info@fpinnovations.ca
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CONSTRUCTION MOISTURE MANAGEMENT – NAIL LAMINATED TIMBER

PROJECT NUMBER: 301013618

Jieying Wang, Scientist, Building Systems

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ABSTRACT

Nail-laminated timber (NLT) is often used as interior structural members of floors, roofs, walls, and elevator/stair shafts. Because prolonged wetting of wood may cause staining, mould, excessive dimensional change (enough to fail connectors), 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 risk.

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APPROVER CONTACT INFORMATION
Dorian Tung
Manager, Building Systems (Vancouver)
dorian.tung@fpinnovations.ca

Sylvain Gagnon,
Manager, Building Systems (Quebec City)
sylvain.gagnon@fpinnovations.ca

REVIEWERS
Rod Stirling, Manager, New Construction Materials
Conroy Lum, Lead Scientist, Building Systems

AUTHOR CONTACT INFORMATION
Jieying Wang
Senior Scientist
Building Systems
6042225649
jieying.wang@fpinnovations.ca

Table of contents

List of figures

List of tables

OVERVIEW

Nail-laminated timber (NLT) is often used as interior structural members of floors, roofs, walls, and elevator/stair shafts. Because prolonged wetting of wood may cause staining, mould, excessive dimensional change (enough to fail connectors), 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 risk.

Figure 1 illustrates a general sequence of construction moisture management planning and decision making. The most important steps include:

- Understanding the wetting potential of the NLT
- Assessing deterioration risk and potential remediation needs
- Deciding the most effective measures to prevent the NLT from wetting
- Preparing measures to take when incidental wetting occurs

Although the document focuses on wetting, over-drying in a dry environment is briefly covered.

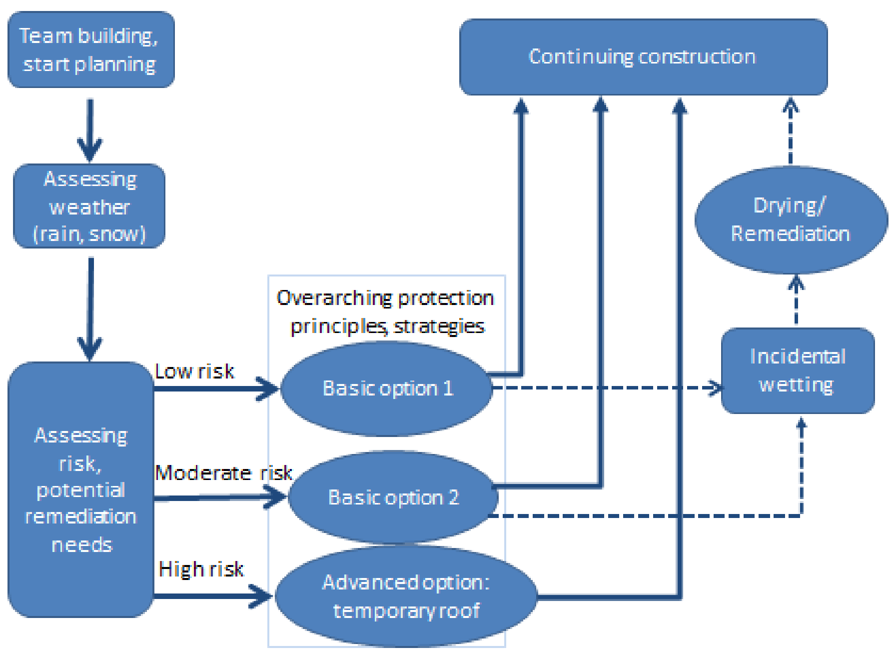

Figure 1 General sequence of construction moisture management planning and decision making for NLT construction.

1 WOOD AND MOISTURE

1.1 NLT basics

NLT is a large built-up structural member made by mechanically fastening dimension lumber stacked on edge. 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, such as dimension lumber and solid-sawn timbers, particularly where large spans are required. NLT can be relatively simply fabricated, without a complicated manufacturing facility. Wood species including Spruce-Pine-Fir (S-P-F) and Douglas Fir-Larch (D. Fir-L), in various sizes (e.g., nominal 2 by 8) 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 12%, in order to reduce shrinkage[1] 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 have more noticeably reduced depth in service. On top of the NLT, plywood or OSB sheathing is often installed to provide in-plane shear capacity, allowing the assembly to be used as a shear wall or structural diaphragm.

