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CONSTRUCTION MOISTURE MANAGEMENT—CROSS LAMINATED TIMBER

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Cross-Laminated Timber (CLT) is an engineered mass timber product manufactured by laminating dimension lumber in layers with alternating orientation using structural adhesives. It is intended for use under dry service conditions and is commonly used to build floors, roofs, and walls. Because prolonged wetting of wood may cause staining, mould, excessive dimensional change (sometimes enough to fail connectors), and even result in decay and loss of strength, construction moisture is an important consideration when building with CLT. This document aims to provide technical information to help architects, engineers, and builders assess the potential for wetting of CLT during building construction and identify appropriate actions to mitigate the risk.

Wetting and Drying Properties

In Canada, most CLT producers use wood of the Spruce-Pine-Fir (S-P-F) and sometimes Douglas Fir-Larch (D. Fir-L (N)) species groups, together with a structural adhesive to make CLT. While the commonly used "S-Dry" dimension lumber has moisture content (MC) of around 19% or lower when it is produced, the MC of the lumber used to make CLT must be within 12±3%, as specified in the North American CLT manufacturing standard ANSI/APA PRG 320. The low initial MC reduces shrinkage and the associated issues when the wood adapts to the drier service environment. While CLT shrinks or swells in its thickness direction with changes in MC, it is highly dimensionally stable in the other two major directions due to the glued cross lamination.

Wetting during construction is mostly caused by exposure to liquid water sources, typically rain. On-site protection in wet weather, such as the rainy winter in a coastal climate, presents a large challenge for any construction. Dried Canadian softwoods including S-P-F and D. Fir in general have high resistance to moisture penetration. This is especially true for the face grain. Weeks or months of sustained exposure is typically required for water to penetrate deep. However, the following locations in a CLT assembly present the largest risks of wetting:

- End grain of boards since end grain is more water-absorptive than face grain (Figure 1);
- Gaps between lamination, which may trap water;
- The splines at joints. Plywood/OSB is overall much more water absorptive than solid wood.

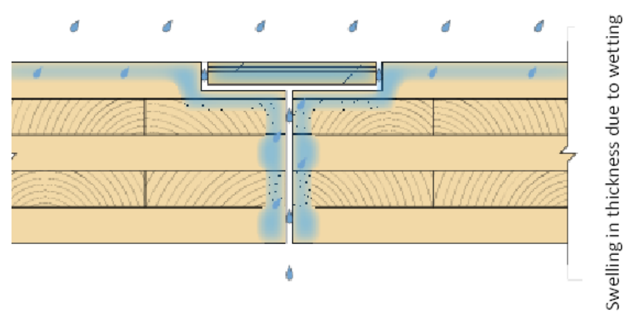

Figure 1. Potential for water absorption at end grain and splines between CLT panels; swelling in the thickness direction.

Being a hygroscopic material, wood exchanges moisture with the surrounding air, i.e., the so-called sorption. Dry CLT will gain moisture by absorbing water vapour in a humid ambient environment. Prolonged exposure (e.g., months) to the high humidity alone in the winter in a coastal climate may cause deterioration, such as excessive swelling and mould growth.

Wetted CLT can dry through moisture evaporation once the wetting sources are removed. Warm, low-humidity, and ventilated environments facilitate drying. The locations (e.g., exposed end grain) that are the fastest to wet up during wetting events also tend to dry quickly. However, drying may take long (weeks, and even months) when moisture has penetrated deep in a large CLT member. Drying will become extremely slow or even impossible when the panel is covered with a low vapour permeance material, such as a roofing membrane.

Moisture Content Measurement

The MC of wood should be monitored during construction. It is typically measured at a construction site by using a portable pin moisture meter, which is based on measuring the electrical resistance between the two pins (Figure 2, top). These meters usually have a working range from 6% to 25%. The pair of pins are typically coated except at their tips to measure the MC between the two tips. Such pins can also be installed at specific depths for continuous measurements (Figure 2, bottom). The measurements during construction should focus on locations with high wetting potential, such as joints and end grain, to provide more accurate information for making decisions about moisture protection and use of forced drying. When conditions allow, MC measurement should be corrected for the effects of wood species, other chemicals (e.g., adhesive, preservative), and temperature. For example, MC readings from damp plywood may overestimate the actual MC by over 10% due to the adhesive and the associated chemicals present in wood.

