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CONSTRUCTION MOISTURE MANAGEMENT – NAIL-LAMINATED TIMBER

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Nail-laminated timber (NLT) is a large built-up member often used as interior structural members for floors, roofs, walls, and elevator/stair shafts. Because prolonged wetting of wood may cause staining, mould, excessive dimensional change (sometimes enough to fail fasteners), and even result in decay and loss of strength, construction moisture is an important consideration when building with NLT. This document aims to provide technical information to help architects, engineers, and builders assess the potential for wetting of NLT during building construction and identify appropriate actions to mitigate the risks.

Wetting and Drying Properties

NLT is made by mechanically fastening dimension lumber stacked on edge (Figure 1). Its use can be found in many century-old buildings in North America. Like other mass timber systems, NLT provides advantages over traditional wood products, particularly where large spans are required. NLT can be relatively simple to fabricate and may not require a sophisticated manufacturing facility, compared to glued mass timber products (e.g., cross-laminated timber, glulam). Wood species including Spruce-Pine-Fir (S-P-F) and Douglas Fir-Larch (D. Fir-L), in various sizes (e.g., nominal 2 in by 8 in) are commonly used to make NLT in Canada and the United States. While "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 NLT is typically around 15%, or even lower like 12%, in order to reduce shrinkage and the associated issues when the wood adapts to the indoor service environment. Otherwise, larger gaps will occur between the boards, and the boards will also show larger reduced depth in service, resulting from shrinkage. On top of the NLT, plywood or OSB structural sheathing is often installed to provide in-plane shear capacity, allowing the assembly to be used as a shear wall or structural diaphragm.

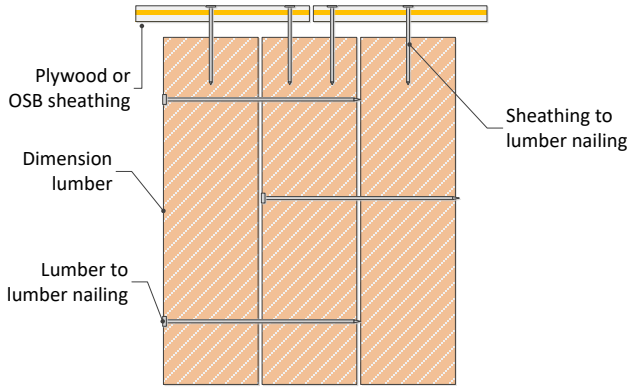

Figure 1. Nail-laminated timber made by mechanically fastening dimension lumber stacked on edge, covered with structural sheathing.

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. However, NLT assemblies can be highly susceptible to trapping moisture. The following locations in an assembly present the largest risks of wetting:

- The small gaps between laminated boards and between boards and sheathing panels have a high potential of trapping moisture. Wetting also results in swelling, which further reduces the gaps between boards and slows down drying (Figure 2).
- Exposed end grain is more water absorptive than face grain within an individual board.
- Plywood/OSB sheathing on the top is overall more water absorptive than solid wood and can become soaked with water relatively quickly, when exposed.

