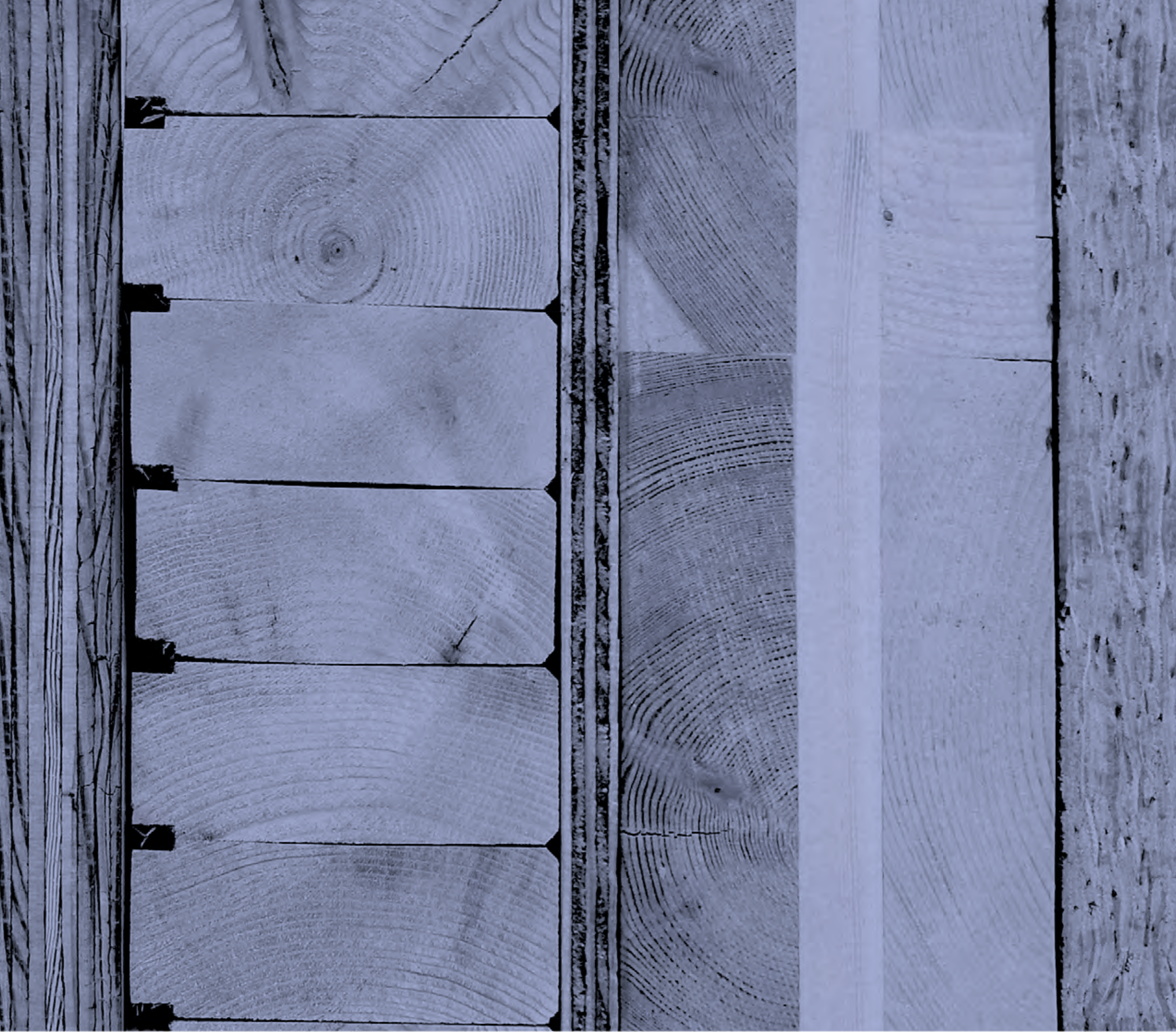
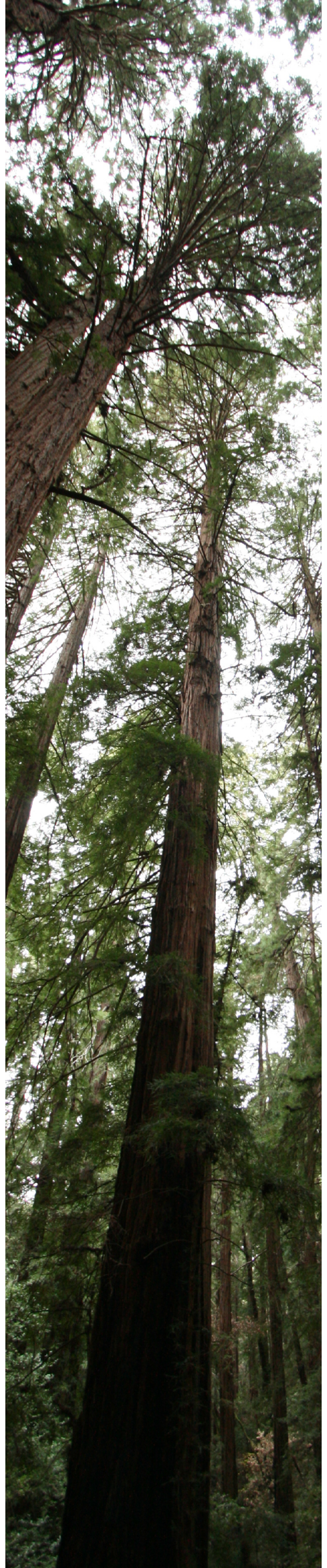


MOISTURE RISK MANAGEMENT STRATEGIES FOR MASS TIMBER BUILDINGS

A guide for designers, construction professionals, and building developers

RDH BUILDING SCIENCE

OCTOBER 2022 | V2.1



ABOUT THIS GUIDE

The intent of this guide is to educate designers, construction professionals, and building developers on best practice design and construction strategies for the moisture management of mass timber buildings. This guide describes measures that the design and construction team may take to mitigate the risks associated with exposing the mass timber enclosure and other elements, including floors, to moisture during construction and occupancy. Version 2 of this guide includes expanded tools, checklists, and guidance.

This guide is a compilation of new and previously published content authored by RDH Building Science; existing resources used to compile this document are included in the resources listed at the end of this guide.

This guide is a companion to *Mass Timber Building Enclosure Best Practice Design Guide* published by RDH Building Science.

ABOUT THE AUTHOR

For over 25 years, RDH Building Science has been committed to leading innovation and change in the design and construction of buildings. We believe that all buildings can be made better through the integration of science, design, and construction expertise. Our team has contributed to mass timber projects throughout the US and Canada and has built a strong understanding of considerations needed to create a durable and high-performance enclosure.

Learn more at rdh.com

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A cross-laminated timber (CLT) floor with post and beam structure. Successful moisture management during construction of this project preserved the finish aesthetic of the mass timber elements exposed to the interior. Wood Innovation Design Centre (Michael Green Architecture). Photo credit: Ema Peter

MASS TIMBER & MOISTURE

The best practice design for mass timber buildings keeps the mass timber components warm and dry throughout the building's construction and occupancy. This is achieved by effectively managing moisture exposure during construction, by ensuring the building enclosure is designed with the necessary layers to control the loads on the enclosure, and by providing the mass timber elements an opportunity to dry out if wetted during unplanned in-service conditions, such as a plumbing leak.

With respect to the enclosure design, an adequately designed mass timber building enclosure controls these loads:

- **Water:** Elements such as cladding, flashing, roof membranes, and water-resistive barriers (WRBs) all contribute to water control in mass timber enclosures.
- **Air:** Reducing air leakage across the mass timber enclosure is managed by an air barrier system.
- **Thermal:** By locating the thermal insulation outboard of the mass timber components, the mass timber enclosure manages heat flow.
- **Water vapor:** The movement of water vapor across the mass timber enclosure is managed by the mass timber element and occasionally by other material layers, such as roof membranes.

Control layers and best practice design principles for mass timber building enclosures are described in RDH's companion document, *Mass Timber Building Enclosure Best Practice Design Guide*.

The remainder of this document discusses moisture management during all phases of the mass timber building's life, starting with design and planning and followed by the development and implementation of a moisture management plan during construction and into occupancy. To successfully implement this plan, the design team, construction team, and building ownership must be aware of the unique moisture management risks and available strategies required for each mass timber project.

The best practice design for mass timber buildings keeps the mass timber components warm and dry throughout the building's construction and occupancy.

MASS TIMBER MOISTURE RISKS

Mitigating moisture risks associated with mass timber buildings and enclosures requires attention to moisture management during design, manufacturing, shipping, construction, and occupancy. Sources of manufacturing and shipping phase moisture may include wetting from rain on unprotected elements during transport or storage. Sources of construction phase moisture may include rainfall and snowmelt, night-sky condensation, and plumbing leaks. Sources of moisture during occupancy can include water intrusion through failures of the building enclosure's water control layers at mass timber assemblies or surrounding assemblies and details. Other sources of occupancy phase moisture include plumbing failures, occupant activities such as bathing and food preparation, appliances that use water, and activation of a fire sprinkler system.

Moisture absorption for mass timber elements is not instantaneous. Long-term or persistent exposure to moisture is likely to be more problematic to the mass timber elements than the overall quantity of water [1]. When mass timber assemblies are subjected to long-term exposure or standing water, moisture can penetrate deep into the mass timber, becoming trapped within the pore structure of the wood, and at locations such as prefabricated panel interfaces, lamination interfaces, splices, exposed end grain, and between laminations and sheathing layers (see Figure 1).

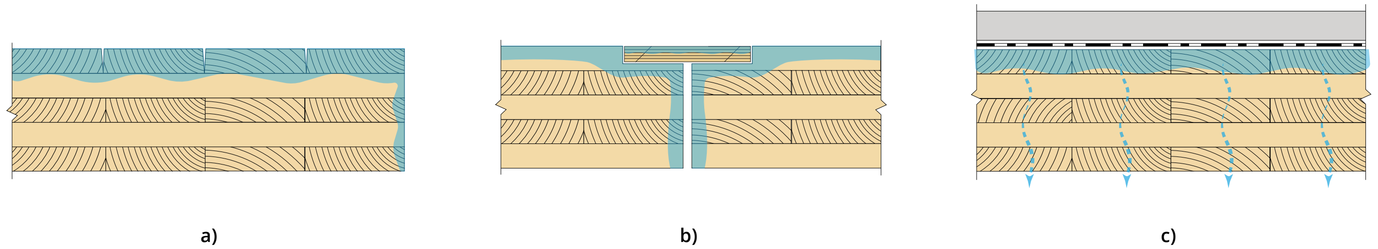


Figure 1 *Moisture can penetrate deep into a) mass timber components, b) mass timber connections, and c) mass timber assemblies.*

Moisture absorption for mass timber elements is not instantaneous. Long-term or persistent exposure to moisture is likely to be more problematic to the mass timber elements than the overall quantity of water.

Figure 2 shows that the amount of annual rainfall throughout the US and Canada can vary from low levels in desert and arid climates to more extreme levels in coastal regions. Rainfall levels can be exacerbated by high wind speeds that produce wind-driven rain. Wind speeds generally increase with height; thus, taller mass timber buildings are likely to see greater water loads than traditional shorter wood-framed structures. Roof assemblies may receive the greatest amount of moisture exposure during the construction phase; however, walls and particularly floors are susceptible to wetting risks, especially if construction schedule delays occur.

The timing of rainfall events can be as important as the amount of rain that falls. This is because the seasonal distribution of precipitation can affect the drying potential of the enclosure after a wetting event. For example, a heavy rainfall that is followed by colder temperatures and/or high humidity levels will provide little opportunity for drying. This consideration can have a significant impact on mass timber panels that may have been erected but are not yet protected from construction-phase moisture.

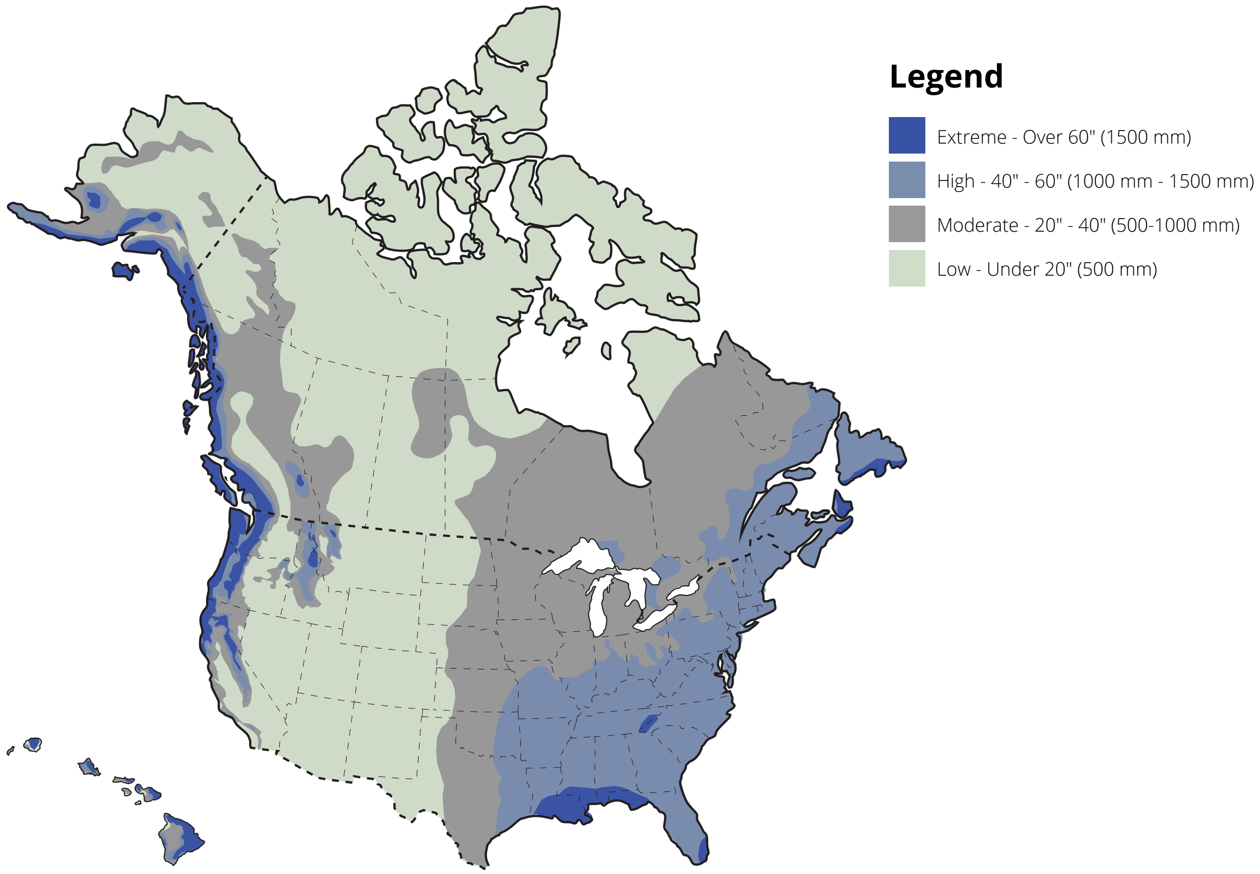


Figure 2 *Rainfall distribution across the United States and Canada [2].*

Moisture can be properly managed during construction with the right design, planning, and construction techniques, but a lack of proper care can affect the aesthetics, structural capacity, dimensional tolerances, and even indoor air quality of the building. Figure 3 shows several examples of the results of poor moisture management during construction. Retroactive attempts to fix these problems require tents or large-scale drying that are costly and can delay the construction schedule.

During building occupancy, bulk water is not the only moisture-related item to consider; the interior environmental conditions also may impact relative humidity values. Mass timber buildings perform best with respect to long-term durability when the interior relative humidity values are between 30% and 50%, with values of between 20% to 60% still being acceptable. Therefore, HVAC and humidity control systems are important elements within mass timber buildings to regulate the indoor environment.

Refer to RDH's *Mass Timber Building Enclosure Best Practice Design Guide* for more discussion on the impacts of in-service ambient relative humidity conditions.

HVAC and humidity control systems are important elements within mass timber buildings to regulate the indoor environment.

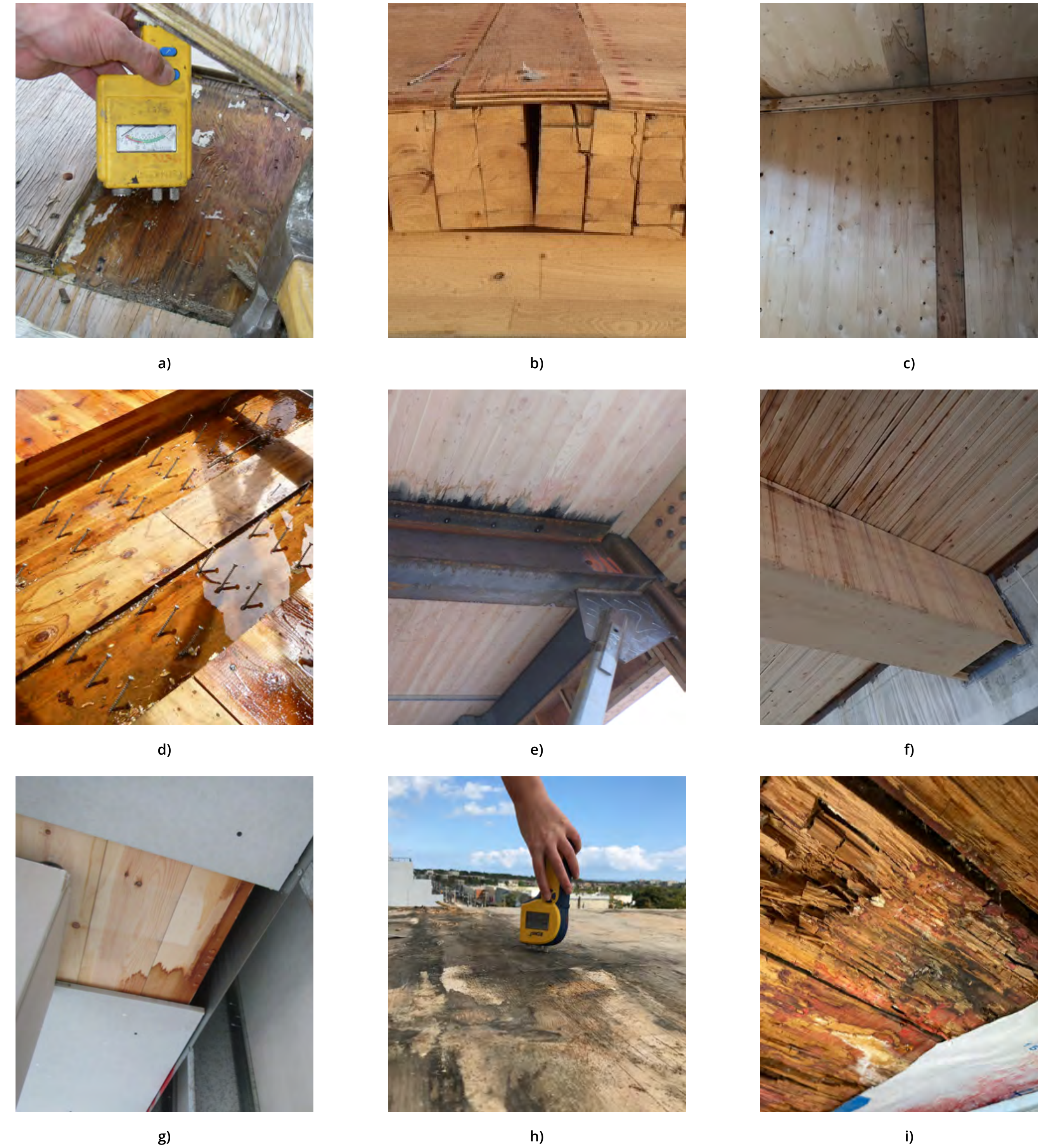


Figure 3 *The results of inadequate construction phase moisture management: a) moisture trapped between layers of built-up plywood over a timber roof panel causing the panel to be saturated with moisture; b) built-up timber panel damage and distortion resulting from moisture-related panel expansion; c) staining on a CLT wall and intermediate floor panels due to ponding water on the floor panels; d) ponding on and absorbing into a composite floor panel before the concrete is installed; e) visible staining on the underside of a CLT floor panel due to corrosion at a steel beam; f) visible staining due to moisture migration through a nail-laminated timber (NLT) panel; g) moisture accumulation within a mass timber ceiling cavity due to installation of interior gypsum board before the installation of adequate moisture protection on the floor panel above; h) microbial growth and deterioration of an unprotected CLT roof panel; and i) severe deterioration of a CLT floor/soffit condition due to water intrusion from the wall above and the use of low-permeance membranes on both the top and bottom of the floor panel.*

Mid-construction of the mass timber Science Collaboration Centre in Chalk River, Ontario. Perimeter hoarding is installed as each floor is completed to protect the mass timber from moisture exposure (Canadian Nuclear Laboratories).