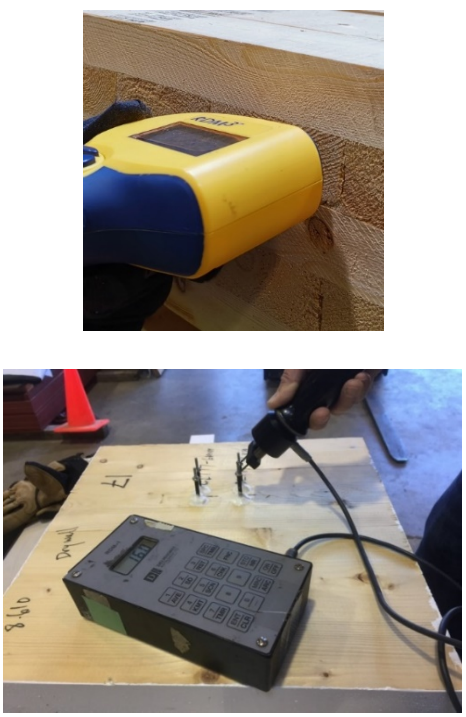

Figure 2. Measuring wood moisture content using a portable pin meter (top) and pre-installed moisture pins (bottom).

On-site Moisture Management

Planning, teamwork

On-site moisture management should be planned for each construction project. This is needed in all climates and becomes particularly important for a large/tall mass timber building in a wet climate/season. The wetting and deterioration risks, potential remedial needs and costs, and protection measures and their costs should be assessed in advance so that when wetting does occur, appropriate measures are taken.

On-site moisture management requires good communication, cooperation, and coordination among all the parties involved. Major responsibilities include:

- The developer/building owner must recognize the importance of moisture protection and set aside funds to cover extra time and measures needed.
- The project architect should lead in most cases to make sure consistent strategies are applied to protect CLT throughout the entire process (i.e., manufacture, shipping, storage, installation) until the wood is completely protected.
- In jurisdictions, such as British Columbia, where a building envelope consultant is involved, this consultant may be tasked to lead the effort.
- The architect or the building envelope consultant needs to work closely with both the manufacturer and the general contractor to implement specified moisture protection measures.
- The contractor should assign a dedicated person to implement protection measures and to monitor wood MC during the construction.

Overarching strategies, principles

The following principles and strategies should be applied to each building project.

- Minimize the time of exposure to the elements, particularly for horizontal elements that allow water to pool.
- Take advantage of off-site prefabrication, including precutting and drilling for connections and various service openings, to minimize site work and time.
- Schedule timber installation during a relatively dry season, if possible.
- Coordinate material delivery for just-in-time installation to eliminate site storage needs.

- Install the roof and complete the enclosure as early as possible to protect the entire structure.
- The structure and each assembly should be designed to minimize the potential of trapping moisture and to allow drying.
- The MC of CLT should be kept below 19% before enclosure. Pay more attention to areas with higher risks (e.g., end grain) when measuring MC.
- Be aware of the layers that encapsulate or shield the CLT (e.g., membranes, concrete layer, and low permeance insulation) to slow down drying. A MC of 16% should be targeted before the CLT is covered with any low vapour permeance material.

Basic protection

The following basic moisture protection measures are applicable to all building projects.

Related to building design:

- In connections design, the risk of screw failures should be mitigated by considering the potential forces generated by swelling of wood resulting from on-site wetting.
- Service openings in CLT floor/roof panels should be concentrated at as few locations as possible to make it easier to apply site-specific measures and to prevent water dripping onto lower levels.
- A self-leveling floor screed with a known low water ratio should be specified to minimize excess water from the mix to be absorbed in the CLT floor base panels.

A manufacturer should:

- Provide CLT users with instructions for on-site storage and handling.
- Upon request, apply in the factory an end sealer with proven performance on edges and pre-made cuts to reduce water absorption through end grain.
- Individually cover each panel prior to shipping with taped and secured opaque lumber wrap, or a self-adhesive membrane, when it is specified.

A contractor should:

When temporary site storage is necessary:

- Members should be stored based on their final positions and installation sequence to facilitate efficient installation.
- The CLT should be ideally stored in well-ventilated shelters using dunnage to keep the wood off the ground. The relative humidity of the environment should be controlled for storage over two months.
- The original wraps should be kept until the CLT is ready for installation. When a wrap is opened, the wrapping should be opened in a manner that prevents rain penetration and encourages drainage and drying.