1.2 Wetting from exposure to liquid water

Exposure to liquid water sources, such as rain, snow/ice melt, and ground moisture imposes the largest risk of wetting for NLT construction. On-site protection in wet weather, such as the rainy winter in a coastal climate presents the largest challenge. Dried Canadian softwood lumber including S-P-F and D. Fir in general has high resistance to moisture penetration[2]; it may take weeks or months of sustained exposure for water to penetrate deep. However, an NLT assembly is susceptible to wetting, because:

- 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.
- The plywood/OSB sheathing on the top is overall more water absorptive than solid wood and can become soaked with water relatively quickly, when exposed.

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[1] The shrinkage of sawn dimensional lumber can be estimated using the equation: $S = D \times M \times C$, where, S = shrinkage amount (mm); D = actual dimension of a wood member in a transverse direction (mm); M = percentage of MC change (%), i.e., the difference between the initial MC (≤28%) and the MC in service; C = shrinkage coefficient. A shrinkage coefficient of 0.25% per 1% change in MC is often used for a cross section. For example, a nominal 2 in. board (38 mm) will have its thickness reduced by about 1 mm when it shrinks from 19% to 8% in service.

[2] Some softwood species, such as southern pines and radiata pine are much more water permeable and require more attention to moisture protection.

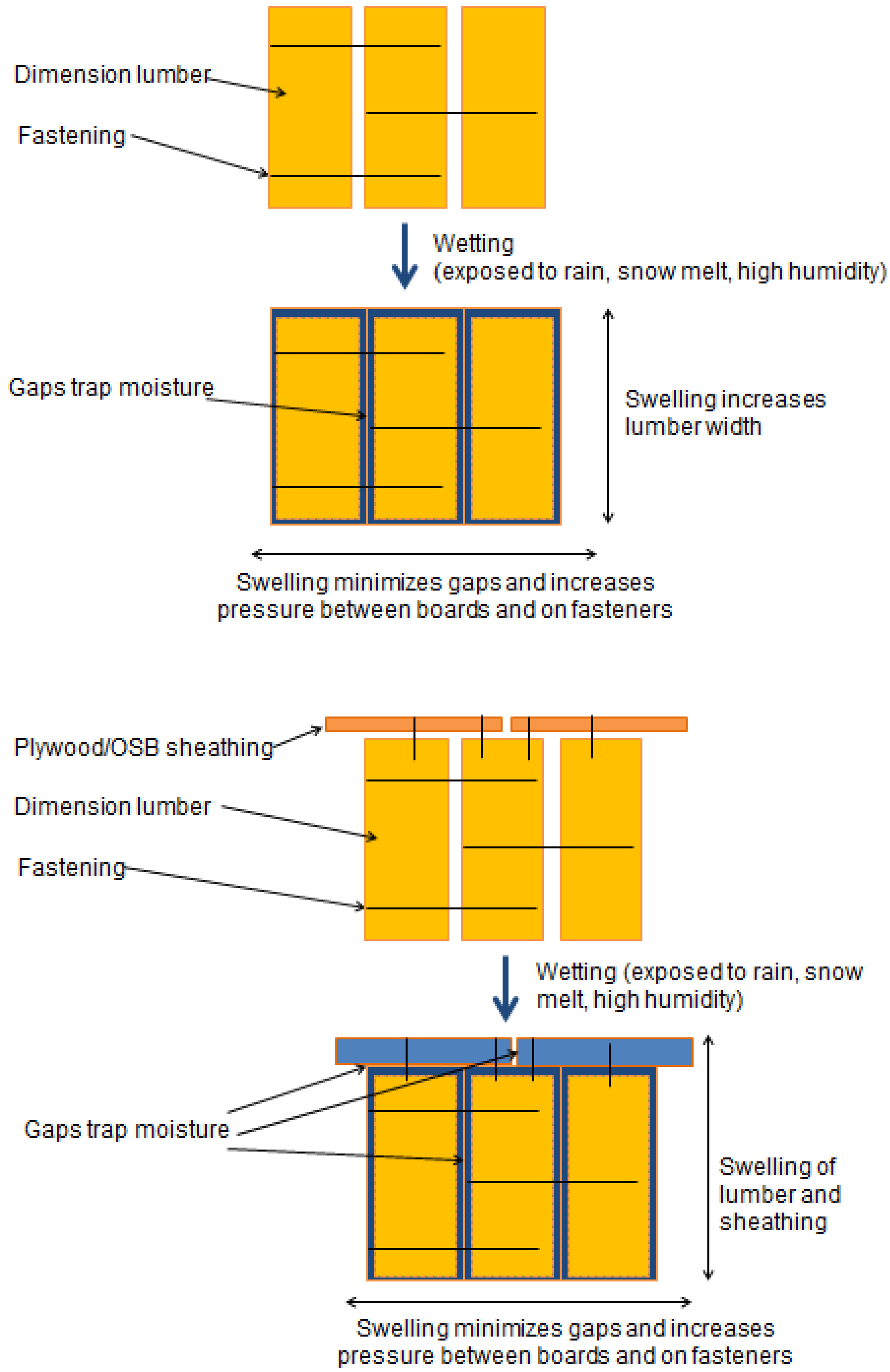

Figure 2 Potential of trapping water between boards of NLT and between NLT and sheathing; potential swelling resulting from wetting (top: NLT; bottom: NLT with sheathing. Gaps in the dry assemblies are exaggerated for an illustrative purpose).

1.3 Wetting from exposure to high humidity

Dry lumber and sheathing also gain moisture by absorbing water vapour in a humid ambient environment. As a hygroscopic material, wood exchanges moisture with the surrounding air, i.e., sorption behaviour. Under a constant humidity and temperature condition, the wood will reach the equilibrium moisture content (EMC) with the environment when it no longer gains or loses moisture.

Vapour diffusion is an overall slower process, compared to water penetration. Also, it does not increase the MC above the fibre saturation point (about 30% on average), unless vapour condenses on the wood surface under extreme conditions. However, under near-saturated humidity conditions, capillary water absorption becomes dominant, which greatly increases the MC. Prolonged exposure (e.g., months) to the high humidity alone in the winter in a coastal climate may cause deterioration, such as excessive dimensional change or mould growth. Figure 3 illustrates a sorption isotherm as well as the transition to capillary water absorption at high humidity levels.