MOISTURE MANAGEMENT PROCESS

Successful moisture risk mitigation of the mass timber building begins early in the design phase and continues throughout the construction phase of the project. A best practice approach to this risk mitigation is to follow a moisture management process that leads to the development of a moisture management plan that can be executed during the construction phase of the project. This plan will anticipate the sources of moisture that the building might experience, incorporate ways in the design to prevent moisture exposure where possible, and outline ways to address moisture exposure when it occurs during construction.

This guide outlines the moisture management process in three steps:

- **Step 1:** Complete a Moisture Risk Assessment for Mass Timber Assemblies
- **Step 2:** Develop a Construction Phase Moisture Management Plan
- **Step 3:** Execute the Design and Moisture Management Plan

Each of these steps is described on the following pages and is illustrated in Figure 4 on page 9 relative to the project phase during which each step occurs. The remainder of this guide offers tools and resources to plan for and manage moisture risks associated with mass timber building components, specifically floor, roof, and wall assemblies. At the end of this guide, a project case study demonstrates the application of the three-step moisture management process and the use of the information and tools shared in this guide.

The planning process outlined within this guide is intended to be collaborative among the design, construction, and development teams to ensure that each team's specific needs are considered and the unique foresight of each team is leveraged when anticipating challenges and making design and planning decisions.

Successful moisture risk mitigation of the mass timber enclosure begins early in the design phase and continues throughout the construction phase of the project.

STEP 1: COMPLETE A MOISTURE RISK ASSESSMENT FOR MASS TIMBER ASSEMBLIES

The first step of the moisture management process is to complete a moisture risk assessment for each mass timber assembly. This step guides the project through an assembly-specific risk assessment that considers the assembly design and informs design revisions (if needed) and construction planning. The risk assessment acknowledges all factors that may contribute to an assembly's moisture exposure risk over the construction and occupancy of the project such as climate, rainfall, construction schedule, length of exposure to moisture, and type of mass timber element. By completing this assessment and applying specific guidance for the assembly type, the project team will identify solutions for factory- or site-installed moisture protection membranes and additional assembly design features and detailing needs. Depending on the flexibility within the design and construction schedule, this assessment can be an iterative process to reduce the anticipated moisture exposure level when possible, thus reducing the moisture-related risks for the mass timber project.

STEP 2: DEVELOP A CONSTRUCTION PHASE MOISTURE MANAGEMENT PLAN

The second step is to complete a construction phase moisture management plan during the project's design phase. This step is informed by the decisions made in Step 1, such as the selection of factory-applied protection and treatment of exposed mass timber surfaces. These decisions will determine the methods and actions required of the construction team to appropriately manage and respond to both anticipated and unexpected moisture exposure events during construction. The moisture management plan defines all activities of the construction team to reduce moisture-related risks and may include providing an active water management team on-site to reduce uptake; implementing the use of small tarps and squeegees or vacuums; and providing whole-building tarping and protection systems, environmental drying, and a mechanical drying contingency.

By developing this plan during the project's design phase, any anticipated construction phase actions can be reasonably incorporated into the project's overall construction schedule and budget. These actions may include contingencies in case changes to the moisture management plan are required to address unforeseen circumstances, such as weather or construction delays.

STEP 3: EXECUTE THE DESIGN AND MOISTURE MANAGEMENT PLAN

The third step is to execute the design and moisture management plan during construction. This step puts into play the early planning work performed by the design, construction, and development teams during Step 1 and Step 2.

During the execution of the design and moisture management plan, the mass timber components of the building must be monitored and evaluated to assess the effectiveness of the moisture management plan to protect the mass timber structure. Some projects may require additional efforts devoted to drying or removing bulk water.

If the moisture management plan is followed, the project will be protected in alignment with the design, construction, and development teams' expectations, and the entire project team will be well prepared to respond to unexpected moisture exposure events.

Figure 4 *The three-step moisture management process relative to the project phase.*

STEP 1 - COMPLETE A MOISTURE RISK ASSESSMENT FOR MASS TIMBER ASSEMBLIES

Ronald McDonald House of British Columbia (Michael Green Architecture).

MOISTURE EXPOSURE RISK

Planning for moisture management begins with an understanding of moisture exposure risk, which is a function of the project's exposure to moisture as well as the type of enclosure assembly or intermediate floor assembly that is being evaluated.

The risks associated with exposing mass timber to moisture can be avoided through the careful selection and design of moisture protection membranes, slope, venting, and long-term WRBs and waterproofing membranes. However, these design decisions must also take into account the building's program; architectural expectations; structural loads; energy, fire, and acoustic performance requirements; and the need to satisfy all the enclosure control layers that are required for construction or other in-service conditions. It is during Step 1 that all project design needs are considered and balanced with the level of moisture exposure risk that the project team is willing to agree to.

MOISTURE EXPOSURE LEVEL & RISK MANAGEMENT

This document frequently uses the term "moisture exposure level." The moisture exposure level identifies the likelihood of a project's mass timber panel being exposed to wetting events that may occur in transport, in storage, or after placement. The moisture exposure level informs the risk assessment of an assembly and is used to guide appropriate protection methods and a better understanding of the moisture-related risks.

The cumulative factors that determine the moisture exposure level of a given mass timber assembly include:

- **Climate and Season.** The local climate and season include rainfall (see Figure 2) and snowfall levels and frequency; wind; and the opportunity for drying events. Sustained exposure to rainfall and snowfall (if left uncleared), significant wind-driven rain events, and minimal opportunities for drying contribute to higher risk exposures, while summertime construction and/or high-intensity but low-frequency rainfall events separated by sufficient dry and sunny conditions contribute to lower risk exposures.
- **Water Management Strategies During Construction.** The presence of panel slope, water diversion/deflection, and drains impact exposure risk. A sloped mass timber panel, water diversion, and/or deflection mechanisms will encourage water to shed away toward drains and roof or floor edges, but they can also increase the risk of concentrated runoff or pools of water at poorly drained areas. Drains can reduce exposure if they are continuously connected to discharge to the building exterior.
- **Exposure Duration.** The duration for which mass timber panels will be exposed is influenced by overhead protection, speed of construction for subsequent levels, and construction delays.
- **Shipping and Storage.** Shipping protection, travel distance from the manufacturing facility and transit time, and site storage can all impact the mass timber panels' exposure to moisture prior to panel placement.

- **Encapsulation or Other Work Below.** The encapsulation of mass timber elements during construction—using gypsum or other moisture-sensitive materials for either fire protection or construction scheduling reasons—greatly enhances the need for water protection above these elements. Where it is imperative that moisture-sensitive materials be installed prior to the roof and walls being enclosed, the floors or roof above need to be made watertight quickly. For this reason, the risk to schedule delays may be a rationale for enhanced moisture protection.
- **Occupancy Phase Exposure.** Designing for moisture and controlling water doesn't end with rainfall or snowmelt. Water control for events during occupancy can also impact mass timber. Examples of occupancy-phase moisture exposure include plumbing leaks, appliance leaks, and food preparation activities. The exposure of mass timber to moisture as a result of these events can be difficult to discover due to floor finishes, including cementitious toppings, compounding the risk of moisture-related movement and potential decay. Moisture issues during occupancy can also disrupt the occupants and building uses while leaks are identified and mass timber elements are dried.

By evaluating these factors against the project-specific design, construction schedule, and anticipated construction methods, an anticipated moisture exposure level can be assigned to an assembly. This guide uses the levels of "low exposure," "moderate exposure," and "high exposure" as described in Figure 5. The greater an assembly's moisture exposure level, the greater the risk for wetting and need for moisture mitigation strategies, or even assembly design changes.

Walls, because of their vertical nature, are typically lower risk for panel wetting and are commonly assigned a low to moderate risk. Horizontal assemblies, due to their greater susceptibility to ponding water and drainage from areas above, have a higher risk for panel wetting (in some climates and seasons) and therefore are assigned a moisture exposure level ranging from low to high exposure.

It's important to consider that the phase at which a project undergoes moisture management planning can have an impact on the anticipated moisture exposure level and resulting moisture protection methods. A project team that begins planning early in the design phase is likely to have more opportunity to make design and construction phase adjustments that will reduce the likelihood of panel wetting, thus lowering the anticipated moisture exposure level. If a project team begins planning late in the design phase or beginning of the construction phase, they may have less design change flexibility and less opportunity to implement factors in construction that would significantly impact the anticipated moisture exposure level. Unanticipated project changes can also change the moisture exposure level; if the construction schedule shifts from panel installation during a dry season to installation during a wet season, the moisture exposure level may increase and further considerations for moisture protection may be required.

The remainder of Step 1 takes a closer look at the relationship between moisture exposure level and appropriate moisture protection strategies for specific assembly types.

Moisture Exposure Level

The moisture exposure level identifies the likelihood of a project's mass timber panel being exposed to wetting events that may occur in transport, in storage, or after placement. The descriptions below identify examples relative to the building schedule and duration of exposure; however, all factors that may contribute to moisture exposure need to be cumulatively considered.

LOW	Low Exposure → Roof above with perimeter protected with tarps or hoarding, *or* → Exposed during dry/drought season when precipitation is unlikely or limited enough to allow full drying of the mass timber.
MODERATE	Moderate Exposure → Roof above, but open at perimeter with periodic precipitation and limited risk of wind-driven rain.
HIGH	High Exposure → No roof above with precipitation expected during exposure duration, *or* → Roof above but open perimeter with wind-driven precipitation expected during exposure duration, *or* → Extended exposure timeline that increases the risk of wetting potential.

Figure 5 *Moisture exposure levels summary for mass timber assemblies.*

ASSEMBLY TYPE

During Step 1, a significant determining factor for assessing the moisture-related risks of a mass timber assembly is to identify the assembly type. Is it a floor, roof, or wall assembly? If it is a floor or roof assembly, is a timber-composite system being considered? The application will dictate the layers within the assembly and how these layers may interact with one another to resist moisture.

This document provides guidance for the following assembly types:

- Floor and roof assemblies
- Composite floor and roof assemblies
- Wall assemblies

Each of these assembly types and its unique moisture risk mitigation strategies are discussed in detail in this guide.

Operational Considerations

During design and planning, it is helpful to consider how the use of mass timber components in the building structure and enclosure may impact building commissioning and building operation. The building's operation will depend on how dry the mass timber components were maintained during construction and the relative difference between the moisture content of the mass timber components and the desired indoor operating conditions.

The project team must consider the need to control indoor relative humidity and temperature following completion of the enclosure but prior to and following commissioning of the mechanical systems. These factors may be controlled by slowly bringing the building to the desired indoor operating conditions.

Slow drying will allow the mass timber to dry to the indoor environment while minimizing the risk that checking will occur.

A mass timber roof assembly. Once all laps of the membrane are sealed, the air and vapor barrier membrane visible in this photo will temporarily protect the mass timber from moisture (Catalyst, Spokane, WA).

FLOOR AND ROOF ASSEMBLIES

Protecting floor and roof mass timber assemblies from moisture usually includes the use of moisture protection methods such as membranes or coatings, panel joint treatments, treatment of common building details, or all three. The selection of a moisture protection method depends on several factors and can be challenging to determine. Not all assemblies or climates and seasons require the same level of moisture protection during construction; thus, it's important to carefully assess each assembly application without unnecessarily impacting construction costs.

A unique set of moisture management planning design tools are provided on page 32 through page 37 to assist the designer with decision-making during Step 1 of the moisture management process for non-composite floor and roof assemblies (for composite floor and roof assemblies, see guidance beginning on page 39). These tools guide the project team through a risk assessment of a mass timber assembly by considering the assembly design and moisture exposure level. The tools then guide the designer to identify construction phase decisions that protect the mass timber assembly at a level that is "optimal" for reducing moisture-related risks. Figure 6 illustrates the progression of these planning tools from assembly through site-installed protection during the design and planning phase and the construction phase.

Each individual planning tool is specific to assemblies comprised of CLT, NLT, dowel-laminated timber (DLT), and mass plywood panels (MPPs); however, the general process through which each tool is used to evaluate the assembly and select an appropriate moisture protection method remains consistent for all four of these mass timber types.

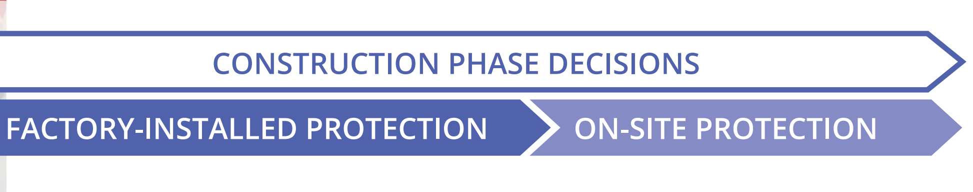


Figure 6 *Moisture planning tool progression for floor and roof assemblies.*

Figure 7 *Mass timber floor assembly with cementitious topping.*

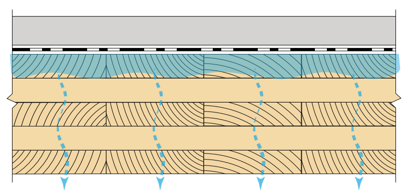


Figure 8 *Cementitious topping over a CLT floor assembly. The installation of a moisture protection membrane in addition to the topping shown restricts drying of the topside of the mass timber panel; therefore, the mass timber needs to be confirmed dry (i.e., less than 16% moisture content) prior to the placement of a topping.*

DESIGN AND PLANNING PHASE DECISIONS

The moisture management planning design tools for floor and roof assemblies begins by identifying the mass timber assembly and its design. The next step is to apply the moisture exposure level that was discussed in detail on page 13 through page 15.

Floor Assemblies

The first consideration for floor assemblies is whether a cementitious topping will be used (see Figure 7). Cementitious toppings enhance the acoustical, fire resistance, and structural performance of the mass timber; however, the use of a cementitious topping must consider that bleed water from the topping can wet the mass timber following its placement, and toppings may trap moisture within the mass timber panel for extended periods of time, as illustrated in Figure 8. The second consideration for floor assemblies is whether there is a need for temporary moisture protection, such as an acoustic mat.

When evaluating a floor assembly that may use a topping, consider the following:

- The mass timber panel needs to be dried to a moisture content of 16% or less prior to being covered. Moisture readings need to be taken using a calibrated moisture meter and may need to be adjusted for the wood species of the panel and temperature.
- Coatings and membranes that can protect the mass timber panel from moisture within the cementitious topping are generally recommended. However, the use of certain acoustic mats (for floor applications) between the topping and mass timber panel can limit wetting from the topping.
- Great care needs to be taken to minimize the assembly's exposure to moisture following the placement of the topping. Moisture can become trapped between the topping and the layers below, increasing the risk that moisture may breach an underlying coating or membrane at discontinuities or through the membrane itself if it is not continuous or able to withstand the water load imposed by the topping.

For roof assemblies, the first consideration is whether a conventional or protected membrane (i.e., inverted roof membrane) roof has been designed.

Roof Assemblies

Conventional roof assemblies shed water at the roof membrane plane, which is the outermost surface of the assembly; the slope of this membrane is often created by tapered rigid board insulation products (see Figure 9). In this case, the mass timber panel structure is flat and lacks slope that would otherwise encourage water to drain across the panel surface. This lack of slope increases the risk for ponding water, which increases the moisture exposure level of the assembly and the likelihood that a moisture protection membrane will be needed to protect the panel from moisture during construction. This membrane is often factory-installed, but may also be a site-installed component, and is often retained in the final roof assembly for the purposes of air control.

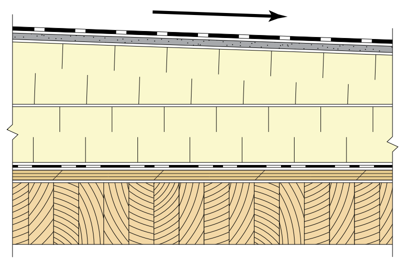


Figure 9 *Conventional roof assembly with tapered rigid insulation.*

In a protected membrane roof assembly, the roof membrane is located on top of the structure and is concealed by additional drainage, insulation, and additional overburden layers. The location of the roof membrane on top of the structure requires that either the mass timber panel is sloped to create drainage for the assembly (see Figure 10 a) or additional layers of tapered insulation and sheathing are used to create slope for drainage (see Figure 10 b). A sloped panel will limit the need for more robust moisture protection methods and provides the option of using the final roof membrane for temporary moisture protection, but only if the membrane is well protected from trade damage and thoroughly reviewed for needed repairs prior to cover. If the panel is flat, additional layers of tapered insulation and sheathing are required within the assembly to provide a sloped surface for the membrane; it is likely that an additional temporary membrane over the mass timber panel will also be required to protect the panel until the buildup of sloped materials and final roof membrane are installed.

Note, in either conventional or protected-membrane roof assemblies, the roof manufacturer must review and approve the mass timber roof assembly for warranty considerations such as wind uplift requirements and material compatibility.

