Ontario climate;
- Low permeance materials such as polyethylene sheeting and other non-vapour permeable water resistive barriers caused slower drying and should be used with caution. While both the interior and exterior low permeance wall panels dried sufficiently quickly to prevent decay initiation, the low permeance material may have a more deleterious effect if an incidental moisture source is present, enabling a rise of local MC over time;
- The drying behaviour of wetted CLT panels is significantly influenced by the configuration of wall assemblies rather than wood species;
- With adjusted material properties and properly assigned initial conditions, simulation results from WUFI were generally in good agreement with field measurements at moisture contents below 25%. However, two notable discrepancies were observed; firstly WUFI tends to overestimate the MC in the centre of the panel by 5-10%; and secondly simulated MCs at locations deeper into the CLT panels were not as responsive to changes in exterior RHs as measurements indicated for wall assemblies with high exterior permeance.

Overall, it seems unlikely that if reasonable measures are taken to protect CLT panels from wetting, construction moisture alone is not likely to be a cause of long term moisture durability issue. However, further study is required to determine the extent to which on-site exposure can cause excessive moisture accumulation under a variety of climates, and with different wood species, exposure times, and CLT manufacturing methods. Further improvement of the hygrothermal model together with refined material properties are required to more accurately model wood, especially at higher MC levels.

THESIS

McClung, V. R. 2013. Field study of hygrothermal performance of cross laminated timber wall assemblies with built in moisture. MASc thesis. Ryerson University, Toronto, ON.