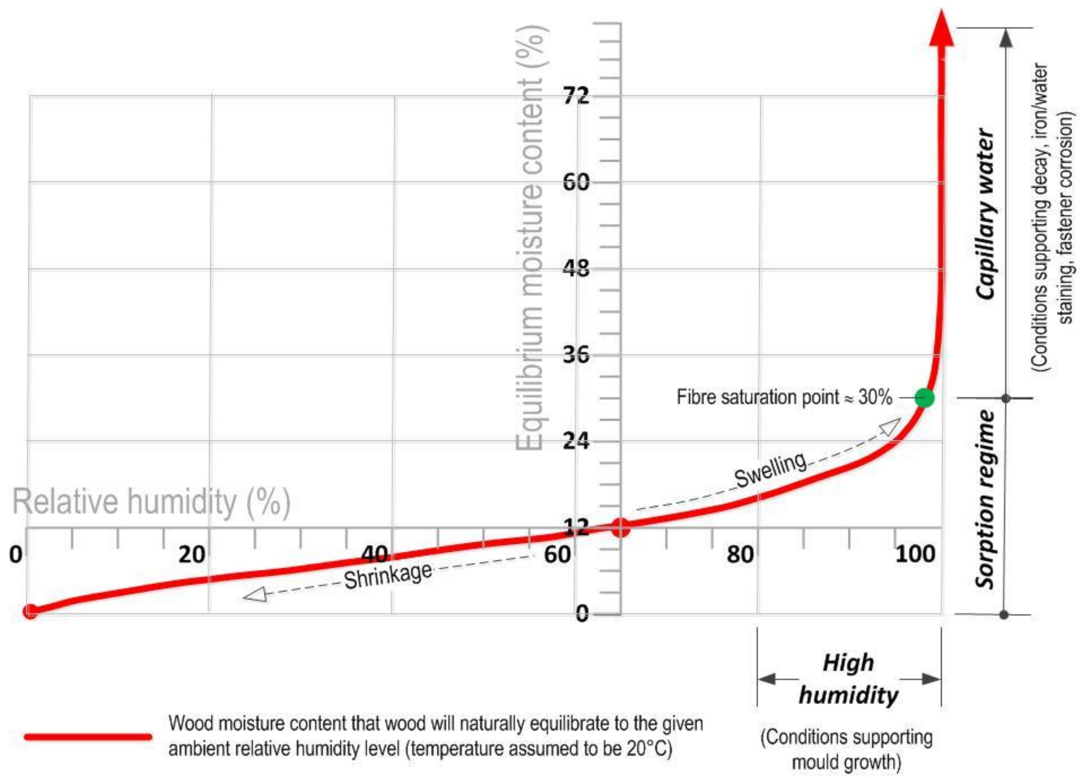

Figure 3 A simplified curve illustrating wood's sorption isotherm under a constant ambient temperature and relative humidity condition, capillary water absorption starting under near-saturated relative humidity conditions, and moisture-associated deteriorations. A theoretical initial moisture content of 12% is assumed for NLT.

1.4 Deterioration types, prevention principles

The major types of moisture-related deterioration that may occur during NLT construction and the fundamentals for prevention are indicated in Figure 3 and summarized in Table 1. Most deterioration types result from prolonged wetting that causes wood MC exceeding 19%.

Among the wetting-related deterioration types listed in Table 1, screw failures, staining, and potential decay are major reasons for remediation during NLT construction. Related to screw failures, NLT may present considerable swelling in two major directions[3] (Figure 2), which increases tolerances and may further trap moisture.

Table 1 Major deterioration types and prevention principles

Deterioration type	Conditions for deterioration	Impact	Prevention principle
Increased tolerances, screw snapping	Excessive swelling (in two directions) resulting from prolonged exposure to moisture (liquid water, high humidity)	Structural performance, tolerance issues	Minimize wetting; speed up construction; use more dimensionally stable wood
Water staining	Exposed to liquid water, causing leaching of extractives	Appearance	Prevent wood from rain and other liquid water
Iron staining	Iron particles (from cutting equipment, fasteners etc.) react with phenolic chemicals in wood, in presence of moisture	Appearance	Prevent wood from moisture sources (e.g., rain); minimize iron particles on wood surfaces
Mould growth	Ambient relative humidity > 80%, ideally in warm weather	Appearance, possibly air quality	Keep wood dry (MC < 19%); keep ambient humidity below 80% if possible. Surface applied mould protection treatments may be an option.
Decay	Wood MC > 26%, ideally in warm weather. Fungi growth also needs a suitable food source and oxygen	Wood loses strength, impact resistance in particular	Keep wood dry (MC<19%); avoid trapping moisture; use preservative-treated or naturally durable wood (e.g., cedar)
Fastener rusting	Fasteners susceptible to corrosion, in presence of moisture (liquid water, high humidity) and oxygen	Fasteners lose strength, cause staining	Keep fasteners from moisture; use galvanized or stainless steel fasteners
Increased tolerances, checking, warping	Excessive/non-uniform shrinkage resulting from low ambient humidity	Mostly appearance, e.g., a visible	Prevent rapid decreases in ambient humidity; humidify the space if necessary

[3] By comparison, CLT swells considerably only in panel thickness due to glued cross lamination.

		gap between boards	
Sun burn	Prolonged exposure to sunlight, leading to UV-induced discoloration	Appearance	Reduce exposure to sunlight; keep opaque coverings whenever possible

1.5 Moisture content measurement

The MC of wood is typically measured at a construction site by using a portable pin moisture meter based on measuring electrical resistance (Figure 4, left). Such a measurement usually has a working range from 6% to 25%. Pins/sensors based on the same principle can be installed at specific locations/depths for continuous monitoring (Figure 4, right). Insulated pins except at the tips are used to measure the MC between the two tips. The measurements should focus on the locations, such as between boards, which tend to trap moisture in order to provide accurate information for making decisions about moisture protection and use of forced drying. This means that long insulated pins, typically assisted with drilling are required for measuring the MC inside a NLT assembly.