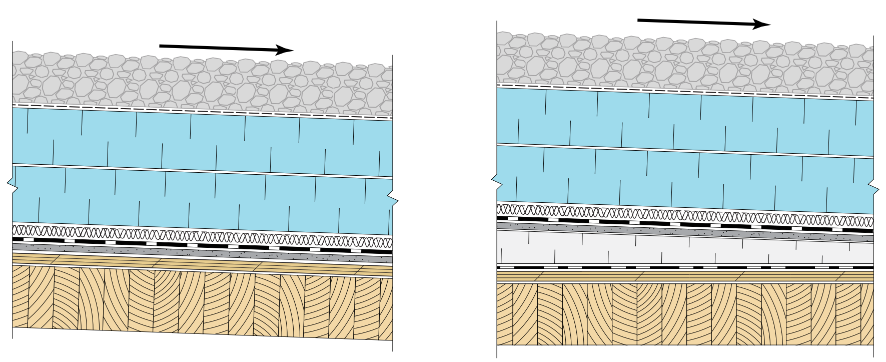


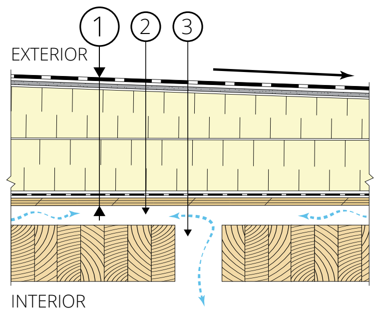
Figure 10 *Protected membrane roof assembly with a) sloped mass timber panel, and b) tapered rigid insulation to create slope.*

Once the roof assembly type is determined, the team will next determine whether the space above the mass timber panel is vented to the interior (see Figure 11).

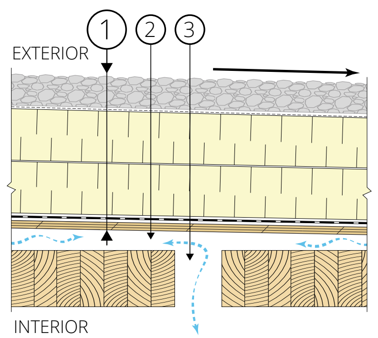
Venting the top side of the mass timber panel to the building interior provides an opportunity for the panel to dry to both the top and bottom sides. Two-sided drying can also aid in locating and drying roof leaks during occupancy.

Detecting a roof leak during building occupancy can be difficult because mass timber can absorb a significant amount of moisture. Structural sheathing can further mask the presence of water. While a leak detection system for the roof can aid in detecting the leak location, a vented panel allows for both visual detection and a drying opportunity. Venting is provided directly above CLT and MPP panels, and between the structural plywood or OSB sheathing of NLT or DLT. This vent space can be achieved with battens (see Figure 12) or sloped over-framing; however, the project's structural engineer will need to confirm the vent space's impact on the structural sheathing boundary and edge nailing requirements. These requirements may block the air cavity connection to the interior, negating the benefit of venting the assembly to the interior.

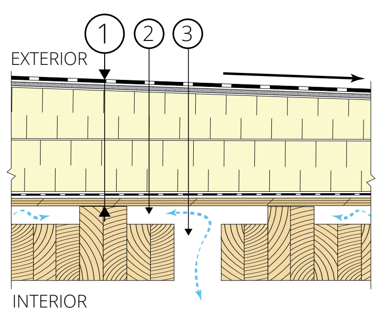
When venting the mass timber roof panel to the building interior, consider that this venting may exclude the timber from the assembly's effective thermal performance calculations for energy code compliance calculations in some jurisdictions. Additionally, the fire code may require the air cavity to be filled with insulation, partially negating the purpose of the open cavity.



a) flat battens



b) sloped over-framing

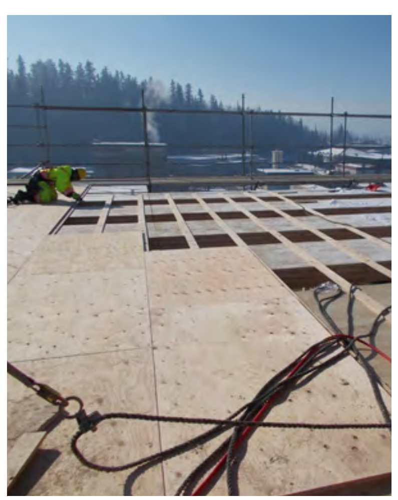


c) variable-height laminations

Legend

1. Roof assembly including ballast (where applicable), roof membrane, insulation, air and vapor control membrane, and structural sheathing
2. Vent space
3. Ventilation pathway to interior

Figure 11 *Vented roof panel options include a) flat battens across a mass timber panel, b) sloped over-framing over a mass timber panel, and c) staggered or variable-height laminations of an NLT or DLT panel.*



a)

b)

Figure 12 *A flat batten venting approach. Structural sheathing is shown a) over the top of the battens, and b) visible on the underside of the batten and vented assembly.*

CONSTRUCTION PHASE DECISIONS

After considering the design and planning phase decisions for a horizontal assembly, construction phase decisions are made. These decisions include selecting appropriate construction phase protection methods, such as the application of coatings, membranes, and other materials; managing moisture at common building interfaces and transitions; and actions required by the construction team to clear water and monitor conditions that are appropriate for the assembly's moisture exposure level.

Construction phase moisture protection can be grouped into two categories: factory-installed protection and site-installed protection. In most instances, both factory- and site-installed protection are necessary to protect the mass timber assembly from moisture.

Factory-installed (i.e., factory-applied) protection includes protective membranes or coatings that are intended to be installed in a factory setting. An example of factory-installed protection is shown in Figure 13. The conditions in a factory setting promote the application of the materials in a dry and accessible environment that is most conducive to appropriate material application and quality assurance standards.

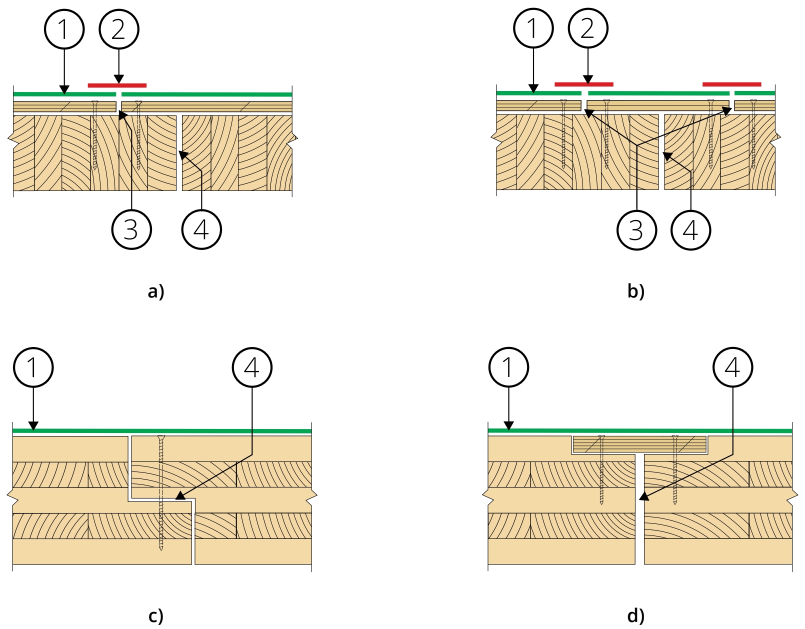
Figure 13 *A CLT floor panel with a factory-installed membrane is being hoisted into place at a project site.*

Figure 14 *Splice joint and drag strut connections visible at CLT panel interfaces.*

Site-installed protection is installed on the project site either directly before mass timber panel placement or following panel placement. It also includes treatment of common building details and interfaces on mass timber buildings where the edge grain of the wood is typically exposed or where moisture may have the opportunity to penetrate deep into the panels at these areas. The edge grain absorbs water more quickly than the surfaces; thus, treatment can greatly benefit moisture risk mitigation.

Common details and interfaces that may need treatment include joints, such as those that occur between mass timber panels; and common building details such as roof-to-wall interfaces, column-to-floor connections, penetrations, wall edges, structural attachments, and parapets (see Figure 14). Various treatment strategies are available but typically use a water-resistive or waterproof tape, membrane, or a combination of these materials to protect against moisture and promote water shedding. Determining the joint and detail treatment coincides with determining the moisture protection type (e.g., a membrane or coating); however, additional steps may be needed to coordinate the joint treatment with structural and even fire requirements. Several examples of panel-to-panel connections are shown in Figure 15 and typical building detail treatments are described in Table 1.

Common types of factory-installed and site-installed moisture protection types are described in detail beginning on page 26.

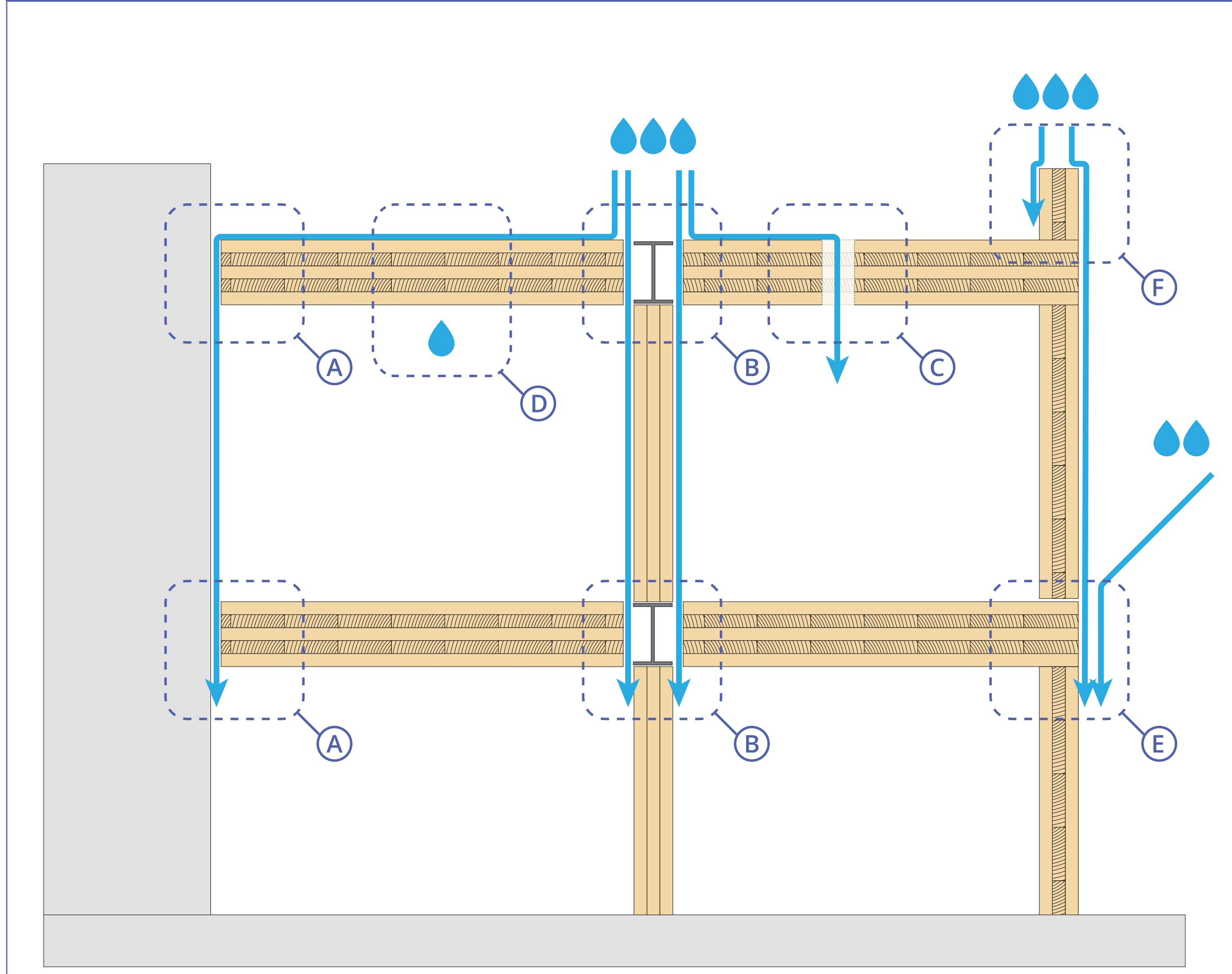


Legend

1. Moisture protection membrane or coating
2. Joint treatment such as tape or membrane
3. Structural sheathing break
4. Panel joint

Figure 15 *Various panel-to-panel connections with joint treatment. Joints shown in a) and b) consider a single layer of structural sheathing over an NLT or DLT panel joint with a moisture protection membrane that has been pre-applied to the panel sheathing layer. Joints shown in c) and d) depict two options for CLT splice joint designs with a continuous moisture protection membrane across the panel top.*

Table 1 *Treatment of Common Mass Timber Building Details*



Legend

- Low moisture exposure level
- Moderate moisture exposure level
- High moisture exposure level
- Moisture runoff path
- Common building detail; reference this table for more information (X)

Table 1 (continued) *Treatment of Common Mass Timber Building Details*

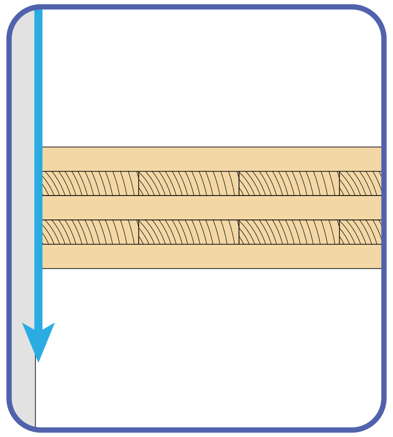
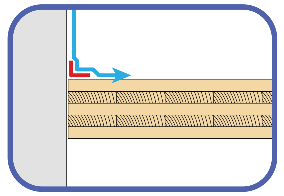
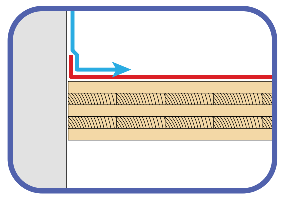
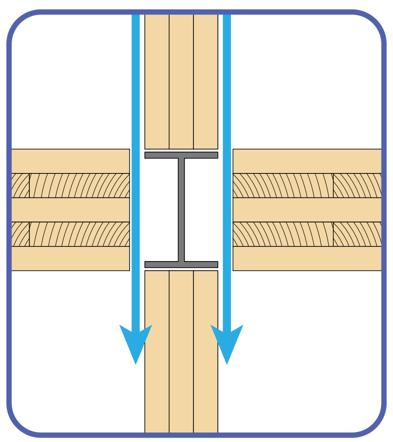
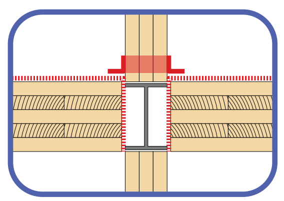
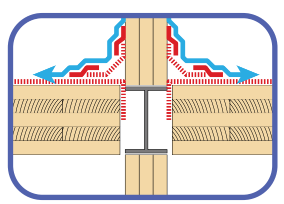
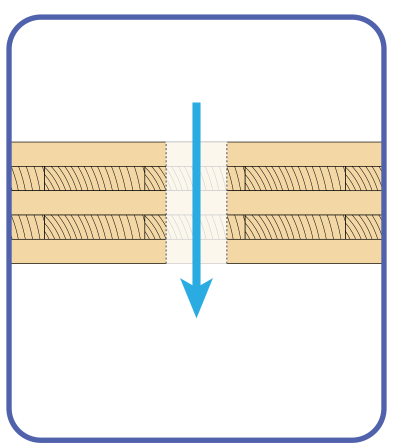
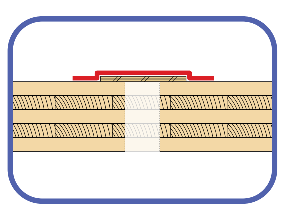
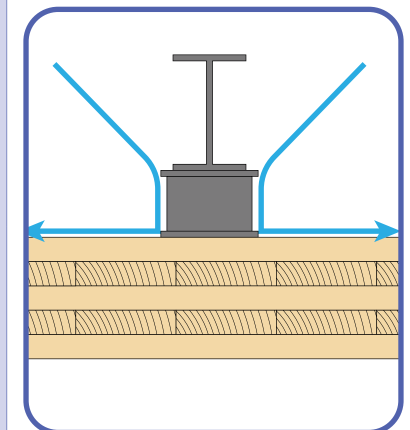
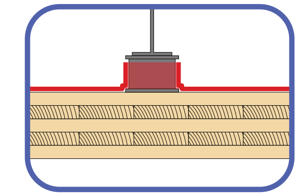
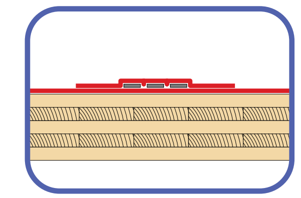
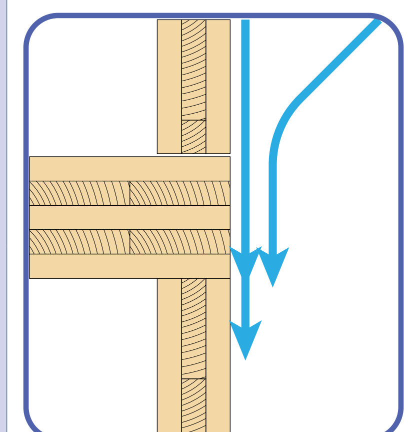
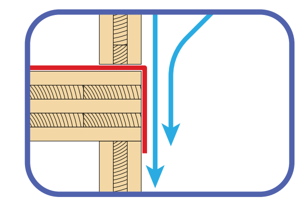
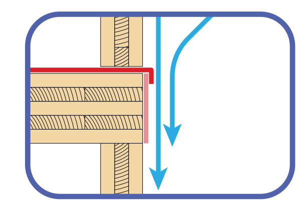
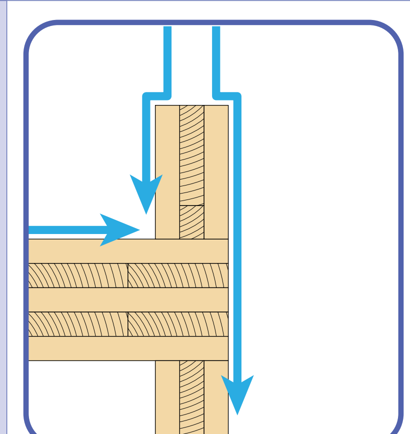
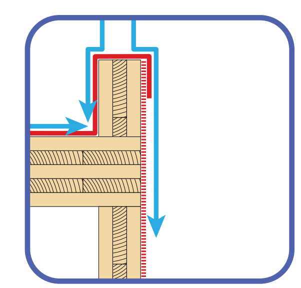
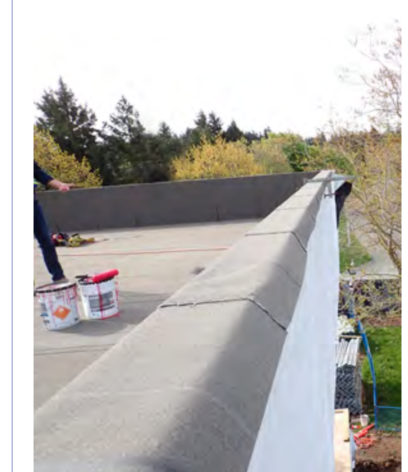
DETAIL	DESCRIPTION	TREATMENT	EXAMPLE PHOTO
A	 Vertical-to-horizontal interface	 Tape	
		 Extend horizontal membrane up wall	
B	 Steel-to-mass timber column interface	 Seal around penetrations	
		 Tent at column	
C	 Penetrations through mass timber	 Plywood and membrane over penetration	

Table 1 (continued) *Treatment of Common Mass Timber Building Details*

DETAIL	DESCRIPTION	TREATMENT	EXAMPLE PHOTO
D	 Structural attachments	 Membrane around connection	
		 Membrane over structural components	
E	 Mass timber edge	 Overhanging house wrap or floor/roof membrane	
		 Wax coat and counterflash with floor/roof membrane	
F	 Mass timber parapet	 Membrane lapped up and over parapet	

MOISTURE MANAGEMENT PLANNING

Depending on the anticipated moisture exposure level for a floor or roof assembly, moisture protection of the mass timber panels may be required to mitigate the risk of moisture damage. The following pages provide several resources to aid the project team through the design and planning project phase. These resources include:

- Moisture Protection Types (Table 2)
- Risk Assessment Matrix (see Table 2, legend)
- Moisture Management Planning Design Tools 1 through 3 for Roof and Floor Assemblies (page 32 to page 37)

Moisture Protection Types

Table 2 describes different types of site-installed or field-installed moisture protection such as coatings and membranes. The table differentiates between products with unique installation and performance factors and risks, and includes an assigned level of protection robustness (low, moderate, or high) for each product type. Protection robustness identifies the suitability of a product type to protect mass timber when exposed to moisture and considers what additional actions may be required during moisture exposure events. The Table 2 legend includes a description of each protection robustness level. Figure 16 includes example photographs of some of the protection types listed.

