Abstract

Cross-Laminated Timber (CLT) panels have been manufactured and used in European design for more than a decade and have demonstrated great structural performance as well as a good market opportunity for the forest industry. The use of CLT panels in North America is newer and gaining a lot of interest in the construction industry as well as in the wood industry.

In terms of durability, a lot of attention has been paid in Europe to protecting CLT panels from getting wet during construction by delivering the products just-in-time, minimizing construction time, and providing temporary shelters during construction. Due to the mass of wood in the product, there is a potential for slow drying from CLT once moisture gets into the panel. In addition, other components used in a CLT building enclosure such as insulation and membranes may also have an impact on the drying ability. Therefore, precautions should be taken during design and construction in order to prevent wetting and facilitate drying, particularly in areas with high moisture loads such as the west and east coasts of North America.

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Cross-laminated timber is an innovative wood product that was first developed in the early 1990s in Austria and Germany and has since been gaining in popularity in residential and non-residential applications in Europe.

In the mid 1990s, Austria undertook an industry-academia joint research effort that resulted in the development of modern CLT. For several years progress was slow but in the early 2000s construction with CLT increased significantly, partially driven by the green building movement but also due to better efficiencies, code changes, and improved marketing and distribution channels. Numerous impressive buildings and other types of structures have already been erected around the world using CLT which is a testimony of the many advantages that this product offers to the construction sector. The light weight and the high level of prefabrication involved which facilitate a quick erection time are just some of the key advantages, especially in mid-rise construction (five to eight storeys). Thermal insulation, sound insulation and fire performances are added benefits resulting from the massiveness of the wood structure.

Product specification

CLT is a multi-layer wooden panel made of lumber. Each layer of boards is placed cross-wise to the adjacent layers for increased rigidity and stability. The panel can have three to seven layers, or more,
normally in odd numbers, symmetrical around the mid layer (Figure 1). The solid wood building system consists of ready-to-use building components which are assembled to form complete frameworks. Dimensional lumber is the main input material. It is possible to use lower grades for the interior layers and higher grades for the exterior layers, and the lumber can be pre-dressed (planed) or dressed at the factory once the panel is assembled. While softwoods dominate, it is feasible to manufacture CLT using hardwoods like poplar or even hybrid panels, e.g. Oriented Strand Lumber (OSL), Laminated Veneer Lumber (LVL) and Laminated Strand Lumber (LSL).

Moisture management
The main sources of moisture for which buildings need to be armed and well designed are rain infiltration, condensation (air infiltration, occupant’s lifestyle, thermal bridging, etc.) and ground-moisture penetration as a result of design and construction deficiencies. Also, one can have wetting problems caused by pipe leakage and other moisture sources during the service life of the construction. The movement of water in terms of redistribution of moisture and drying depends on local conditions within the assemblies, i.e. the moisture content and properties of the materials, as well as the indoor and outdoor conditions. CLT panels, due to their mass and composition, present a potential for slow drying once moisture gets into the panel. With this in mind, precautions should be taken during design and construction to ensure long-term durable performance of CLT constructions, particularly for areas with high moisture loads such as the west and east coasts of North America.

One way of preventing these kinds of damages is to design the building assembly with the use of proper material combinations given its environmental conditions. Building elements and construction procedures should be assessed for their individual functions as well as their potential impact on the performance of the entire building.

Construction moisture
Sufficient attention must be paid to protect CLT in order to minimize wetting during storage, transportation and construction. Overall the extent of prefabrication in North America is very small compared with that in Europe, and would also take time for the construction industry in North America to shift toward a culture to fully protect wood products from precipitation during construction. Under typical circumstances, CLT products will be manufactured at moisture content (MC) levels around 15 per cent. A significant amount of moisture, depending on local climate, construction season and time, product quality and on-site storage method, could infiltrate into the panels/material if they are left outside without wrapping, sheltering or other protection methods. CLT may be manufactured with small openings between lumber junctions, depending on wood species, lumber quality, lamina configurations and bonding methods. Cracking in and between lamina may also occur after manufacturing as a result of drying or wetting and re-drying. All these product characteristics may accelerate moisture penetration and/or entrapment on construction site. Good practices for storage and material handling should include the following: delivery of the product close to the construction site, preparation and cleanliness of the storage area (considering good drainage and ventilation if possible), tents available on construction site for wood components storage (CLT, I-Joists, structural panels, etc.) and good wrapping practices.

CLT panels should be wrapped until installation and stored off the ground. If the CLT panels get wet, a drying time should be planned and maintained until MC of the panel is considered to be acceptable.

Planning of construction steps must be done carefully in order to reduce construction time and moisture risks for all wood components. Utilisation of temporary tents (Figure 2) could be an option during rainy seasons on the coast. These tents have been used in Europe to protect the entire project site and provide good protection for rain, snow or wind.

Planning, besides reducing construction time, should also consider assembling of floors and roofs as soon as walls are installed.

Design to manage moisture in service
Design of buildings should consider multiple lines of defense to prevent potential moisture entrapment and accumulation in building enclosures. Among various moisture sources, wind-driven rain is potentially
the most serious source of moisture for building enclosures, particularly in coastal climates. It is recommended to implement the following principles and measures in order to reduce rain load for CLT construction. The three Ds – deflection, drainage and drying – provide a good summary of the priorities that should be considered during design in order to improve moisture management.

Deflection
Wind-driven rain can be diverted and deflected away from building assemblies by using pitched roofs and overhangs. Long-term experience and research confirm that overhangs can be highly effective in reducing moisture loads. They should be taken as the first priority for consideration during design. Overhangs can typically be created by roofs, awnings, flashings with drip edges, floor assemblies which extend past exterior walls and balconies/roof decks that provide protection to building components at lower levels.