When conditions allow, MC measurement should be corrected for the effects of wood species and temperature. Special calibration is required for measuring wood-based composites (e.g., plywood and OSB) and preservative- or fire retardant-treated wood, as added chemicals often alter the wood resistance and consequently MC readings. For example, MC readings from damp plywood may overestimate the actual MC by over 10% due to the adhesive and the associated chemicals present.

Figure 4 Measuring wood moisture content using a portable pin meter (left) and pre-installed moisture pins (right).

1.6 Drying potential

Once the wetting sources are removed, wetted NLT may dry when the ambient environment allows. Warm, low-humidity, and ventilated environment facilitates drying. However, drying will be very slow (e.g., months, years) once moisture gets trapped between the boards. Wetted plywood/OSB sheathing may dry faster than laminated boards, when it is exposed to a favorably environment. Covering the assembly with low vapour permeance materials, such as roofing membranes may eliminate the drying potential. Preventing wetting has the highest priority to ensure durable NLT construction.

2 CONSTRUCTION MOISTURE MANAGEMENT

2.1 Planning, teamwork

On-site moisture management must be carefully planned for each construction project involving NLT given its 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. As illustrated in

Figure 1, 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 manufacturer and the contractor should each assign a dedicated person to implement protection measures and to monitor wood MC.

2.2 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 (Option 1 or 2 in “Basic protection: pre-installing sheathing and tapes/membranes”).
- Minimize the time of exposure to the elements. Inadequately protected NLT should not be exposed to rain 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 laminating boards, 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 allow 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[4] further slows down drying.

2.3 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 5).

[4] This can be generally defined to have vapour permeance below 60 ng/Pa•s•m². It can include all roofing membranes, faced polyiso board, 1.5” and thicker extruded polystyrene, 2” and thicker closed-cell spray foam, 1.5 in. and thicker concrete screed, and vinyl coverings.