RDH established the levels of protection robustness based on material testing, field observations, and our experience in forensic investigations of mass timber buildings. Products in addition to those listed in Table 2 may be available; however, alternate products should be carefully considered by a building enclosure professional for their applicability to each unique project condition.

Risk Assessment Matrix

There is a correlation between protection robustness and anticipated moisture exposure level as described in the Risk Assessment Matrix included in the Table 2 legend on page 29. Generally speaking, low, moderate, and high moisture exposures are "optimally" managed by protection types with low, moderate, or high protection robustness, respectively. An "optimal" selection from the Risk Assessment Matrix correlates to a protection robustness with the least likelihood to lead to moisture damage to the mass timber. The Risk Assessment Matrix recognizes that it is impossible to eliminate risk entirely; thus, what is defined as "optimal" in the matrix has been evaluated as the point of diminishing returns. Increasing the membrane robustness past the "optimal" level would result in a smaller reduction of risk than if robustness was increased from "caution" to "optimal." When determining the acceptable level of risk, the project team is recommended to evaluate the potential time delays and potential future costs if a wetting event was to occur.

Moisture Management Planning Design Tools

Three moisture design tools have been provided for CLT, NLT and DLT, and MPP floor and roof assemblies. Through a series of assessment queries, these tools guide the designer through the selection of various factory- or site-installed protection methods suitable for a project-specific anticipated moisture exposure level to achieve an optimal risk level. As shown in Table 2, there are multiple products with varying levels of protection robustness. The acceptable risk level is up to the discretion of the project team; therefore, the combination of moisture exposure level and protection robustness may differ from what is presented in the tools. To learn how the tools can be developed for alternative risk levels, refer to the case study discussion beginning on page 59.

Refer to the Moisture Management Process Case Study presented in this guide to see for a demonstration of how the Moisture Management Planning Tools are applied to a project.

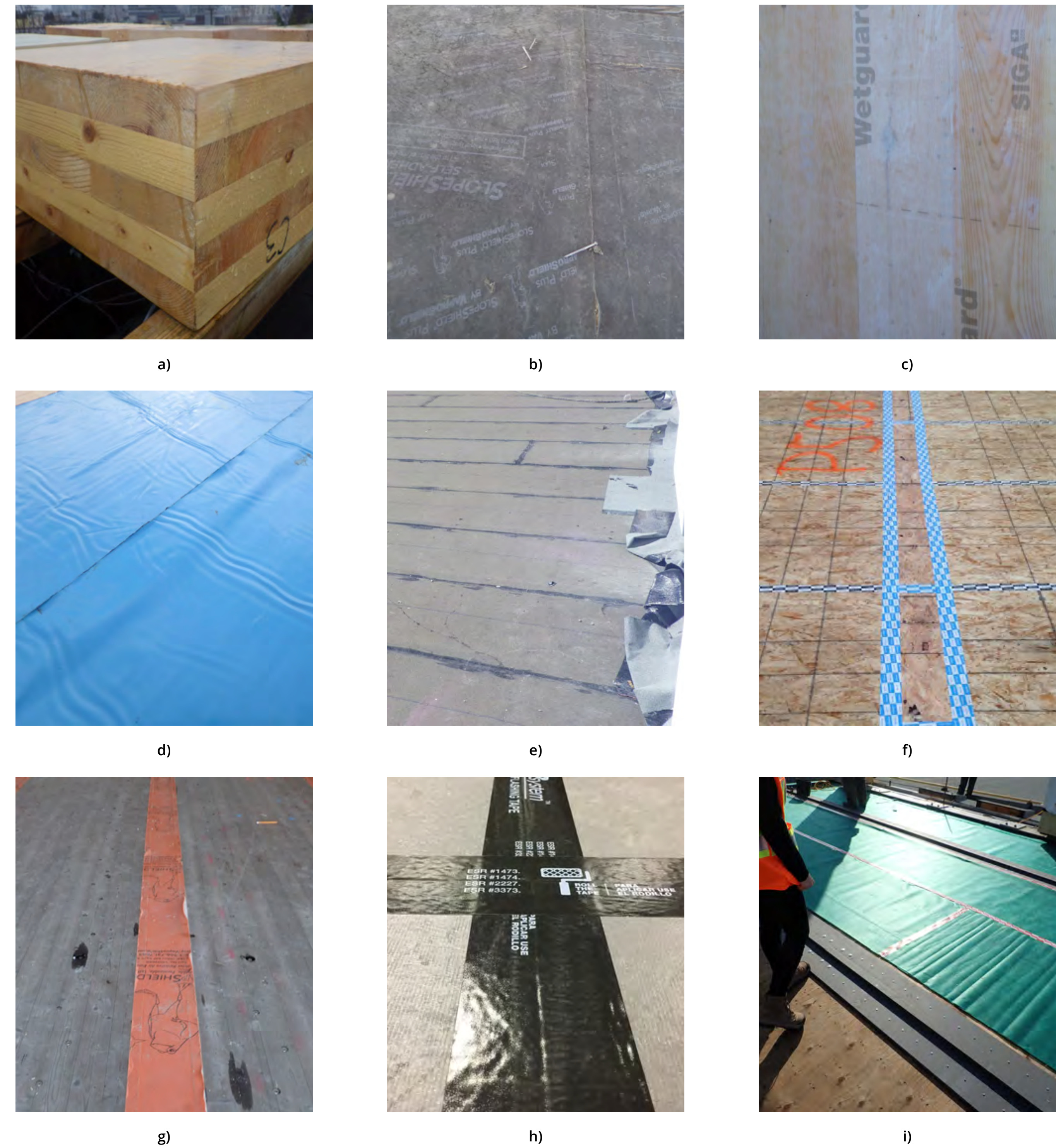


Figure 16 *There are a variety of moisture protection types such as: a) hydrophobic coating, b) vapor-permeable self-adhered membrane; c) vapor-semi-permeable self-adhered membrane; d) vapor-impermeable self-adhered membrane; e) vapor-impermeable self-adhered SBS roofing base sheet; f) vapor-impermeable tape installed at sheathing joints; g) vapor-permeable tape installed at panel joints; h) coated sheathing with taped joints; I) vapor-impermeable loose-laid acoustic mat with taped laps.*

Table 2 *Mass Timber Moisture Management Moisture Protection Types*

***Table 2** (cont.)* *Mass Timber Moisture Management Moisture Protection Types*

	PRODUCT DESCRIPTION	SHORT FORM	INTENDED USE AND APPLICATION	PROTECTION PROPERTIES	KEY CONSIDERATIONS	PROTECTION LEVEL
MEMBRANES	Vapor-impermeable loose-laid sheet	VIMP SHEET	→ Not intended for large areas of coverage → Emergency or short-term protection of targeted areas and tarping/hoarding → Site-installed	→ Water-shedding and waterproof → Vapor impermeable; does not allow drying through the membrane → Loose laid; not adhered to the substrate, so it requires fastening or weighing down → Laps require sealing and/or taping	→ Any water bypassing the sheet can freely travel around beneath the surface and can become entrapped below → Easily damaged, often slippery	L
MEMBRANES	Vapor-permeable self-adhered membrane	VP SAM	→ Temporary protection, typically for floors or short-term exposed roof panels → Often used for permanent air barrier and water-resistive barrier functions → Not a vapor barrier → Factory- or site-installed	→ Water-shedding, not completely waterproof → Vapor permeable; does allow drying through it; however, it can also allow some wetting → Self-adhered to the substrate with self-adhered laps; lap joints/seams may require additional sealing beyond self-adhesive	→ Properties (e.g., water repellency, vapor permeability, life span) dependent on product, chemistry, and exposure → Most membranes originally designed for wall applications are not intended for horizontal applications; ensure product selected is suitable for ponding water → Thin and easily damaged by construction activities and traffic → May require a primer to install → Adhesion to damp wood is challenging for most products → Most products have not been tested for adhesion/uplift capacity in roof assemblies	M
MEMBRANES	Vapor-semi-permeable self-adhered membrane	VSP SAM	→ Temporary mass timber protection, typically for floors or short-term exposed roof panels → Can be used for permanent air barrier and water-resistive barrier functions → Not a vapor barrier → Factory- or site-installed	→ Water-shedding, not completely waterproof → Low vapor permeance (1 US perm); does allow limited drying through it; however, it can also allow some wetting → Self-adhered to the substrate with self-adhered laps; lap joints/seams may require additional sealing beyond self-adhesive	→ Limited number of available products → Properties (e.g., water repellency, vapor permeability, life span) dependent on product, chemistry, and exposure → Thin and easily damaged by construction activities and traffic → Adhesion to damp wood is challenging for most products → Has not been tested for adhesion/uplift capacity in roof assemblies	M
MEMBRANES	Vapor-impermeable self-adhered membrane (with sealed laps) A variety of product types are available but often bituminous based with polyethylene facers	VIMP SAM	→ Temporary mass timber protection, typically for short-term exposed roof panels → Often used for permanent air barrier/vapor barrier/water-resistive barrier functions → Is a vapor barrier → Is often listed as part of the finished roof assembly → Factory- or site-installed	→ Water-shedding and waterproof → Vapor impermeable; does not allow drying through it → Self-adhered to substrate; laps are self-adhered but require sealant or additional membrane/tape and primer beyond self-adhesive to maintain waterproofing	→ Large variety of widely available products → Can be slippery; however, products are available with a texture suitable for slip resistance → Moderately easy to damage by construction activities and traffic → Often requires a primer to wood and for tested adhesive characteristics → Adhesion to damp wood can be challenging for many products → Wood must have a moisture content below 16% prior to application to avoid trapping moisture beneath → Prone to blistering if mass timber below is damp and membrane is exposed to solar radiation → Many membranes have been tested for adhesion/uplift capacity in roof assemblies	M
MEMBRANES	Vapor-impermeable self-adhered SBS roofing base sheet (with heat-fused laps)	VIMP Roof	→ Temporary mass timber protection typically for roof panels → Often used for permanent air barrier/vapor barrier/water-resistive barrier functions → Is a vapor barrier → Is often listed as part of the finished roof assembly → Factory- or site-installed	→ Water-shedding and waterproof; higher degree of waterproofness than VIMP SAM → Vapor impermeable; does not allow drying through it → Self-adhered to substrate; laps are heat-fused and may be torched (site) or electrically welded (factory or site) → Cold adhesives for SBS can also be used to achieve similar fused lap joints	→ Readily available from SBS roofing manufacturers → Available with sanded texture for slip resistance and enhanced toughness → Harder to damage than VIMP SAM by construction activities and traffic → Often requires a primer to wood and for tested adhesive characteristics → Adhesion to damp wood can be challenging → Wood must have moisture content below 16% prior to application to avoid trapping moisture beneath → Prone to blistering if mass timber below is damp and membrane is exposed to solar radiation → Is a vapor barrier, which in a roof assembly may be required for the final roofing system → Many membranes have been tested for adhesion/uplift capacity in roof assemblies	H

Legend

Moisture Exposure Level

The moisture exposure level identifies the likelihood of a project's mass timber panel being exposed to wetting events that may occur in transport, in storage, or after placement. The descriptions below identify examples relative to the building schedule and duration of exposure; however, all factors that may contribute to moisture exposure need to be cumulatively considered.

LOW – Low Exposure
- → Roof above with perimeter protected with tarps or hoarding, *or*
- → Exposed during dry/drought season when precipitation is unlikely or limited enough to allow full drying of the mass timber.

MODERATE – Moderate Exposure
- → Roof above, but open at perimeter with periodic precipitation and limited risk of wind-driven rain.

HIGH – High Exposure
- → No roof above with precipitation expected during exposure duration, *or*
- → Roof above but open perimeter with wind-driven precipitation expected during exposure duration.
- → Extended exposure timeline that increases the risk of wetting potential.

Protection Robustness

Robustness level of the mass timber panel achieved by applying protective membranes or coatings.

L – LOW – Low Protection Robustness
- → Coatings, loose-laid protection, or targeted protection.
- → Immediate action required in a wetting event.

M – MODERATE – Moderate Protection Robustness
- → Water-shedding/vapor-permeable membrane.
- → Action required in a timely manner in a wetting event.

H – HIGH – High Protection Robustness
- → Waterproof membrane with heat-welded laps.
- → No immediate action required in a wetting event.

Risk Assessment Matrix

PROTECTION ROBUSTNESS \ MOISTURE EXPOSURE LEVEL	LOW	MODERATE	HIGH
L – LOW	✓ OPTIMAL	? CAUTION	✕ AVOID
M – MODERATE	✓	✓ OPTIMAL	? CAUTION
H – HIGH	✓	✓	✓ OPTIMAL

Table 2 (cont.) *Mass Timber Moisture Management Moisture Protection Types*

	PRODUCT DESCRIPTION	SHORT FORM	INTENDED USE AND APPLICATION	PROTECTION PROPERTIES	KEY CONSIDERATIONS	PROTECTION LEVEL
COATINGS	Thin film hydrophobic (water-repellent) coating to coat surfaces	Top Coat	→ Surface of CLT and MPP panels → Typically factory-installed, though it can also be site-installed	→ Beads water at the surface and reduces water absorption into the mass timber surface, which aids in easier surface management	→ Limited effective life span; easily worn out by construction activities and wear → Film forming and penetrating stain/sealer/paint products available in a range of chemistries → Properties (e.g., water repellency, vapor permeability, life span) dependent on product, chemistry, and exposure	L
COATINGS	High build paraffin wax or thick film hydrophobic (water-repellent) coating to seal end grain	Edge Coat	→ Edge grain of CLT and MPP panels → Typically factory-installed	→ Beads water at the surface and reduces water absorption into the mass timber end grain, which protects panel edges and penetrations	→ Limited life span in-service, though it is suitable for short-term construction phase protection → Effectiveness depends on the roughness of the edge grain, thoroughness of the application, and thickness of the coating → Paraffin wax coatings are easily damaged → Only coatings intended for wood end grain are recommended (i.e., Top Coat products are not very effective on end grain)	L
SHEATHING AND JOINT PROTECTION	OSB with factory-applied water-resistive barrier coating or painted plywood	Coated Sheathing	→ NLT or DLT panels → Typically factory-installed	→ Repels water at the surface of the sheathing and reduces water absorption, which aids in easier surface management	→ Not uniform due to joints in between sheathing boards → Limited effective life span; easily worn out by construction activities and wear → Film forming and penetrating stain/sealer/paint products available in a range of chemistries → Properties (e.g., water repellency, vapor permeability, life span) dependent on product, chemistry, and exposure	L
SHEATHING AND JOINT PROTECTION	Vapor-impermeable or semi-permeable tape installed at joints in panels or sheathing	Taped Joints	→ Suitable for joints protection or sealing laps of compatible membranes → Site-installed	→ Water-shedding → Vapor impermeable or semi-permeable; allows limited drying or no drying through depending on product	→ Properties (e.g., water repellency, vapor permeability, life span) dependent on product, chemistry, and exposure → Adhesion to damp wood can be challenging; however, some tapes do bond to damp wood → Due to targeted application, water can often bypass tape at checks in wood → Wood must have moisture content below 16% prior to application to avoid trapping water beneath → Compatibility with different substrates varies by product	L
SHEATHING AND JOINT PROTECTION	Coated sheathing with vapor-impermeable or semi-permeable tape installed at joints	Coated Sheathing with Taped Joints	→ Wood sheathing over NLT or DLT panels → Some sheathing and tape systems used for permanent air barrier/vapor barrier functions	→ The combination of coated sheathing helps repel water at the surface, reduces absorption, and prevents water migrating into joints between sheathing boards → See Coated Sheathing and Taped Joints for additional properties	→ See Coated Sheathing and Taped Joints for additional properties	M
ACOUSTIC MAT	Vapor-impermeable loose-laid acoustic mat (with taped laps) being utilized as temporary moisture protection	VIMP LL Acoustic Mat	→ Floors with cementitious topping → Site-installed	→ May be water-shedding → Vapor-impermeable; does not allow drying through it → Loose laid; not adhered to the substrate, so it requires fastening or weighing down → Laps require sealing and/or taping	→ Range of available products, chemistries, geometries, and thicknesses → Any water bypassing the sheet can freely travel beneath the surface and become trapped → Wood must have moisture content below 16% prior to application to avoid trapping moisture beneath → Easily damaged by construction activities and traffic	L
ACOUSTIC MAT	Self-adhered vapor-impermeable acoustic mat (with sealed or taped laps) being utilized as temporary moisture protection	VIMP SA Acoustic Mat	→ Floors with cementitious topping → Site-installed	→ Water-shedding → Vapor impermeable; does not allow drying through it → Self-adhered to the substrate; laps are self-adhered but require sealant or additional membrane/tape and primer beyond self-adhesive to maintain water-shedding surface	→ Limited number of available products → Wood must have moisture content below 16% prior to application to avoid trapping water beneath → Easily damaged by construction activities and traffic → Adhered acoustic mats may have slightly less desirable acoustic properties than loose-laid products and must be factored into acoustic performance	M

Legend

Moisture Exposure Level

The moisture exposure level identifies the likelihood of a project's mass timber panel being exposed to wetting events that may occur in transport, in storage, or after placement. The descriptions below identify examples relative to the building schedule and duration of exposure; however, all factors that may contribute to moisture exposure need to be cumulatively considered.