During the installation:

- Erection of a floor level should not exceed one week's time.
- Promptly remove standing water/snow/ice on the installed CLT floors/roofs.
- Install tarps prior to night/weekend breaks to cover the installed top floors or roofs when rain is forecasted.
- Schedule to install plywood/OSB joint splines on CLT floors/roofs just before the next installation (e.g., concrete screed, roof membranes) to protect the splines from wetting.

Advanced protection

More advanced site protection is strongly recommended for a building project in a wet climate and when the cumulative exposure time to water is expected to exceed two months. The higher initial costs are often offset by reduced time loss, increased construction efficiency and quality, and elimination of re-drying and other remedial needs. In addition to the above-described principles and basic measures, one of the following three options is recommended to further reduce the wetting risk.

Option 1: Creating water-proof shells with existing walls, floors, and roofs through construction sequencing and localized compartmentalization. This aims to utilize existing building components to efficiently shelter the inside structure before a completely watertight enclosure is possible. The parts of the building including roofs, floors, and exterior walls starting from lower levels should be made watertight as early as the construction allows. This also allows the lower floors to be made safer in terms of fire risks as it allows drywall to be installed early.

- Install exterior walls quickly following erection of the main structure. Try to avoid installing more than two storeys of open floors without exterior walls during the construction.
- Install and make continuous as soon as possible water-resistant barriers of the exterior walls.

- Seal floors using membranes and concrete screed so that they are able to function as a temporary roof (examples shown in Figure 3 and Figure 4).

Figure 3. Joints between CLT floor panels sealed with tapes in a project in Vancouver.

Figure 4. A floor is made watertight using plastic sheets in a mass timber building in Montreal.

Option 2: Floor/roof panel protection through pre-installing self-adhesive membranes.

- The upper surface of each CLT panel used for a floor or roof has self-adhered membranes pre-installed in the factory for moisture protection, in addition to applying a sealer on edges, pre-made cuts, and service openings.
- This membrane should resist wear and tear, and remain water resistant for the duration of construction. It should not introduce slipping hazard.
- A vapour-permeable membrane with proven water resistance should be specified for floor panels. Concrete screed can be directly installed above.
- For a roof, this membrane will ideally serve permanently as part of the roofing membrane. The installation may require co-ordination with a professional roofer.
- Any joints and interfaces should be immediately sealed following panel installation to prevent rain/snow melt from seeping through the gaps and getting trapped within the wood members.
- Install the exterior walls and the roof as early as possible to provide a complete enclosure.

Option 3: Whole-building protection through installing a temporary roof.

- A temporary roof can be installed to shelter the entire structure or part of the structure. Such weather protection is common in building retrofits to maintain normal living conditions. It will provide the most reliable moisture protection for new construction.
- A fixed tent, similar to those used in retrofits, can be built with scaffolding and tarps to protect roof and cladding installations.
- A movable tent, which is raised as each storey is built, has been used in large timber projects in Europe (see an example in Figure 5). A similar technology has been developed in Canada for steel structures. A temporary roof can provide protection for the entire construction when the budget allows.

Figure 5. Using a liftable temporary roof to protect timber construction in Sweden.

Drying and Remediation

- Wetted wood (including CLT and joint splines) should be dried before it is closed in.
- Actions should be taken to prevent further wetting prior to drying. Any liquid water on the surface should be removed (e.g. by vacuuming, mopping).
- Drying occurs naturally when the ambient environment is favourable; that is, warm air with low relative humidity (e.g., < 65%).
- Where the ambient environment is not ideal, or the drying needs to be accelerated for quicker enclosure, accelerate the drying process by using fans, space heating (electrical heaters preferred), or dehumidification.
- For localized areas, such as joints and connection areas with severe wetting, blowing hot air may provide more efficient drying.
- Non-structural components, such as drywall, insulation, and other coverings, may need to be removed or replaced as they may trap moisture and reduce the drying capacity of the wood members.
- Other remedial treatments may also become necessary. For example, when wetting has caused discolouration (e.g., mould growth, staining) on members, sanding the surface is usually the most efficient way to remove the staining before finishing or refinishing.

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