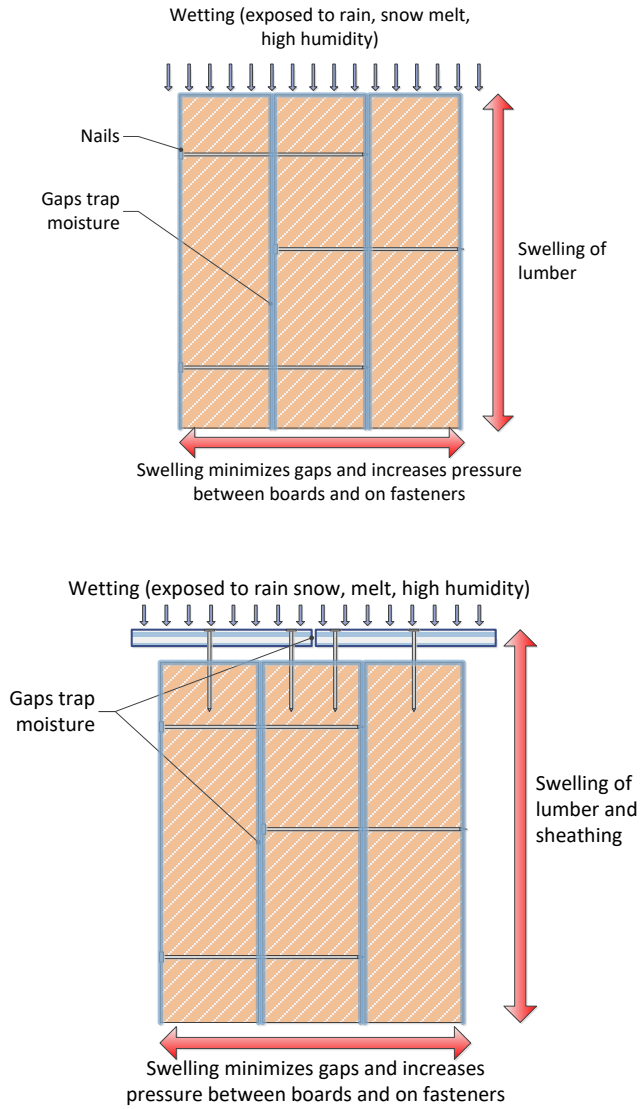

Figure 2. Potential of trapping water between boards of NLT and between NLT and sheathing, and potential swelling resulting from wetting (top: NLT; bottom: NLT with sheathing. Blue indicates wetting for an illustrative purpose).

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

Wetted NLT may dry through moisture evaporation once the wetting sources are removed. Warm, low-humidity, and ventilated environments facilitate drying. Some locations (e.g., exposed sheathing, exposed end grain) that are fast to wet up during wetting events also tend to dry more quickly. However, drying may take long (e.g., months) when moisture has penetrated deep inside a large NLT member, such as between the laminated boards. 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 moisture content (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 3, 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 3, 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 3. 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 must be carefully planned for each construction project involving NLT given its high susceptibility to trapping water. Site protection is needed in all climates and becomes extremely important for a large/tall 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 to make informed decisions.

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 NLT 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.

- Measures should be provided to protect NLT from rain in most climates (depending on the wetting risk, choose Option 1 or 2 described below as a basic protection).
- Minimize the time of exposure to the elements. Inadequately protected NLT should not be exposed even for as short as one week.
- The total exposure time of a building should not exceed two months in any climate before full enclosure.
- Take advantage of off-site prefabrication, including pre-installing sheathing and precutting and drilling for connections and various service openings, to minimize site work and time.
- Schedule timber installation during 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 facilitate drying. For example, some drainage and ventilation mechanisms may be introduced in an NLT assembly.
- The MC of NLT should be kept below 19% (at any location) before enclosure.
- Be aware that enclosure, particularly the addition of a low vapour permeance material further slows down, and even eliminate drying.

Basic protection: Team responsibilities

The following basic moisture protection measures should be taken by each member of the team for all 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 NLT 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 amount should be specified to minimize excess water from the mix to be absorbed in the wood base below.

A manufacturer should:

- Pre-install sheathing and membrane in the factory as specified, choosing Option 1 or 2 described below as a basic protection.
- Provide users with instructions for on-site storage and handling.
- 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.
- Store NLT 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.
- When an NLT panel is covered with a lumber wrap, the original wrap should be kept until it is ready for installation.

During the installation:

- Immediately seal the joints between sheathing as specified, choosing Option 1 or 2 described below.
- Promptly remove standing water/snow/ice on installed floors/roofs.
- Install tarps prior to night/weekend breaks to cover installed top floors or roofs when rain is forecasted.
- Erection of a floor level should not exceed one week's time.

Basic protection: Pre-installing sheathing and tapes/membranes for low and moderate risk

The wetting risk is pre-assessed primarily based on the weather condition during the construction. For low risk, the following Basic Option 1 is recommended; for a moderate level of risk, Basic Option 2 should be taken. In both options, all plywood/OSB sheathing is pre-installed in the factory. When the sheathing must be installed in a staggered fashion at NLT joints to meet structural requirements, lap joints can be created through staggering the sheathing panels between adjacent NLT members and be then pre-protected. The lap joints should immediately receive second taping upon installation to prevent water penetration into the joints.

Basic Option 1: This is applicable only in a low wetting risk environment. It utilizes pre-installed sheathing to provide a low level of protection to the NLT below, with the joints between the sheathing panels and those between NLT panels pre-sealed with tapes in the factory, and with the lap joints re-sealed at the job site (Figure 4).