LOW — Low Exposure
- → Roof above with perimeter protected with tarps or hoarding, *or*
- → Exposed during dry/drought season when precipitation is unlikely or limited enough to allow full drying of the mass timber.

MODERATE — Moderate Exposure
- → Roof above, but open at perimeter with periodic precipitation and limited risk of wind-driven rain.

HIGH — High Exposure
- → No roof above with precipitation expected during exposure duration, *or*
- → Roof above but open perimeter with wind-driven precipitation expected during exposure duration.
- → Extended exposure timeline that increases the risk of wetting potential.

Protection Robustness

Robustness level of the mass timber panel achieved by applying protective membranes or coatings.

L LOW — Low Protection Robustness
- → Coatings, loose-laid protection, or targeted protection.
- → Immediate action required in a wetting event.

M MODERATE — Moderate Protection Robustness
- → Water-shedding/vapor-permeable membrane.
- → Action required in a timely manner in a wetting event.

H HIGH — High Protection Robustness
- → Waterproof membrane with heat-welded laps.
- → No immediate action required in a wetting event.

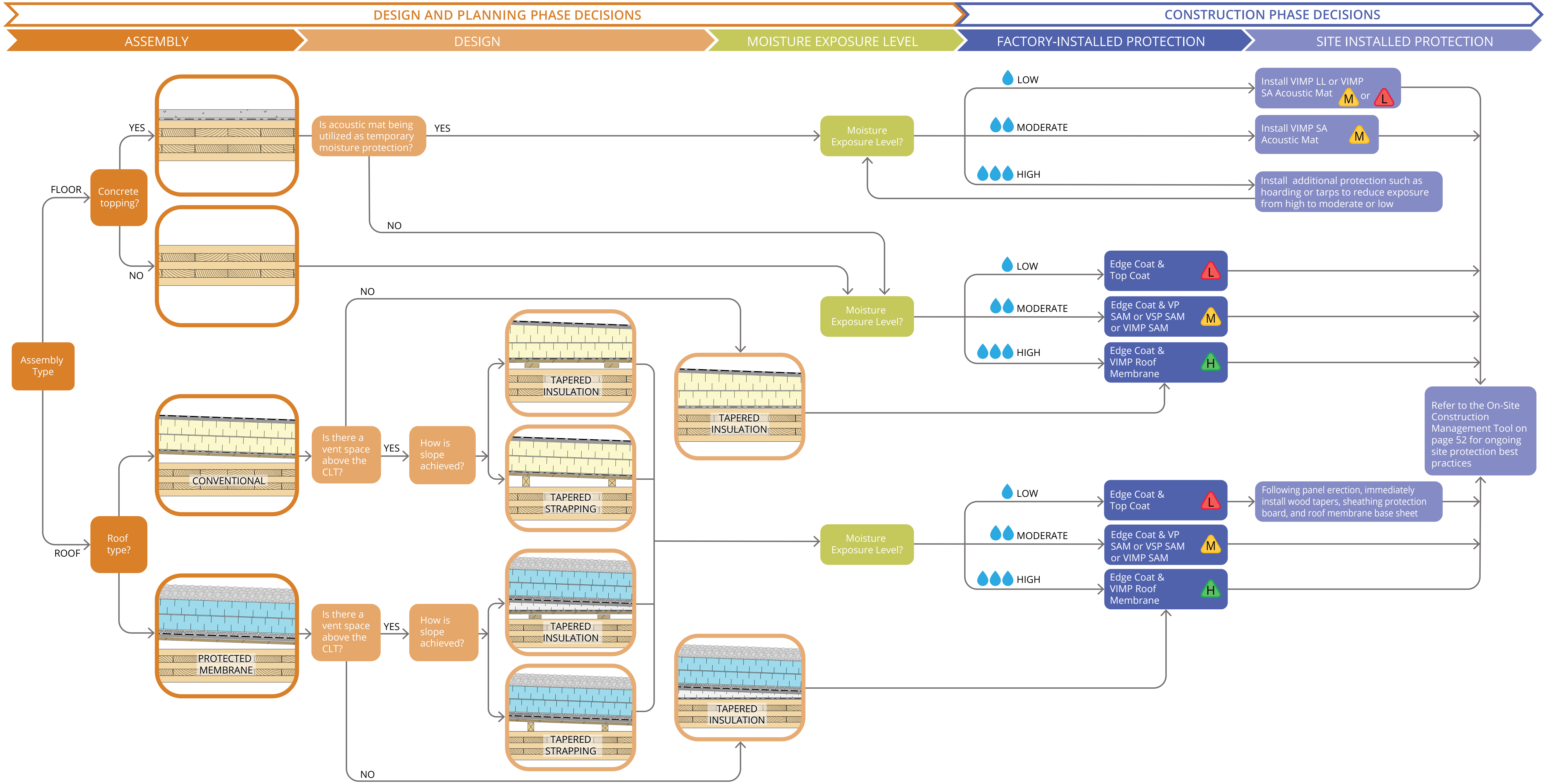
Risk Assessment Matrix

PROTECTION ROBUSTNESS \ MOISTURE EXPOSURE LEVEL	LOW	MODERATE	HIGH
L LOW	OPTIMAL	CAUTION	AVOID
M MODERATE	✓	OPTIMAL	CAUTION
H HIGH	✓	✓	OPTIMAL

Moisture Management Planning Design Tool 1

CLT Roof and Floor Assemblies

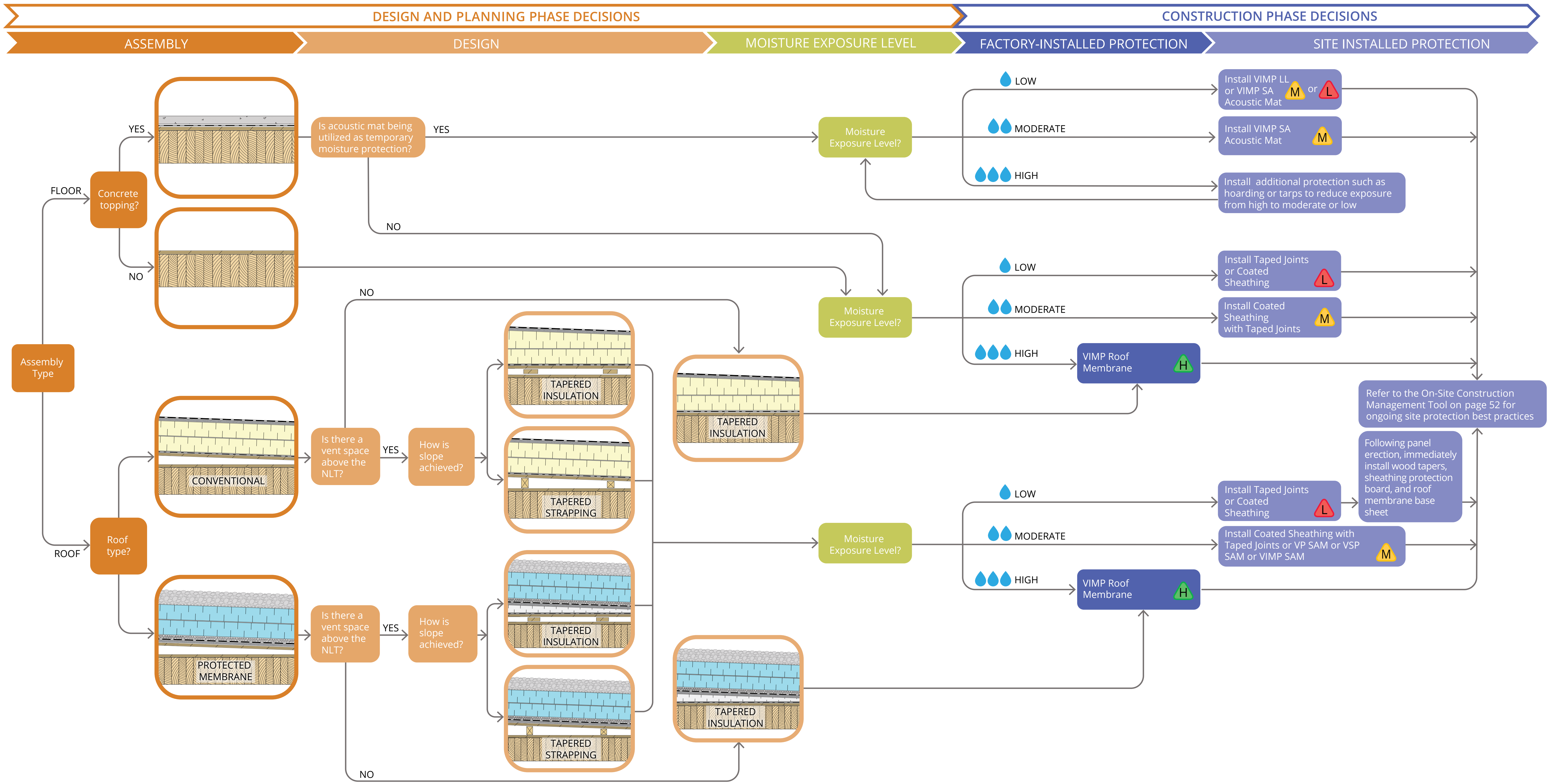
All protection levels and exposure combinations presented in this tool are deemed to be at least an optimal risk level.
Refer to Risk Assessment Matrix on page 29.



Moisture Management Planning Design Tool 2

NLT and DLT Roof and Floor Assemblies

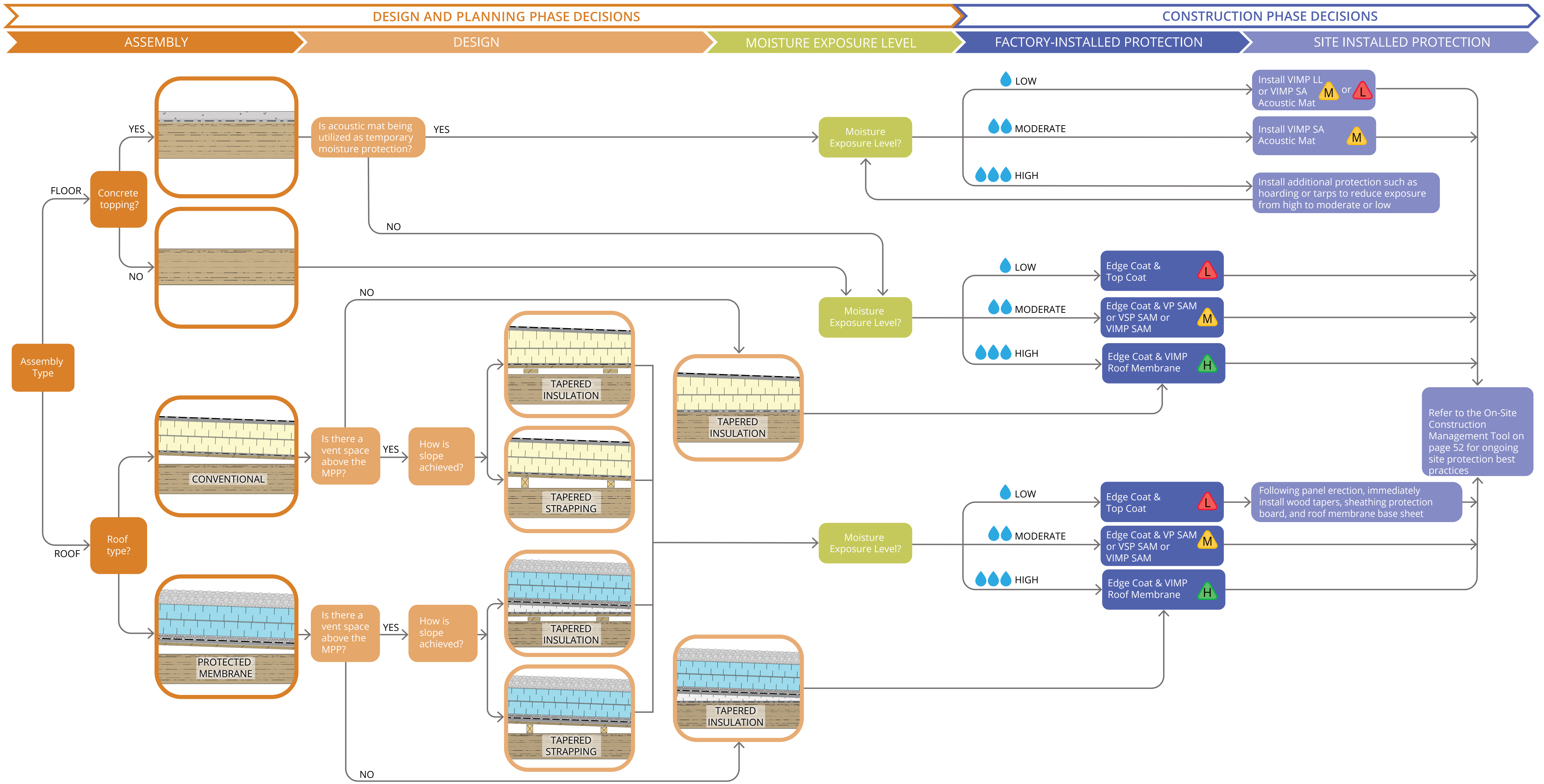
All protection levels and exposure combinations presented in this tool are deemed to be at least an optimal risk level.
Refer to Risk Assessment Matrix on page 29.



Moisture Management Planning Design Tool 3

MPP Roof and Floor Assemblies

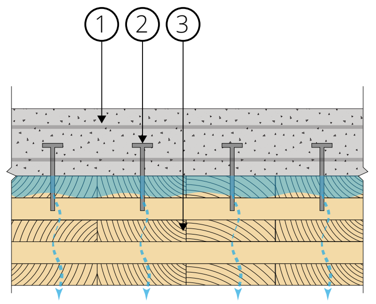
All protection levels and exposure combinations presented in this tool are deemed to be at least an optimal risk level.
Refer to Risk Assessment Matrix on page 29.



Timber-concrete composite CLT floor with shear connectors installed prior to concrete pour.

TIMBER-CONCRETE COMPOSITE FLOOR AND ROOF ASSEMBLIES

Timber-concrete composite (TCC) assemblies may be used on either floor or roof assemblies. A TCC assembly is comprised of a reinforced concrete topping mechanically attached to a horizontal mass timber panel with shear connectors (see Figure 17) such as screws, "Nelson®" type studs, and high-strength bolts. This type of assembly is often chosen to meet seismic requirements but has the additional benefit of enhancing the acoustical, fire resistance, and structural performance of the mass timber. A TCC assembly may be either pre-cast or poured-in-place; however, this guide focuses on a poured-in-place application.



Legend

1. Structural concrete topping
2. Shear connectors
3. CLT floor or roof panel

Figure 17 *Timber-concrete composite assembly. The installation of a temporary membrane in addition to the topping essentially eliminates drying of the topside of the mass timber panel; therefore, the mass timber needs to be confirmed dry (i.e., less than 16% moisture content) prior to the placement of a topping.*

The concrete topping mix used for TCC systems has less excess water compared to self-leveling cementitious screeds or gypsum concrete. However, there is a limit to the drying capability of mass timber, which is affected by concrete thickness, mass timber thickness, and weather. Pouring of wet concrete introduces water to the mass timber panels. When evaluating any design that may use a composite assembly, consider the following:

- If the mass timber is wet prior to a concrete pour, the moisture in the concrete can exceed the mass timber's safe storage capacity, resulting in elevated and risky moisture levels at the wood-to-concrete and shear connection interface.
- If additional water is introduced to concrete following the pour (such as a rainfall event), the excess moisture will eventually make its way to the mass timber panel below.

Both of these cases present a high risk for trapping moisture within the assembly, increasing the likelihood for long-term moisture damage. Thus, great care must be taken to minimize the introduction of additional moisture to the TCC assembly before and after the placement of the topping.

For TCC floors, if the moisture exposure level of a floor assembly is anticipated to be low, moisture protection methods may not be necessary. However, in a TCC roof assembly, the concrete topping will eventually be covered by an air and vapor barrier, thus significantly limiting the ability for moisture to dry through the topside of the assembly. As a result, it is recommended that appropriate moisture protection be installed on the mass timber panel. The images shown in Figure 18 illustrate the results of a two-dimensional hygrothermal modeling exercise and demonstrate the need for moisture protection to separate the concrete topping from the mass timber components at both the panel top and, most critically, the panel edge.

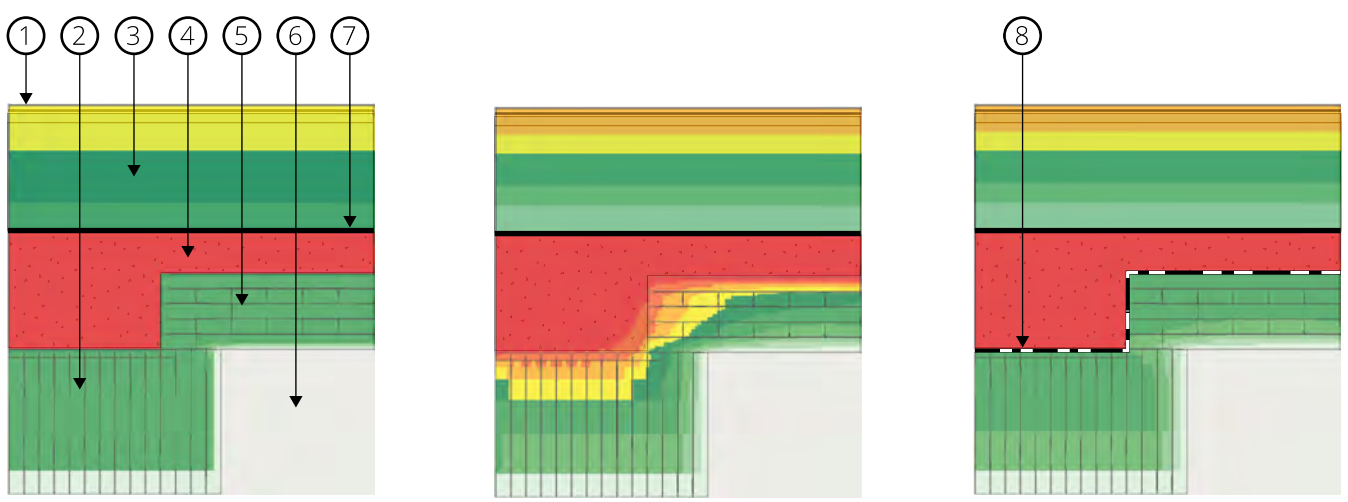
Additionally, covering the concrete reduces the rate of the concrete's ability to dry. Thus, it is best practice to pour concrete for composite floor assemblies after the enclosure walls are in place and the floor above is installed (with penetrations sealed); it is also best to avoid covering the concrete during the curing process.