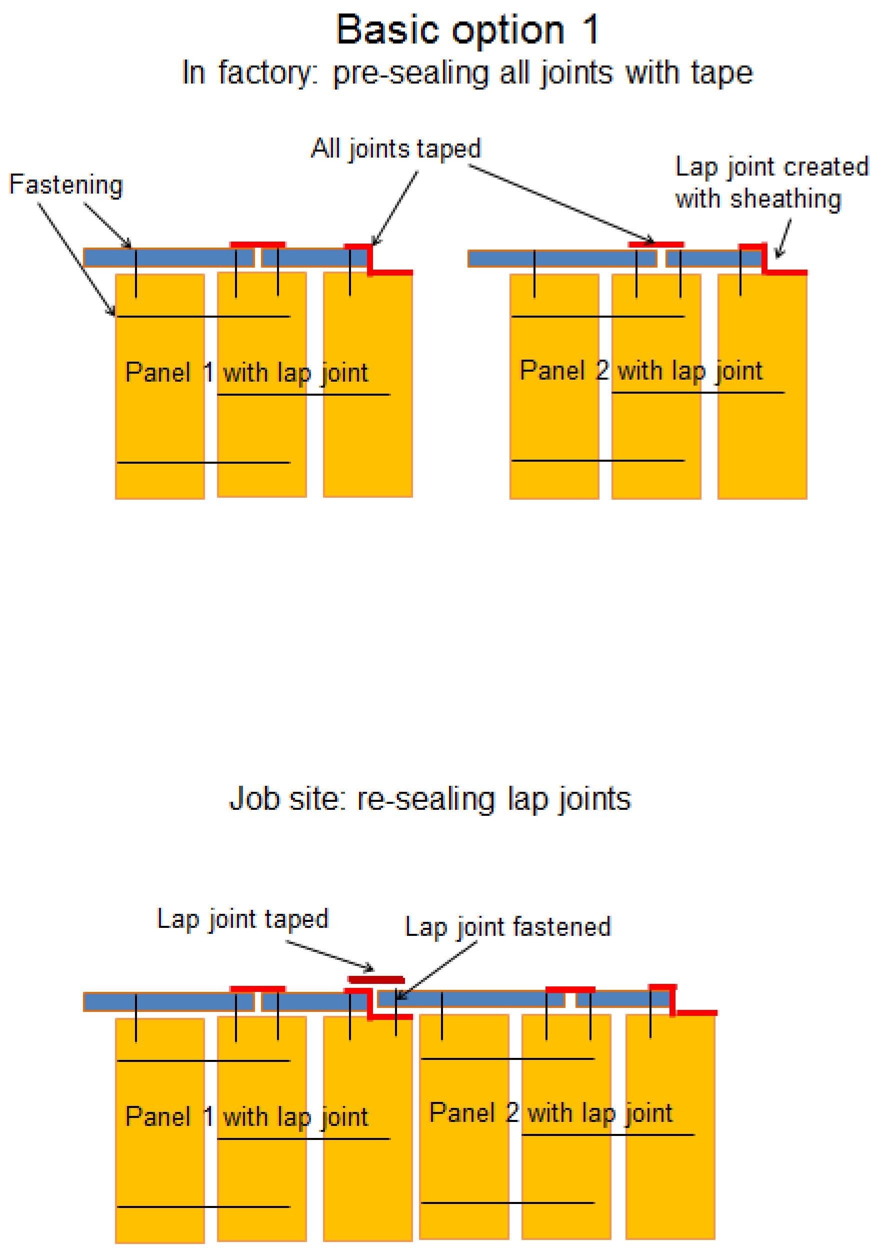

Figure 5 Basic option 1: for a low wetting risk environment, pre-sealing all joints between sheathing in factory (above), and re-sealing lap joints at job site (below).

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 6).