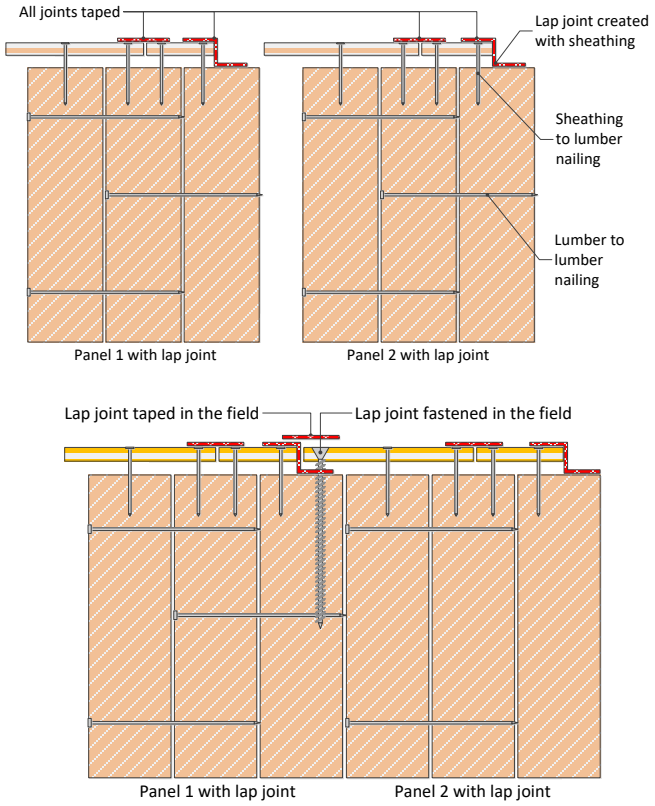

Figure 4. Basic Option 1: for a low wetting risk environment, pre-sealing all joints between sheathing in factory (above), and re-sealing lap joints at job site (below).

Basic Option 2: When there is a moderate level of wetting risk, the entire sheathing including all joints should be pre-protected in the factory with self-adhesive membrane, and then with the lap joints sealed at the job site (Figure 5).

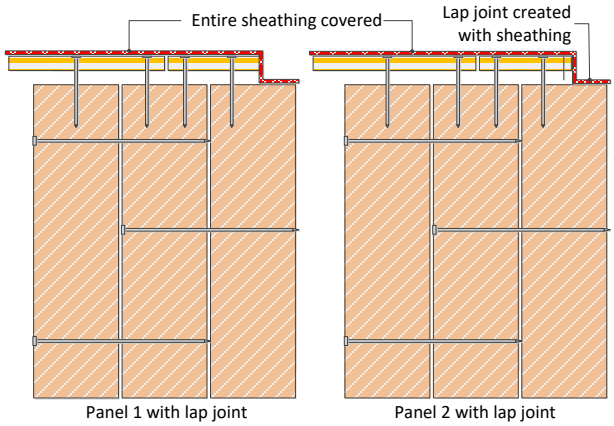

Figure 5. Basic Option 2: for a moderate level of wetting risk, pre-protecting entire sheathing in factory, and re-sealing lap joints at job site.

Considerations for selecting tapes/membranes:

- This membrane should resist wear and tear and remain water resistant for the duration of construction.
- For safety, the membrane used on surfaces where there will be foot traffic during the construction (e.g., floors, roofs) should not introduce any slipping hazard.
- A vapour-permeable tape/membrane with proven water resistance should be specified for floor panels. Concrete screed can be directly installed above.
- For a roof, the self-adhesive membrane will ideally serve permanently as part of the roofing membrane. The installation may require co-ordination with a professional roofer.

Advanced protection: Protection with a temporary roof for high wetting risk

A temporary roof can be installed to shelter the entire structure or part of the structure. This will provide the most reliable moisture protection for NLT construction and should be seriously considered for a building project in a wet climate and when the exposure time 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.

- A fixed tent, similar to those used in retrofits, can be built with scaffolding and tarps to protect roof and cladding installation (Figure 6).
- 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 7). This can provide protection for the entire construction when the budget allows. A similar technology has been developed in Canada for steel structures and might be adapted to timber construction.

Figure 6. Using a temporary tent to protect roof construction in a Vancouver project (photo credit: RDH Building Science).

Figure 7. Using a liftable temporary roof to protect timber construction in Sweden.

Drying and Remediation

- Wetted wood (including NLT and sheathing) 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 laminated boards, joints, and connection areas with severe wetting, blowing hot air may provide more efficient drying.
- The local sheathing should be ideally removed to dry the laminated boards for severe wetting.
- Non-structural components, such as membrane, 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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