If the concrete topping of a TCC roof is poured during the dry season with no anticipated precipitation, the recommended approach is to delay the installation of the membranes over the top of the concrete (weather permitting) to allow the concrete to expel as much moisture as possible. Any precipitation on the concrete negates the drying benefit of delaying the membrane installation; therefore, the team should continuously monitor the weather forecast. If precipitation is anticipated during the concrete pour, the concrete will need to be protected by tenting or other appropriate protection measures. **It is strongly advised to not install TCC assemblies when the anticipated moisture exposure level is determined to be high.**

The need for moisture protection in TCC assemblies depends on the anticipated moisture exposure level (as discussed on page 15), whether the assembly is a floor or a roof. Table 3 describes recommended protection methods for TCC assemblies. When the moisture exposure level necessitates a protective membrane, it is recommended to install a vapor-impermeable roofing membrane with heat-fused laps prior to shear connector installation and to detail around the connectors once installed. If the shear connectors are already installed, it is recommended to use a liquid-applied, vapor-impermeable membrane. Shear connectors in a TCC assembly prevent a perfectly uniform waterproofing, so some water is expected to reach the panel; therefore, standing water should still be avoided.

Legend

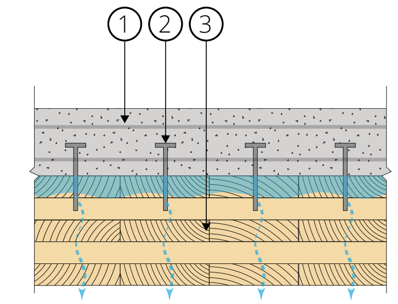
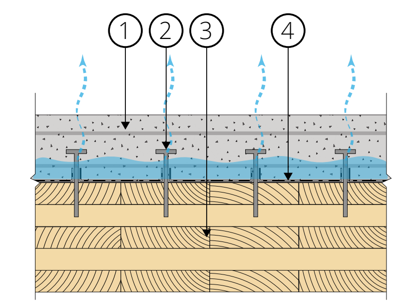
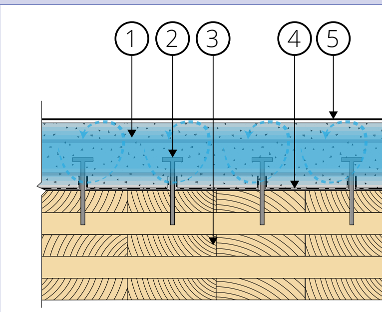
1. Roof membrane and cover board
2. Glulam beam
3. Insulation
4. Concrete topping
5. CLT roof panel
6. Building interior
7. Air and vapor barrier
8. Vapor-impermeable membrane



a) b) c)

Figure 18 *Two-dimensional hygrothermal model of TCC roof assembly at a column-to-panel interface where the moisture level is visualized from red (wet) to green (dry) to light green (very dry). The conditions shown are a) initial conditions immediately after a concrete pour, b) moisture migration into the wood beam and column after 12 months if no moisture protection was provided between the mass timber and concrete topping, and c) the mass timber elements maintained in a dry condition when a vapor-impermeable membrane is installed on the top and edge surfaces of the mass timber.*

Table 3 *On-Site Moisture Management Recommendations for Timber-Composite Concrete Roof and Floor Assemblies*

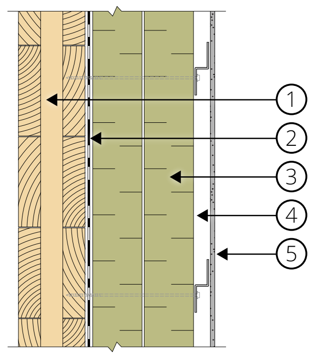
	Moisture Exposure Level	Recommended Moisture Protection	Assembly	
	FLOOR ASSEMBLY			
FLOOR WITHOUT MASS TIMBER MOISTURE PROTECTION	Low moisture exposure level. ***AND*** No panel edge exposure to concrete.	No protection		**Legend** 1. Structural concrete topping 2. Shear connectors 3. CLT floor panel
	Pre-pour considerations: Mass timber to be <16% moisture content prior to pouring concrete. Avoid pouring concrete until the enclosure walls are in place and the floor or roof above is installed (with penetrations sealed).			
FLOOR WITH MASS TIMBER MOISTURE PROTECTION	Low to moderate moisture exposure level. ***OR*** Panel edge of mass timber will be exposed to concrete during pour.	Vapor-impermeable membrane on surface. If the panel edge of mass timber is exposed to concrete, install vapor-impermeable membrane on edges.		**Legend** 1. Structural concrete topping 2. Shear connectors 3. CLT floor panel 4. Vapor-impermeable membrane
	Pre-pour considerations: Mass timber to be <16% moisture content prior to installing protection. Shear connectors will penetrate a membrane and increase the risk for water intrusion at connection points; thus, limit standing water. Avoid pouring concrete until the enclosure walls are in place and the floor or roof above is installed (with penetrations sealed).			
	ROOF ASSEMBLY			
TCC ROOF	Low to moderate moisture exposure level.	Vapor-impermeable liquid-applied membrane on mass timber. ***AND*** Watertight vapor barrier with consideration for adhesion to damp concrete (e.g., vented SBS base sheet) as recommended by the roofing supplier.		**Legend** 1. Structural concrete topping. 2. Shear connectors 3. CLT floor or roof panel 4. Vapor-impermeable membrane 5. Watertight vapor barrier
	Pre-pour considerations: Mass timber to be <16% moisture content prior to installing on-site protection. Shear connectors will penetrate a membrane (where used) and increase the risk for water intrusion at connection points; thus, limit standing water. **Post-pour considerations:** Install site protection of a partially adhered vented membrane for adhesion to damp concrete.			

* Refer to page 15 for Moisture Exposure Levels. It is strongly advised to not install TCC assemblies in unprotected conditions or high exposure levels.

Origine, Quebec City, Canada (Yvan Blouin Architecte). Photo credit: Stephane Groleau

WALL ASSEMBLIES

Wall assemblies include exterior insulated (see Figure 19), interior-insulated, or split-insulated wall assemblies that incorporate the best practices design guidance outlined in the *Mass Timber Building Enclosure Best Practice Design Guide*. These assemblies include products and systems appropriately located to satisfy the need for and continuity of air, water, thermal, and vapor control layers, and that promote panel drying and drainage of the cladding system.



Legend

1. Mass timber panel
2. Air barrier and water-resistive barrier
3. Exterior insulation
4. Ventilated and drained cavity
5. Cladding

Figure 19 *Exterior-insulated CLT wall assembly.*

The anticipated moisture exposure level for wall assemblies is typically low to moderate depending on the season in which panels will be installed and if additional moisture strategies such as tarps are used. However, high moisture exposure levels may need to be considered if panel transport and storage cannot provide appropriate seasonal protection or excessive drainage and runoff is directed at wall areas from horizontal assemblies above.

For all moisture exposure levels, protecting mass timber wall panels from wetting during the construction phase includes either factory- or site-installed application of WRB membranes. Factory-installed WRB membranes are applied during the manufacturing process of the panels and prior to the panels' delivery to the project site. This approach offers the benefit of protection during shipping and on-site staging and can reduce the building dry-in period. Once the mass timber panels are erected on-site, the exposed faces and edges of the mass timber wall panel (including the panel joints, rough openings, and penetrations) receive additional protection such as membranes or hoarding.

If factory installation of WRB membranes is not feasible, then a WRB membrane must be installed in parallel with, or shortly following, the erection of the mass timber panels on-site. Mass timber exterior walls should be protected as soon as possible with a WRB membrane, preferably when the panels are dry.

Whether factory- or site-installed, and regardless of exposure level, a vapor-permeable WRB membrane is desirable to allow the wood to dry while preventing further water absorption. Applying a vapor-impermeable membrane over mass timber panels that are already wet can be problematic for two reasons: drying of the timber will be impeded, and the membrane may not adhere well to the wet wood. If the panels are wetted before the protective membrane is applied, it may be necessary to provide temporary shelter above the wall assembly to dry the panels.

The exposed edges of the mass timber wall panel at joints, rough openings, and penetrations, such as those shown in Figure 20, consist of horizontal, unsloped surfaces that are unable to readily shed water. These details are at the highest risk for moisture intrusion; therefore, these details have a higher moisture exposure level than field-of-wall areas and require appropriate and effective moisture protection methods during the construction phase to minimize wetting risks. To provide moisture protection until the remaining wall assembly layers are installed, the following measures should be taken:

- Install isolated tarping of openings, taking care to not damage any finishes that will remain exposed during in-service conditions.
- Pre-strip rough openings and penetrations with WRB membranes/flashings such as those shown in Figure 21. Plans must be made to clear any ponding water (including snow and ice) from horizontal areas covered with vapor-permeable membranes in a timely manner during construction.
- Separate the mass timber wall from concrete surfaces using a vapor-impermeable membrane.
- Elevate the mass timber walls a sufficient elevation above grade and provide additional protection of the wall base to prevent the mass timber from wicking water.
- Divert water draining from floor and roof assemblies and from wall areas above using appropriate drainage tactics and hoarding.
- Actively remove ponding water that may develop around wall areas using vacuums, squeegees, and other water-removal tactics.

Even with these precautions, it is likely that mass timber panels will experience some wetting during transport or construction, and that they will be installed with built-in moisture in localized areas. Therefore, the most durable wall design strategies will use vapor-permeable materials to allow excess moisture to escape the assembly, thereby minimizing damage and deterioration. In cases where exterior materials with low vapor permeance are selected, the mass timber panels should be dry (i.e., with a moisture content below 16%) prior to their installation.

Project Documents

The decisions made during Step 1 will be memorialized in the mass timber project drawings and specifications. Items to include in these documents that are of particular interest for the mass timber building include:

- Mass timber assembly mock-up requirements, including the required moisture protection methods (e.g., protection type, joint treatment, and common building interfaces)
- Third-party review requirements
- Allowable limits for wetting of the mass timber during construction
- On-site monitoring and testing requirements
- Requirements for the general contractor and/or mass timber subcontractor to provide and follow a written moisture management plan
- Clear depiction of moisture protection methods on drawings, including at common building interfaces

Figure 20 *CLT wall panels with exposed penetrations and rough openings prior to on-site application of a WRB membrane.*

Figure 21 *CLT wall panels with factory-installed air barrier and WRB membrane and window rough opening membranes prior to on-site installation of windows and panel joints.*

STEP 2 - DEVELOP A CONSTRUCTION PHASE MOISTURE MANAGEMENT PLAN

Drains in the mass timber roof structure are connected to discharge to the building exterior and away from wall areas, minimizing the risk that water will reach the floor below.

ON-SITE CONSTRUCTION PHASE MOISTURE MANAGEMENT PLAN

Successfully managing the moisture exposure of mass timber components depends on the designer implementing features to prevent moisture exposure at the earliest stages of the design phase. Effective moisture management is equally contingent on the contractor implementing a moisture management plan throughout the construction phase. The following pages provide the contractor with guidance for developing a construction phase moisture management plan, from pre-delivery to project completion, to prepare their team for managing construction phase moisture and possible unexpected exposure risks.

Contractors can use the On-Site Construction Moisture Management Tool, shown on page 52, during the following construction stages: pre-delivery, delivery, storage, installation, and post-installation. The tool is applicable for vertical and horizontal wall, floor, and roof assemblies (including TCC floors and roofs). The tool includes a pre-delivery checklist that outlines the contractor's key tasks to complete prior to the delivery of mass timber to the project site.

> *Effective moisture management is equally contingent on the contractor implementing a moisture management plan throughout the construction phase.*

Figure 22 *A temporary drain connection at a mass timber roof panel.*

The contractor's plan will need to be customized to the project-specific design and weather conditions, including items such as these:

- **Schedule and delivery plans:** This may include plans for just-in-time delivery to minimize staging needs and moisture exposure risks; and plans to schedule installers (i.e., waterproofing subcontractor or roofing subcontractor) at the time of panel installation to ensure moisture protection membrane detailing work is performed in parallel or shortly following placement.
- **Moisture protection methods:** Methods may be articulated as written descriptions or through redlines on drawings to document the methods that will be implemented for protecting panels, common building details, and joints (see Figure 22).
- **Water removal plans:** These plans may include instruction on when an on-site active water management team will be implemented and methods to remove standing water from unsloped mass timber areas using mops, squeegees, and shop vacuums (see Figure 23).
- **Checklists:** These checklists may include daily and weekly checklists to monitor drainage and moisture content or pre-pour and post-pour checklists for assemblies with concrete toppings (see Figure 24).
- **Moisture exposure response:** This may include a strategy to dry the mass timber if the moisture content exceeds the recommended limits and what resources will be at the ready on-site for implementation if needed (see Figure 25). Plans will recognize that the overall depth of the mass timber and the extent of water intrusion (should it occur) will determine the most effective drying strategy.

The contractor may also want to consider adding a contingency to the project budget to cover items such as tenting, mechanical drying, moisture stain removal, and moisture monitoring in case changes to the moisture management plan are required to address unforeseen circumstances such as moisture exposure episodes or weather or construction related delays.

The On-Site Construction Moisture Management Tool, shown on page 52, is meant to serve as a self-guided template or starting point for contractors to develop their own project-specific moisture management plan.

Refer to the Moisture Management Process Case Study presented in this guide to see how the On-Site Construction Moisture Management Tool can be used to guide construction phase activities and for an excerpt of the Case Study specific construction phase moisture management plan.

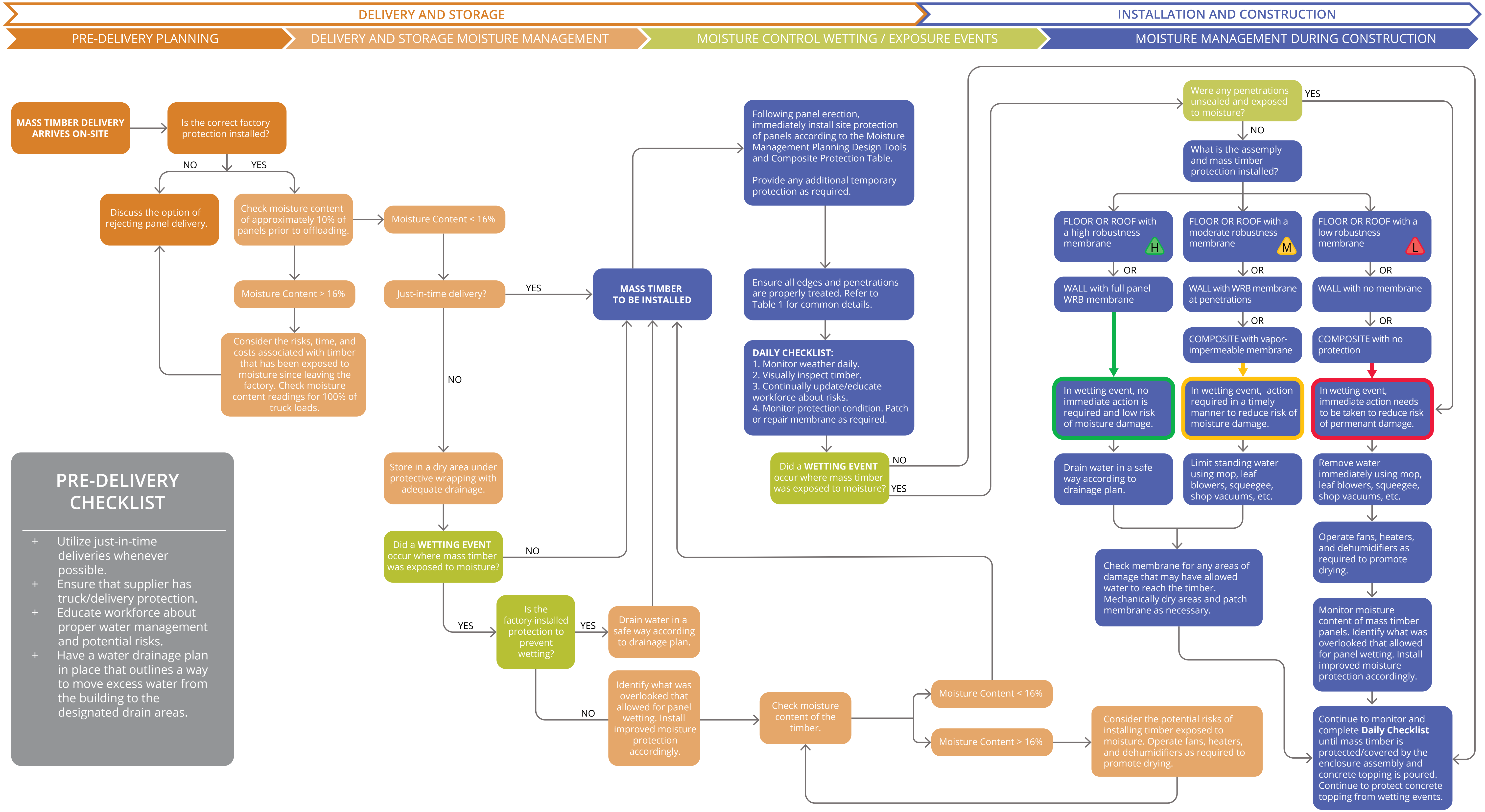
Figure 23 *A worker removes standing water from a wood-framed roof assembly using a squeegee.*

Figure 24 *Moisture content reading taken at the base of a mass timber column that has been exposed to moisture; regular readings are part of the moisture exposure response plan.*

Figure 25 *Heater and dehumidifier used in response to a moisture exposure event.*

On-Site Construction Moisture Management Tool

Mass Timber Management from Pre-Delivery to Project Completion



PRE-DELIVERY CHECKLIST

- Utilize just-in-time deliveries whenever possible.
- Ensure that supplier has truck/delivery protection.
- Educate workforce about proper water management and potential risks.
- Have a water drainage plan in place that outlines a way to move excess water from the building to the designated drain areas.

STEP 3 - EXECUTE THE DESIGN AND MOISTURE MANAGEMENT PLAN

An engineer performs a site visit to monitor the moisture content of mass timber components during construction.

CONSTRUCTION PHASE PROJECT EXECUTION

During Step 3: Execute the Design and Moisture Management Plan, the design of the mass timber building and its enclosure elements come to life. The careful planning performed by the design, construction, and development teams are put into action, and the evaluation and monitoring of the mass timber components of the building's assemblies continue through to occupancy.

It is in Step 3 that the team reconvenes at the project site to determine whether the moisture management plans are being implemented as developed. The team also considers whether changes to construction phase factors—such as schedule, labor and material availability, and seasonal weather—are conforming to the anticipated factors that guided their decisions during the Step 1 assessment.

Should these factors change and the actual moisture exposure level exceeds the anticipated moisture exposure level, contingency plans will be put into action. These contingency plans may include the need to implement more active water removal tactics, tenting, drying, or the application of a more robustness moisture protection method.

The project case study included in this guide provides examples of scenarios that may arise during Step 3 and how the project team may either implement the existing plan or adapt their plan to meet the project's needs.