Drainage
Numerous occurrences of premature building envelope failure and excessive moisture damage to exterior walls in residential buildings across Canada and the United States are directly related to the use of exterior claddings that represent the “face seal” approach to prevent rain penetration. Some jurisdictions, such as the city of Vancouver, have mandated the use of exterior claddings which incorporate rainscreen design principles; that is, the exterior walls contain both a first line and second line of defence where the latter has a capillary break to permit drainage, and flashing to ensure that any water penetration through the cladding will not adversely affect the remainder of the wall assembly. With that in mind, drainage can be facilitated by good design, construction and material selection of wall assemblies.

Most European designs of CLT wall assemblies provide air space behind cladding for drainage and ventilation; however, they do not always integrate weather-resistant barrier (WRB) in the assembly, probably due to the lower moisture loads in the parts of Europe where CLT has been used in construction. In North America, the control of rain water in a typical wood-framed wall usually requires an air space and a drainage plane located behind the exterior cladding, which often takes the form of building paper or house wrap. While the air space allows for pressure equalization when properly vented or open to the outside and compartmentalized, the drainage plane allows liquid water, which usually comes from rain penetrating through the cladding, to drain. With the CLT assembly, the drainage is taken over by the WRB, which should be installed directly on the CLT panel, on the exterior surface (Figure 3). Measures should be taken to maintain the continuity of the exterior water-resistive barrier (WRB) in the assembly, they do not always integrate weather-resistive barrier (WRB) in the assembly, however, assemblies provide air space behind clad-

The design process should include drainage systems even if they are protected by overhangs. Water can easily accumulate and infiltrate into the structure if improperly detailed. Like roofing systems, balconies and roof decks should be sloped to the outside, taking into account potential building settlement. Fasteners or other penetrations passing through the waterproof membrane should be avoided on any horizontal surfaces.

Windows and doors require appropriate design and installation measures in order to manage moisture effectively. Architectural elements like overhangs and balconies can reduce moisture risks on the exterior surface of a building. Window detailing should be done carefully and provide a path for infiltrating water to drain downward and be directed outside the envelope system. Appropriate head flashing and sill flashing should be provided to divert and drain water, and prevent moisture penetration.
Drying and condensation control

While drying cannot generally be relied upon as a primary moisture management strategy, building assemblies with good drying ability will improve the tolerance of CLT for any built-in moisture, as well as for the small amounts of moisture that may have penetrated during building service. Compared with conventional wood-frame construction, CLT assemblies may require more consideration during design due to the potentially slow drying due to the mass of wood in the product. In a traditional wood-frame wall assembly, vapor flow control is usually achieved on the inside surface (cold climate) of the batt insulation using a sheet of either asphalt impregnated kraft paper (a vapor retarder), polyethylene (a vapor barrier), or in some cases a vapor retarding paint on the gypsum board.

The vapor permeance of a 3 1/2-in. thick softwood CLT panel is less than 30 ng/Pa·s·m² (~0.5 US Perms) at normal indoor RH levels, based on the typical vapor permeance of solid softwood. Therefore, the CLT panel itself could have the ability to control the flow of vapor through the assembly in most situations. This property must be considered in the design of a wall assembly and should be used as a design advantage instead of disadvantage. This further highlights the importance of placing insulation on the exterior side of the CLT panel to ensure the vapor retarding layer is on the warm side of the insulation.

Air movement

Air infiltration and exfiltration is controlled through enclosure assemblies to prevent interstitial condensation and minimize space-heat energy loss or unwanted heat gain. Air flow through wall assemblies can be controlled using either a single material or, more commonly, a series of materials which together make up a continuous air barrier system.

In a traditional wood-framed wall assembly, air flow has to be controlled with an air-barrier approach using either: sealed polyethylene, air-tight drywall, sealed sheathing, or sealed sheathing membrane. CLT are massive wood components but the air-tightness of CLT panels is dependent on the joints between the individual boards and the individual layers.

Gaps between individual boards or layers and checking in boards may occur due to shrinkage during storage, transportation and construction as a result of drying or cyclical wetting and drying. Manufacturing processes such as edge-gluing between boards can help improve the air tightness of the panel. If the CLT panels are used as part of the air barrier assembly within a building, appropriate measures such as flexible sealant joints between CLT panels and other elements of the air barrier assembly would be required for air-barrier continuity. However, in most cases the CLT panel itself cannot be relied upon for air tightness, and it may be better practice to provide the primary air-barrier system using other materials within the assembly.

CLT may provide a good buffer for vapor due to the hygroscopic nature and the mass of wood in the product. Considerations should be given to vapor permeance of interior and exterior layers in assemblies to prevent any potential vapor condensation. The general rules for this are:

Prevent ground moisture penetration

Moisture from soil and concrete may migrate into CLT and affect the long-term durability. CLT should be separated from soil contact and the depth of foundation between the bottom of the panel and the adjacent grade should be higher than 8 inches. The clearance may be increased for severe soil moisture risk such as for areas with high water table. CLT walls should be separated from concrete slabs by a damp-proof membrane. The ground must be sloped away from the perimeter of the building to facilitate drainage.

This paper focused on strategies for insulation placement, vapor flow control, air-leakage, and rainwater penetration for the design of CLT building assemblies. Due to the short history of this construction system, more research is to be conducted, and durability performance in service is still to be assessed.

PHOTOGRAPHY AND ILLUSTRATIONS

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