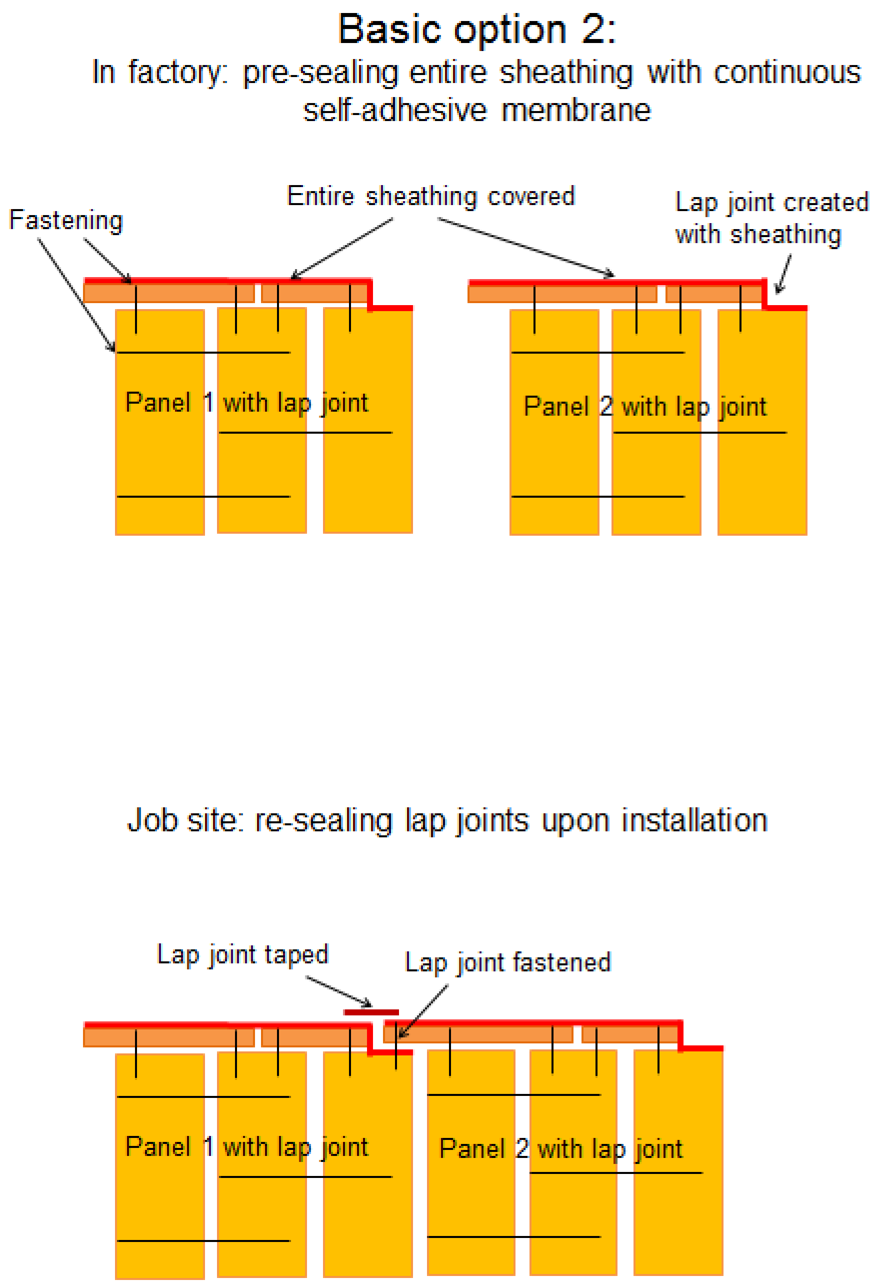

Figure 6 Basic option 2: for a moderate level of wetting risk, pre-protecting entire sheathing in factory (above), and re-sealing lap joints at job site (below).

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.

2.4 Basic protection: additional considerations and measures

The following additional considerations and measures from the perspectives of design, manufacture, and construction are applicable to all building projects.

Related to building design:

1. In connections design, risk of screw failures should be mitigated by taking into account the potential forces generated by swelling of wood resulting from on-site wetting.
2. Service openings in NLT floor/roof panels should be concentrated at fewer locations as possible to make it easier to apply site-specific measures to prevent water dripping to lower levels.
3. 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 wood panels below when the concrete cures.

A manufacturer should:

1. Individually cover each panel prior to shipping with fully taped and secured opaque lumber wrap when there is no self-adhesive membrane on the panels.
2. Apply in the factory an end sealer with proven performance on edges, and pre-made cuts and service openings to reduce water absorption.

A contractor should:

1. When temporarily site storage is necessary:
   a. Members should be stored based on their final positions and installation sequence so to facilitate efficient installation.
   b. The NLT 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.
   c. When the panels are covered with lumber wrap, the original wrap should be kept until the time of installation.

2. During the installation:
    a. Erection of a floor level should not exceed one week's time.
    b. Promptly remove standing water/snow/ice on installed floors/roofs.
    c. Install tarps prior to night/weekend breaks to cover installed top floors or roofs, when rain is forecasted.

2.5 Advanced protection: protection through installing 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. A fixed tent, similar to those used in retrofits, can be built with scaffolding and tarps to protect roof and cladding installation (Figure 7).