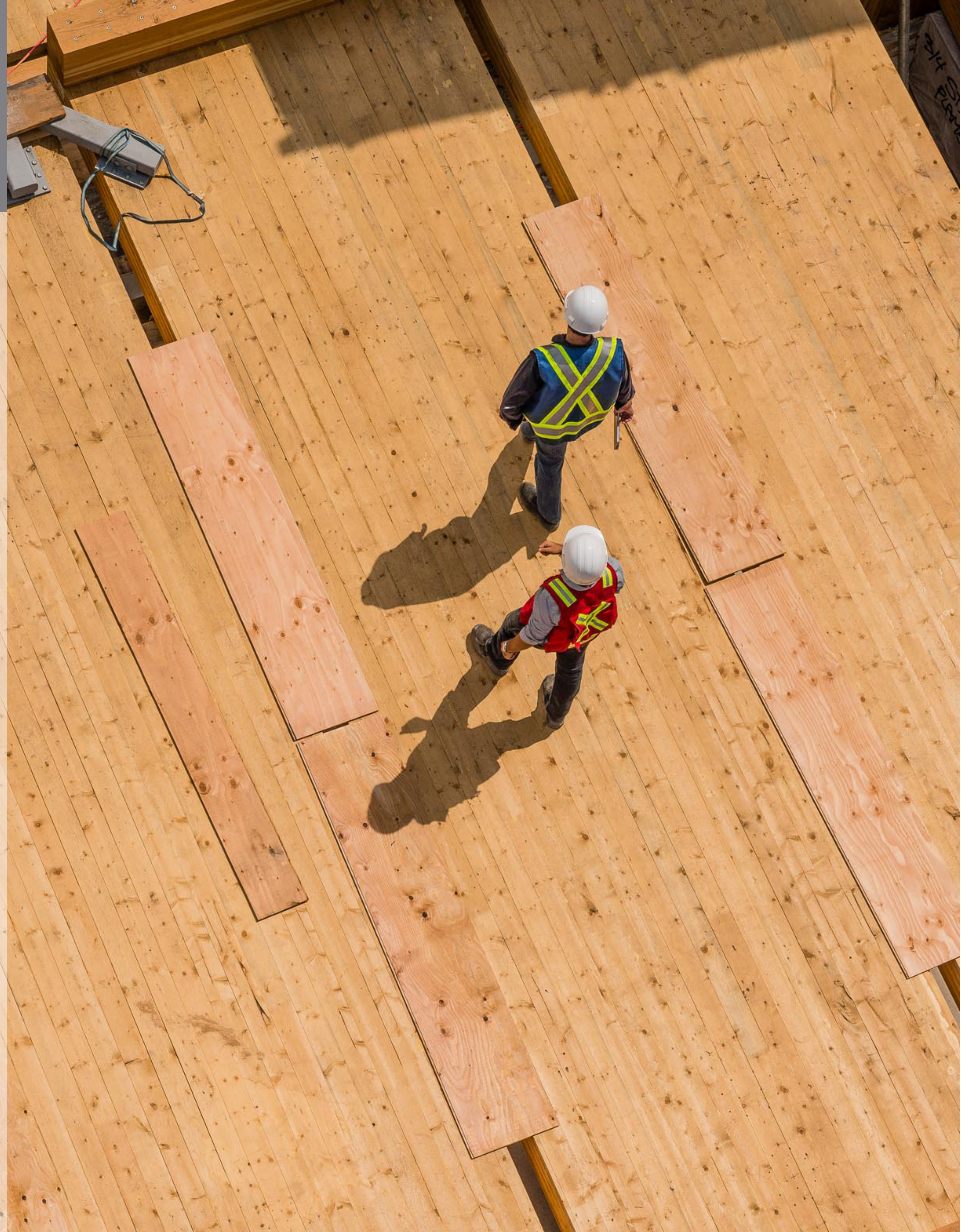
⚠ Post-Installation: Drying of Mass Timber Panels

Post-installation drying of mass timber components is identified as an emergency response resulting from wetting that exceeds the recommended moisture content limits (post-installation drying should not be considered a normal step in the construction of a mass timber building). When moisture content exceeds the recommended limits established during the project's moisture management planning, the drying strategy devised during the planning phase of the project is implemented.

When drying is implemented, the rate of drying for large dimension wood panels is controlled to minimize checking. Active heating and dehumidification, in combination with ventilation, is used in lieu of natural ventilation for more effective drying of mass timber panels. Should membranes exist on the mass timber panels, these membranes should be removed whenever possible to allow drying of both the top and bottom sides of the timber panels. The additional tactic of tenting may need to be considered if the drying process needs to be expedited.

CASE STUDY - MOISTURE MANAGEMENT PROCESS

A mass timber floor structure.



FLOOR AND ROOF CASE STUDY

This case study explores how the three-step moisture management process, including the tools and information provided throughout this guide, can be applied to a project with mass timber floor and roof assemblies. The case study demonstrates how multiple moisture protection and risk assessment options are identified; an excerpt of an example moisture management plan; and construction phase scenarios that present both expected and unexpected moisture exposure events and how the project team could respond.

1 STEP 1 - COMPLETE A MOISTURE RISK ASSESSMENT FOR MASS TIMBER ASSEMBLIES

The floor and roof moisture management planning design tools on page 32 through page 37 and the Risk Assessment Matrix on page 29 can be used to determine the best suited protection for a project to achieve "optimal" risk. However, achieving the optimal risk level does not mean that the assembly is risk free; rather, the optimal risk level means the moisture exposure level and protection robustness are balanced. The level of risk a project team is willing to take on may vary. To complete a meaningful risk evaluation, the project team must begin planning early and gathering stock of all the relevant information.

Step 1 Case Study Description

An architect designed an 8-story building located in the Pacific Northwest. The building has a concrete elevator core, and floors 2 through 8 and the roof are CLT (see Figure 26). The CLT floors are designed with a cementitious topping with an acoustic mat between the CLT and topping. The CLT roof is a conventional assembly with a tapered insulation package and no vented cavity.

The case study project team began the moisture management process early. They considered what design decisions had been made thus far and how those decisions influenced the protection options considered. The information on the next page describes the risk assessment process performed by the case study team and the moisture protection options that were considered for both the floor and roof assemblies.

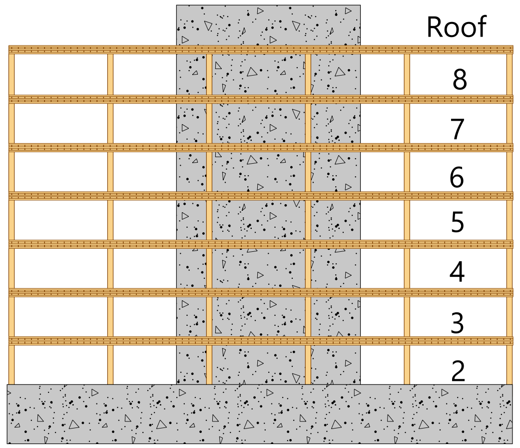


Figure 26 *Sketch of case study mass timber building.*

Floor Moisture Management Protection

Developed from Assembly Design Tool 1 and Table 2 Moisture Protection Types

DESIGN AND PLANNING PHASE CONSIDERATIONS

The assembly design was finalized and the project team was limited to membrane and on-site protection options to manage moisture.

FLOOR ASSEMBLY CONSIDERATIONS

- The acoustic mat that would be used is mesh; therefore, it does not provide water protection.
- The concrete topping would add moisture to the mass timber floor panel.

MOISTURE EXPOSURE LEVEL CONSIDERATIONS

- The construction schedule anticipated 3 weeks from panel installation before the enclosure walls would be installed.
- Floor installations would be exposed for approximately 1.5 weeks until the next floor level was installed.
- The floors were scheduled to be complete between the end of summer and start of fall, and some rain was expected.

CONSTRUCTION PHASE CONSIDERATIONS

Based on the moisture exposure levels defined in this guide, it was determined that the CLT roof panels had a moderate (💧💧) exposure level.

Given the moisture exposure level, high protection robustness (M) was identified to achieve optimal risk level.

FACTORY-INSTALLED PROTECTION CONSIDERATIONS

- The option to factory-install a membrane was limited to the types of protection that the panel manufacturer had experience with and the factory was currently set up to support.
- If factory-installed membrane was not an option, Top and Edge Coat protection (red) could be installed in the factory for short-term protection until a membrane was installed on-site.

SITE-INSTALLED PROTECTION CONSIDERATIONS

- Site-installed membranes would require immediate application to reduce wetting risk for the mass timber.
- If the CLT was to be exposed to moisture, the membrane application would need to be delayed until the CLT was dried to 16% moisture content or less.

Risk Assessment Matrix

PROTECTION ROBUSTNESS	MOISTURE EXPOSURE LEVEL: LOW	MODERATE	HIGH
L LOW	✓ OPTIMAL	? CAUTION	✕ AVOID
M MODERATE	✓	✓ OPTIMAL	? CAUTION
H HIGH	✓	✓	✓ OPTIMAL

Floor Moisture Management Protection (continued)

Developed from Assembly Design Tool 1 and Table 2 Moisture Protection Types

NARROWING DOWN THE OPTIONS

After taking stock of all relevant information that could impact the protection options for the CLT floor assembly and reviewing the potential membranes in the Moisture Protection Types table, the project team narrowed their options down to three possibilities as illustrated in Figure 27 and described below. A detailed description of each option is included on page 64.

Option 1: Factory-Installed VIMP SAM

Option 1 was the optimal protection scenario, taken directly from Assembly Design Tool 1. Given the floor assembly and the moisture exposure level, a factory-installed membrane of high robustness was identified to achieve an optimal risk level.

Option 2: Site-Installed VIMP SAM

Option 2 is the same membrane as Option 1. However, the factory manufacturing the CLT panels is unsure whether schedule constraints will allow for a factory-installed membrane to be installed prior to shipping. If the project team was to achieve a final optimal risk level, they would need to consider having only a Top and Edge Coat installed when the panels are delivered and site installation of the moisture protection membrane.

Option 3: Site-Installed Taped Joints

Due to budgeting reasons, the project team considered taking on a higher risk and using a method that provided low protection robustness (L). Option 3 considered taping joints and not installing a membrane. The cost savings of using a less robust material compared to potential costs of a moisture contingency plan would be evaluated prior to making a final decision.

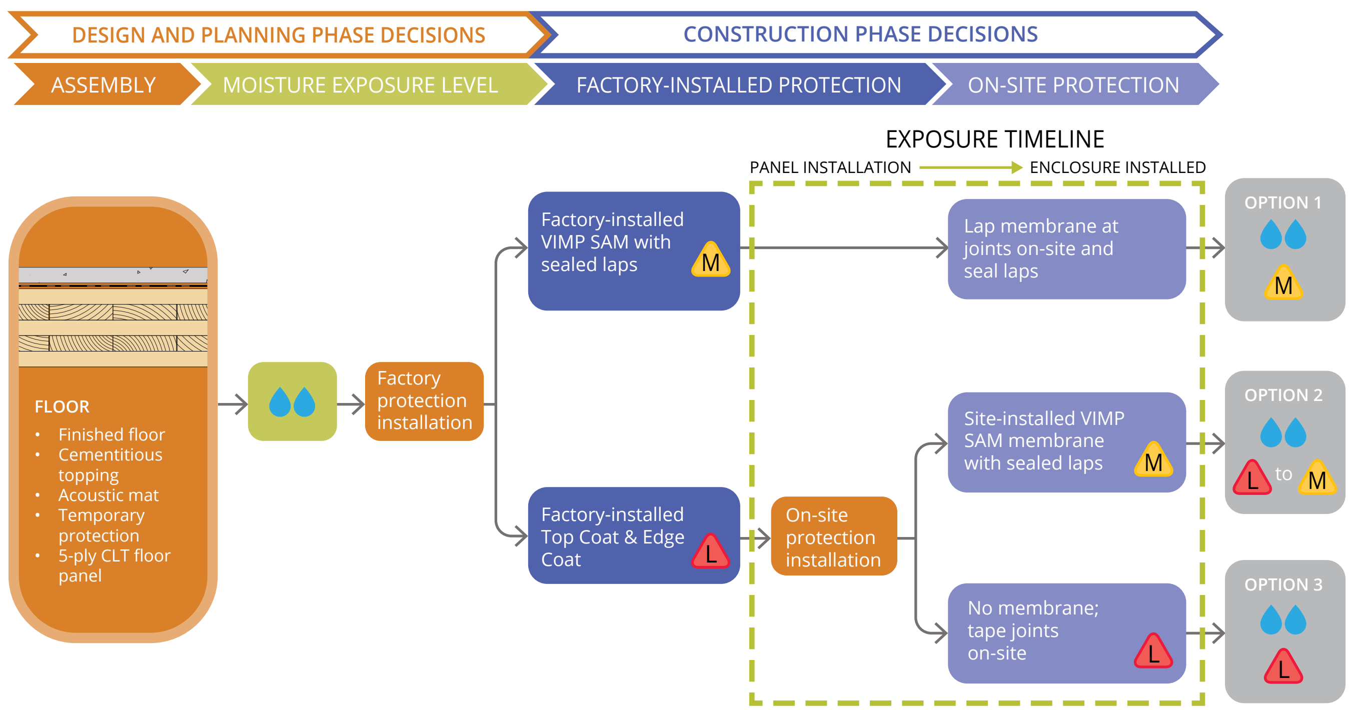


Figure 27 *Case study moisture management planning flowchart for a CLT floor with cementitious topping showing three options.*

RISK ASSESSMENT: Floor Moisture Management Protection

OPTION 1

M

OPTION 1 Optimal Factory-Installed Membrane

Vapor-impermeable self-adhered membrane with sealed laps

Moisture Exposure Level: Moderate
Membrane Robustness Level: Moderate
Risk Assessment: Optimal

Considerations:

→ The membrane robustness level is moderate; therefore, in a wetting event, action would need to be taken in a timely matter to avoid standing water. There is a risk of standing water migrating under the membrane laps.

→ When the CLT floor panels are installed, the membrane will need to be lapped and sealed at the joints between the panels on-site and an additional membrane will need to be installed over the drag struts.

OPTION 2

L to M

OPTION 2 Factory-Installed Membrane not an Option

Factory-installed water-repellent sealer on panel surface (Top Coat) and high build paraffin wax on the end grain (Edge Coat) + site-installed vapor-impermeable self-adhered membrane with sealed laps (VIMP SAM)

Moisture Exposure Level: Moderate
Membrane Robustness Level: Low upon panel delivery. Moderate after membrane is installed.
Risk Assessment: Medium risk upon panel delivery (Caution). Optimal risk after membrane is installed.

Considerations:

→ Prior to installation of the membrane, the panel would have a Top Coat and edge sealer with a low protection robustness. In a wetting event, immediate action would be required and mechanical drying or delay of the membrane installation may be required.

→ The membrane is vapor impermeable so there would be limited drying potential after the membrane is installed. The moisture content of the mass timber would need to be less than 16% before membrane installation.

→ After membrane installation, the protection robustness level would be Moderate; therefore, in a wetting event, action would need to be taken in a timely matter to avoid standing water. There is a risk of standing water migrating under the membrane laps.

OPTION 3

L

OPTION 3 Taking On Greater Risk

Factory-installed water-repellent sealer on panel surface (Top Coat) and high build paraffin wax on the end grain (Edge Coat) + site-installed vapor-impermeable tape at the joints and splines

Moisture Exposure Level: Moderate
Membrane Robustness Level: Low
Risk Assessment: Moderate risk (Caution)

Considerations:

→ Protection robustness level would be Low throughout the entire exposure duration; therefore, in a wetting event, immediate action would be needed and mechanical drying or delay of the concrete pour may be required. If standing water was not removed, it could absorb into the CLT and there is a risk of standing water migrating under the tape.

→ The tape is vapor impermeable, so there would be no drying potential at joints after the tape is installed.

→ The moisture content would need to be less than 16% before tape installation and before the cementitious topping is poured.

Conventional Roof Moisture Risk Assessment

Developed from Assembly Design Tool 1 and Table 2 Moisture Protection Types

DESIGN AND PLANNING PHASE CONSIDERATIONS

The assembly design was finalized and the project team was limited to membrane and on-site protection options to manage moisture.

ROOF ASSEMBLY CONSIDERATIONS

- The roof assembly design had no vented cavity, so moisture in the mass timber would not have the ability to dry to the topside after the roof assembly layers were installed.
- The moisture protection membrane that would protect the mass timber in the roof assembly would also serve as the air/vapor barrier in the final roof assembly. This membrane would be required to be approved by the manufacturer for warranty considerations, such as wind uplift and material compatibility.

MOISTURE EXPOSURE LEVEL CONSIDERATIONS

- The construction schedule anticipated 2 months between panel installation and final roof installation.
- The roof was scheduled to be completed in autumn, and rain is expected.
- There was no overhead protection, such as tenting, planned for the project.

CONSTRUCTION PHASE CONSIDERATIONS

Based on the moisture exposure levels defined in this guide, it was determined that the CLT roof panels have a high (💧💧💧) exposure level. Given the moisture exposure level, high protection robustness (H) is recommended to achieve optimal risk level.

FACTORY-INSTALLED PROTECTION CONSIDERATIONS

- The option to factory-install a membrane was limited to the types of protection that the panel manufacturer had experience with and the factory was currently set up to support.
- If a factory-installed membrane was not an option, Top and Edge Coat protection (red) could be installed in the factory for short-term protection until a membrane was installed on-site.

SITE-INSTALLED PROTECTION CONSIDERATIONS

- Site-installed membranes would require immediate application to reduce wetting risk for the mass timber.
- If the CLT was to be exposed to moisture, the membrane application would need to be delayed until the CLT was dried to 16% moisture content or less.

Risk Assessment Matrix

PROTECTION ROBUSTNESS	MOISTURE EXPOSURE LEVEL: LOW	MODERATE	HIGH
L LOW	✓ OPTIMAL	? CAUTION	✗ AVOID
M MODERATE	✓	✓ OPTIMAL	? CAUTION
H HIGH	✓	✓	✓ OPTIMAL

Conventional Roof Moisture Risk Assessment (continued)

Developed from Assembly Design Tool 1 and Table 2 Moisture Protection Types

NARROWING DOWN THE OPTIONS

After taking stock of all relevant information that could impact the protection options for the CLT roof assembly and reviewing the potential membranes in Moisture Protection Types table, the project team narrowed their options down to three possibilities as illustrated in Figure 28 and described below. A detailed description of each option is included on page 67.

Option 1: Factory-Installed VIMP Roof Membrane

Option 1 was the optimal protection scenario, guided by Assembly Design Tool 1. Given the roof assembly and the moisture exposure level, a factory-installed membrane of high robustness was identified to achieve an optimal risk level.

Option 2: Site-Installed VIMP Roof Membrane

Option 2 was identified as the same membrane as Option 1, but the factory responsible for manufacturing the CLT panels was unsure if factory installation of the moisture protection membrane could occur within the factory due to schedule constraints. If the project team was to still achieve an optimal risk level, they would need to consider a factory-installed Top and Edge Coat and site-installed membrane.

Option 3: Site-Installed VIMP SAM

Due to budgeting reasons, the project team considered taking on greater risk by using a membrane that provided moderate protection robustness (M) such as VIMP SAM. The VIMP SAM was selected from the other moderately robust membranes identified in the Moisture Protection Types (Table 2) because the VIMP SA membranes could serve as the air barrier membrane for the final roof assembly and had been tested for adhesion/uplift capacity in roof assemblies. The cost savings of using a less robust material compared to potential costs of a moisture contingency plan would be evaluated prior to making a final decision.

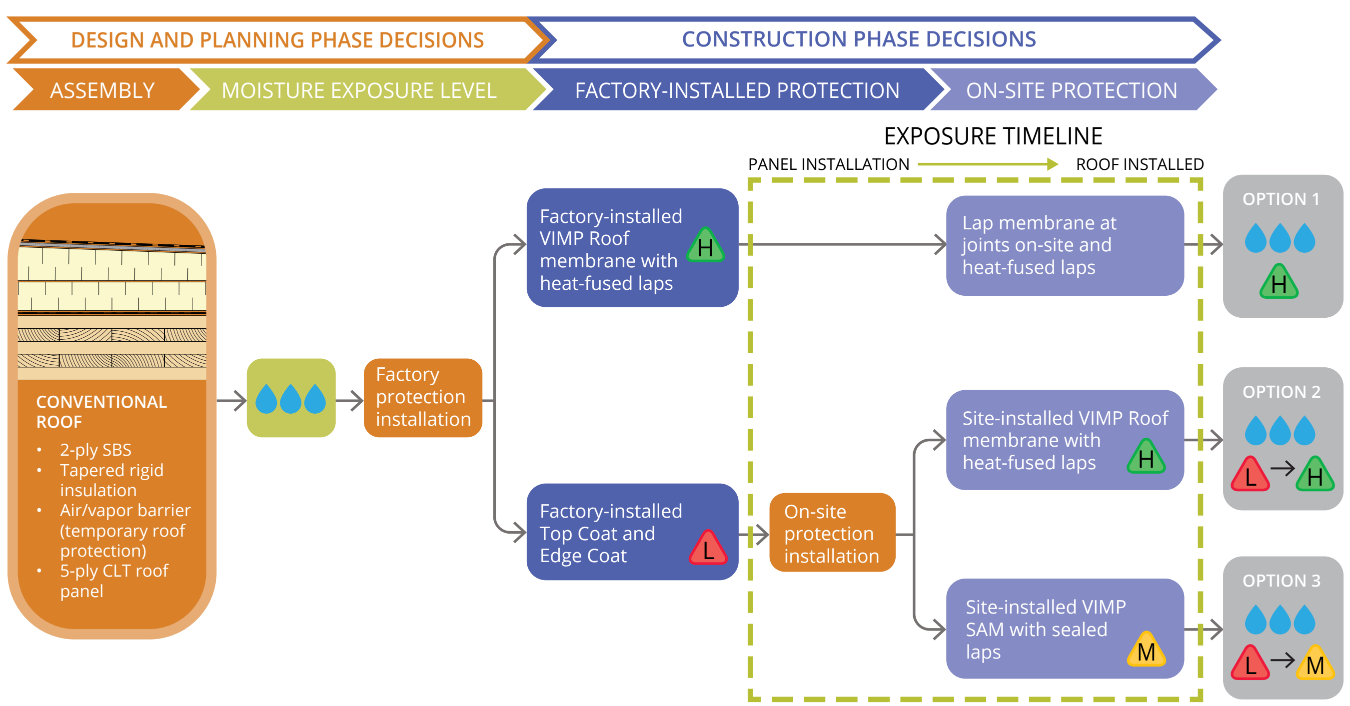


Figure 28 Case study moisture management planning flowchart for a CLT conventional roof assembly with three options.

RISK ASSESSMENT: Conventional Roof Moisture Risk Assessment

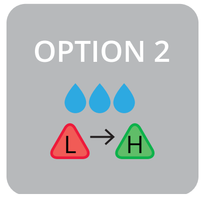
OPTION 1 Optimal Factory-Installed Protection

Factory-installed, vapor-impermeable, self-adhered SBS roofing base sheet with heat-fused laps (VIMP Roof)

Moisture Exposure Level: High
Membrane Robustness Level: High
Risk Assessment: Optimal

Considerations:

- The membrane robustness level is high; therefore, in a wetting event, no immediate action would be required. The membrane would act as a temporary roof until the final roof assembly is installed.
- During CLT panel installation, the membrane would be lapped and heat-welded at splines between panels on-site and an additional membrane would be installed over drag struts and other penetrations through the membrane.



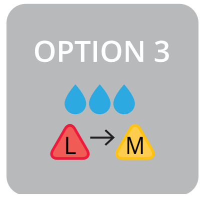
OPTION 2 Factory-Installed Membrane Not an Option

Factory-installed water-repellent sealer on panel surface (Top Coat) and high build paraffin wax on the end grain (Edge Coat) + site-installed, vapor-impermeable, self-adhered SBS roofing base sheet with heat-fused laps (VIMP Roof)

Moisture Exposure Level: High
Membrane Robustness Level: Low upon panel delivery. High after membrane is installed.
Risk Assessment: High risk upon panel delivery (Avoid if possible). Optimal risk after membrane is installed.

Considerations:

- Prior to installation of the membrane, the panel would have a Top Coat and Edge Coat that provides low protection robustness. In a wetting event, immediate action would be required and mechanical drying or delay of the membrane installation would also be required.
- The membrane is vapor impermeable, so there would be limited drying potential after the membrane is installed. The moisture content of the mass timber would need to be less than 16% before membrane installation.
- After the membrane is installed, the protection robustness level would be high; therefore, in a wetting event, no immediate action would be required. The membrane will act as a temporary roof until the final roof assembly is installed.



OPTION 3 Taking On Greater Risk

Factory-installed water-repellent sealer on panel surface (Top Coat) and high build paraffin wax on the end grain (Edge Coat) + site-installed, vapor-impermeable, self-adhered membrane with sealed laps (VIMP SAM)

Moisture Exposure Level: High
Membrane Robustness Level: Low upon panel delivery. Moderate after membrane is installed.
Risk Assessment: High risk upon panel delivery (Avoid if possible). Moderate risk after membrane is installed (Caution).

Considerations:

- Prior to installation of the membrane, the panel would have a Top Coat and Edge Coat that provide low protection robustness. In a wetting event, immediate action would be required and mechanical drying or delay of the membrane installation would also be required.
- The membrane is vapor impermeable, so there would be limited drying potential after the membrane is installed. The moisture content of the mass timber would need to be less than 16% before membrane installation.
- After the membrane is installed, the protection robustness level would be moderate; therefore, in a wetting event, action would need to be taken in a timely matter to avoid standing water. There would be a risk of standing water migrating under the membrane laps.
- Taped and/or sealant applied to all laps is recommended with a vapor-impermeable SA membrane to enhance the robustness of membrane laps. Unsealed laps would result in a low level of protection and would be at high risk for trapping moisture under the membrane.

After all relevant protection options are considered, the project team can discuss and select a final option based on desired risk levels and other considerations, such as budget. Step 2 can now begin, and the project team can develop a construction phase moisture management plan.

STEP 2 - DEVELOP A CONSTRUCTION PHASE MOISTURE MANAGEMENT PLAN

The On-Site Construction Moisture Management Tool presented on page 52 lays out key steps in a moisture management plan. The tool provides an overview of considerations but does not compare to the value of a project-specific moisture management plan. Step 2 of this case study outlines important content in a written plan and highlights key documents to include to create accountability within the project team and to ensure that moisture management strategies are being followed throughout the construction schedule. This plan is specific to the case study; a construction management plan does not need to be limited to the information shown on the following pages, but plans suited to the unique characteristics of each project are encouraged by this guide.

Step 2 Case Study Description

After performing the risk assessment for Step 1 of the case study, the project team decided that the roof would have a factory-installed VIMP Roof membrane with heat-fused laps (high protection robustness level in high moisture exposure conditions).

The project team also decided the floors would have a factory-installed Top Coat and Edge Coat, and site-installed vapor-impermeable tape at joints and splines (low protection robustness in moderate moisture exposure conditions). Because there is less protection, there will be a greater need for a moisture contingency plan for the mass timber floors.

Step 2 Case Study: Excerpt of an On-Site Moisture Management Plan

Developed from Step 1 Case Study and the On-Site Construction Moisture Management Tool

Note: Referenced plan documents are not included within this excerpt, but a summary of commonly included documents is included at the end of the Step 2 case study.

DELIVERY TO SITE

- Upon delivery to site, the team accepting panel delivery will review a sample of the panels to confirm the correct factory protection is installed and that the maximum moisture content of the panels meet the project-specific requirements (see included **Mass Timber Delivery Acceptance Checklist**).

JUST-IN-TIME DELIVERIES

- The CLT will be hoisted directly from the truck to the installation location to avoid double handling, thus mitigating additional damage to the membrane.

STORAGE

- After the concrete first floor is complete, an area will be assigned for temporary storage until the material is required for install (see the included Site Plan with location marked).
- The material will be positioned on adequate supporting dunnage, 8" off the ground.
- The material will remain in the factory wrapping until it is required for install.

GENERAL INSTALLATION

- Slits will be cut in the bottom of the factory wrapping to provide ventilation and prevent water from being trapped in the wrapping once mass timber components are installed.
- Penetrations and interfaces will be covered the same day as panel erection (see the included **Moisture Management Details Package**).

FACTORY-INSTALLED PROTECTION CONSIDERATIONS

- The option to factory-install a membrane was limited to the types of protection that the panel manufacturer had experience with and the factory was currently set up to support.
- If factory-installed membrane was not an option, Top and Edge Coat protection (red) could be installed in the factory for short-term protection until a membrane was installed on-site.

INSTALLATION OF CLT FLOOR PANEL (WITH FACTORY-INSTALLED TOP AND EDGE COATINGS)

- The CLT panels and spline material will be installed first. Immediately following panel erection, tape will be installed on-site at splines.

Contingency for precipitation during installation:

- ☑ In the case of an extreme weather event during installation, general laborers on-site will assist with water management atop CLT panels. To manage the water, the laborers will squeegee water off the flooring surface to designated areas along the face of the building where water is to be pushed off the deck surface (see the included **Floor Drainage Plan** with marked location where water is to be removed).
- ☑ Taping of joints will be delayed until the wood has been allowed to dry and the moisture content will be measured prior to tape installation. If required, electric heaters and fans will be used to mechanically dry the mass timber.

INSTALLATION OF CLT ROOF PANEL (WITH VIMP SA ROOFING MEMBRANE)

- First the CLT panels and spline material will be installed.
- Immediately following panel erection, the roofer will be coordinated to be on-site to heat-fuse laps and detail penetrations.

Contingency for precipitation during installation:

- ☑ In the case of an extreme weather event, the SBS membrane will be temporarily lapped and general laborers on-site will assist with water management atop the CLT panels. To manage the water, the laborers will squeegee water off the flooring surface to designated areas along the face of the building where water is to be pushed off the deck surface (see the included **Roof Drainage Plan** with the marked location where water is to be removed).

GENERAL CONSIDERATIONS

- Moisture management strategies and the importance of early leak detection and membrane upkeep will be included in onboarding site orientation for new workers.
- Checklists will be completed every Monday to ensure ongoing moisture management (see the included **Weekly Checklist**).
- The protection installed is a low robustness membrane. In a wetting event, immediate action will be taken to reduce the risk of permanent damage. Water will be squeegeed off the flooring surface to designated areas along the face of the building where water is to be pushed off the deck surface (see the included **Floor Drainage Plan** with the marked location where water is to be removed).

Contingency for weather:

- ☑ In the case of an extreme weather event, general laborers on-site from Monday to Friday will assist with water management of the floor CLT panels.
- ☑ On weekends, the lead contractor will monitor the weather. In the case of extreme weather on a weekend, an on-call team will be called to remove water atop CLT floor panels.
- ☑ If required, electric heaters and fans will be used to mechanically dry the mass timber.

CLT ROOF PANEL (WITH VIMP SA ROOFING MEMBRANE)

- Protection installed is a high robustness membrane. In a wetting event, no immediate action is required and there is a low risk of moisture damage.
- Water will be removed in accordance with the drainage plan as necessary to carry out work in the area (see the included **Roof Drainage Plan** with the marked location where water is to be removed). Water will be removed by squeegeeing to the designated area. Once parapet walls are installed, water will be removed using portable pumps and directed to the designated areas.

Contingency for weather:

- ☑ Excessive standing water will be removed from panel areas in accordance with the drainage plan.

CONCRETE TOPPING INSTALLATION

- Concrete floor topping placement will be completed after enclosure walls are installed. Prior to placement, a sampling of moisture readings will be taken to confirm the panels are dry (see included **CLT Pre-Pour Checklist**).
- If required, electric heaters and fans will be used to mechanically dry the mass timber.

Common Moisture Management Planning Documents

The documents listed below are commonly included in a moisture management plan package that is submitted to the design team prior to construction. Documents 2 through 7 are not included within this guide for this case study; however, a short description of each is provided.

1) **Written Plan Outlining All Phases:** See the above case study plan.
2) **Mass Timber Delivery Acceptance Checklist:** This document will include the minimum number of moisture content readings to be taken at delivery acceptance and will include who to contact if the mass timber does not meet the moisture content limits established by the project team.
3) **Site Plan:** This document will include a site plan of the project site and document the designated material storage area(s). The plan will also provide other relevant information, such as the location of the on-site moisture meter.
4) **Moisture Management Details Package:** This document includes sketches or redlined details that identify the moisture protection methods to be used at common building details and panel joints and edges.
5) **Drainage Plan:** This plan identifies the appropriate drainage paths for controlling site water. This plan will include where to direct water off roof edges, at piped drains, etc. for all floors and the roof. Drainage plan may vary by stage of construction (e.g., water may no longer be directed over the edge of the roof or over exterior walls if parapet installation is complete).
6) **Weekly Checklists:** Checklists will include items monitored or performed at regular intervals, such as ongoing moisture management. Checklists may include the following: monitor the weather forecast, review the underside of mass timber panels for leaks, review membranes for damage, etc.
7) **Pre- and Post-Pour Checklists:** These checklists will confirm when moisture content readings are taken and may outline required sequencing requirements prior to pouring concrete. Post-pour protection methods are also included.

STEP 3 - EXECUTE THE DESIGN AND MOISTURE MANAGEMENT PLAN

Once Step 1 and Step 2 are complete, the moisture risk assessment of each mass timber assembly has been performed; and through many discussions among the project team members about moisture protection methods, contingency plans, and construction schedules, a moisture management plan has been created. Now construction can begin. The more thorough the moisture management plan, the more prepared the construction team will be, but there are always unforeseen circumstances. Step 3 of this case study presents three example scenarios encountered when executing the moisture management plan.

Step 3 Case Study Description

The team planned that the CLT floors would have a Top Coat and Edge Coat installed in the factory and vapor-impermeable tape installed on-site at panel joints and splines (low protection robustness in moderate moisture exposure conditions). Due to the low membrane robustness, the project team planned to squeegee water off floors during rain events. The CLT roof membrane would have a VIMP Roof membrane (high protection robustness in high moisture exposure conditions). Due to the high membrane robustness, no action should be needed in a rain event. The case study project team encountered the following three scenarios during Step 3 of the moisture management process.

Scenario 1: Implementing Contingency Plans

Floors 2 to 6 were installed in early fall with a Top Coat, Edge Coat, and vapor-impermeable tape at joints and splines. During the installation of the floors, the site experienced periodic rain. When rainfall was significant enough to pond water, on-site laborers used squeegees or leaf blowers to remove water off the CLT floor panels to an appropriate drainage location, as identified in the drainage plan.

After one rain event, it was discovered that several penetrations were unprotected and exposed to moisture. The area was temporarily protected from additional wetting with tarps while the penetrations were dried with the use of fans and electric heaters. Once the moisture content of the CLT at these penetrations was confirmed to be in an acceptable range according to the project documents, the penetrations were protected so there would be no more risk of wetting in future rainfall events.

Some additional chemical stain removal and sanding was required to address moisture staining of the exposed CLT and glulam beams, drawing from contingency funds.

Scenario 2: Iterating Moisture Management Plans

Due to an unforeseen construction delay, the upper two floors were not constructed until later in the fall when the amount of rainfall was higher. Therefore, the actual moisture exposure level was higher than originally anticipated in the Step 1 risk assessment. Rather than frequently implementing the weather contingency plan, which would have required around-the-clock squeegeeing and would increase the likelihood of fans and heaters being needed to dry the panels, the project team met and re-evaluated their current strategies. They decided to install a vapor-impermeable self-adhered membrane (VIMP SAM) with sealed laps (moderate robustness) on-site for floors 7 and 8, thus reducing the need to follow a weather contingency plan during rain events. Regular visual reviews of these floors were still performed to confirm the membrane was sufficiently protecting the CLT and that no areas of water intrusion had occurred.

Scenario 3: According to Plans

The roof CLT panel had a VIMP SA roof membrane with heat-fused laps installed. Due to the high protection robustness that this membrane provides, and the project waterproofing subcontractor regularly patching any damage in the membrane as needed, there were no leaks during rain events and there was no need for mechanical drying. As a result, staining of the CLT was minimal and the additional sanding and finishing contingency for the project was not required.

REFERENCES

[1] T. C. Sheffer, “A climate index for estimating potential for decay in wood structures above ground,” *Forest Products Journal*, Vol. 21, No. 10, pp. 25–31, 1971.

[2] RDH Building Science Inc., Total Annual Rainfall Levels Across the United States and Canada. Map by RDH Building Science Inc. Data courtesy of National Oceanic and Atmospheric Administration, 2018.

ADDITIONAL RESOURCES

Additional resources for guidance on best practice enclosure design principles for mass timber enclosures include the following:

- *Mass Timber Building Enclosure Best Practice Design Guide*, RDH Building Science
- *Cross-Laminated Timber (CLT) Handbook*, FPInnovations and RDH Building Science
- *Nail-Laminated Timber: U.S. Design and Construction Guide*, RDH Building Science
- *Nail-Laminated Timber: Canadian Design and Construction Guide*, RDH Building Science
- *Technical Guide for the Design and Construction of Tall Wood Buildings in Canada*, RDH Building Science
- *ANSI/APA PRG 320: Standard for Performance-Rated Cross-Laminated Timber*, American National Standards Institute and APA–The Engineered Wood Association
- *Encapsulated Mass Timber Construction Up to 12 Storeys*, Architectural Institute of British Columbia and Engineers & Geoscientists British Columbia
- *Mass Timber Building Science Primer*, Mass Timber Institute

Many of the above resources can be accessed through RDH's online technical library at https://www.rdh.com/technical-library/.

CONTACT US

VANCOUVER
604 873 1181
van@rdh.com

SEATTLE
206 324 2272
sea@rdh.com

PORTLAND
503 243 6222
por@rdh.com

BOSTON
617 545 4004
bos@rdh.com

SAN FRANCISCO
510 788 8915
sfb@rdh.com

VICTORIA
250 479 1110
vic@rdh.com

COURTENAY
250 703 4753
cou@rdh.com

TORONTO
416 314 2328
tor@rdh.com

WATERLOO
519 342 4731
wat@rdh.com

| rdh.com

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