b. 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 8). This can provide protection for the entire construction when the budget allows.

Figure 7 Using a temporary tent to protect roof construction in a Vancouver project.

Figure 8 Using a liftable temporary roof to protect timber construction in Sweden.

Figure 9 Drying of timber roof using electrical heating blankets under a temporary roof.

3 DRYING & 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 or 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, forced drying, such as using fans, space heating (electrical heaters preferred), or dehumidification can be used to speed up drying (Figure 9).
- For localized areas, such as laminated boards, 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 should be removed as they may trap moisture and reduce the drying capacity of the wood member.

Other remedial treatments may also become necessary, for example:

- When wetting has caused discolouration (e.g., mould growth, staining) on appearance members, sanding the surface is usually the most efficient way to remove the staining before finishing or refinishing.

4 PROTECTION AGAINST RAPID DRYING

Large gaps between boards, excessive checking and warping usually result from rapid drying, over drying, or cyclic wetting and drying and cause aesthetical and dimensional issues. They can occur both during construction in a dry climate and in service, particularly when the space is suddenly heated.

- Mechanical humidification is typically applied to maintain the humidity level of the environment and to slow down wood drying.
- A relatively closed space needs to be created for applying mechanical humidification during the construction in a dry climate.
- Humidity control is important for a mass timber building in its first few years' service to allow the wood to slowly adjust to the service environment.

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Pointe-Claire
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Québec
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Québec, QC
Canada G1V 4C7
(418) 659-2647