Australia & New Zealand XLam Envelope Guide

Use of this guide

Thank you for choosing to design with mass timber. XLam manufacture Cross Laminated Timber (CLT) from one hundred percent natural and renewable radiata pine. Each lamella and panel is unique, even with great care by XLam, slight deviations in grain pattern, knot location and colour will occur. By choosing to design in mass timber you are embracing the natural beauty of a renewable building material, it's perfection is in its natural imperfection.

The information in this guide is based on testing methodology and certification owned by XLam. The information is provided for use in the design and specification of XLam manufactured Cross Laminated Timber (CLT) only. The guide is not intended as general information and guidance for all manufactured Cross Laminate Timber (CLT). The guide and information is specific to XLam CLT and no warranty is given to the suitability and application of the information to other manufacturers CLT.

Design Guide Description

This guide provides an overview for the specification, design, and installation of XLam CLT panels as part of an overall building envelope assisting in delivering healthy, comfortable, durable, low carbon buildings. It provides examples of typical wall and roof build ups, general factors to be taken into consideration for achieving long term durability and energy efficiency based on consultation with industry experts, review of available literature and XLam's extensive project experience.

Application

This design guide has been prepared for the use of suitably qualified construction professionals to assist in the design and specification of XLam panels in relationship to the management of the transfer of heat, air and vapour. Products referred to in this document other than XLam panels are presented for information purposes only and due regard should be given to the relevant Australia and New Zealand Standards and other manufacturers literature. Advice on overall building design issues including but not limited to: stability, loading, temporary stability during construction, fixings, fire engineering and overall acoustic performance are not covered in this guide and advice should be sought from suitably qualified professionals.

It is the responsibility of the user to ensure that the use of this design guide is appropriate and to exercise professional judgement when using this document. Full responsibility for the design and compliance with Building Code of Australia (BCA) and New Zealand Building Code (NZBC) and all relevant Australian and New Zealand Building Standards rests with the design professional specifying the product. This guide is not intended to be used as a specification or evidence for compliance in the building approval process and should not be inserted as-is into specifications. Whilst all care has been taken in the preparation of this guide, XLam does not warrant that the information will be suitable in all circumstances. The final specification remains the responsibility of the designer, approval of the design needs to be obtained from the relevant building authority. XLam will not accept any liability for the failure of any other elements of the building which cause subsequent failure on an XLam product.

Update and Version Control

This design guide is identified with a version number and date of issue. The latest issue is always on the XLam website. It is the user's responsibility to ensure that the latest version is in use at all times.

Introduction

This guide is an aid to delivering best practice construction details that include cross-laminated timber (CLT). In this guide, the critical factors for the successful construction of CLT building envelopes are examined. The aim is to empower design and construction teams to deliver durable, high-performance projects. Insulation and construction membranes are specified in the context of CLT construction to manage the transfer of heat, air, and vapour. The impact on other BCA and NZBC requirements such as where non-combustible linings and cavity barriers are required should be considered in the design phase.

The Building Envelope Control Layers

The building envelope may be defined as the enclosing elements of the building that function as the physical separator between the artificially heated and cooled (conditioned spaces) and the ambient conditions. Providing more than just physical separation between inside and out, the building envelope must also perform structurally as well as allow control of the transfer of heat, air, moisture, light and provide appropriate fire and acoustic separation. The location of each layer (Figure 1) depends on a range of factors, many of which are dynamic, including climate and materials. It is vitally important that the below water, air, vapour, and thermal control layers are defined and implemented correctly to achieve their desired function for the long-term durability and performance. General definitions:

- Primary Water Control Barrier - keeps rain out of the building.
- Secondary Water Control Membrane - a membrane intended to collect and discharge any water that may penetrate a building envelope or cladding, excluding damp-proofing and flashing materials.
- Vapour Control Membrane - a pliable building membrane designed to either allow or restrict the transfer of water vapour across the membrane.
- Pliable Building Membrane – a material that is able to be folded back on itself without causing structural damage to the product that affects its material properties.
- Air Control Layer - a layer that keeps air inside or outside of the building. This layer may also act a the Vapour Control Layer
- Thermal Control & Insulation Layer – keeps heat in/out of a building, this layer needs to be continuous to be effective.
- Ventilation Layer - Air Gap - allows for the dissipation of moisture outside of the building enclosure

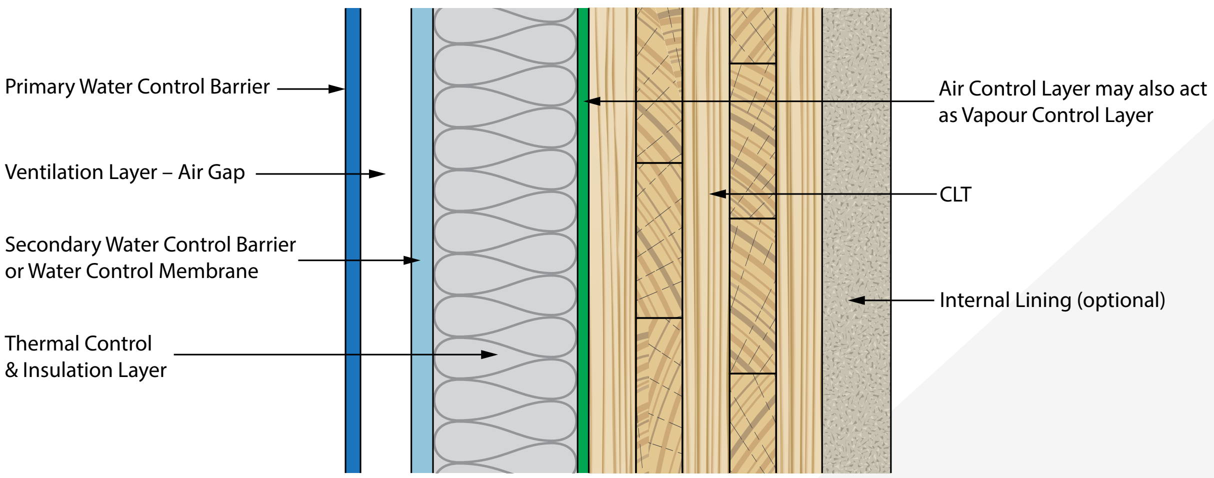

Figure 1 Building Envelope Control Layers

Primary Water Control Barrier

The primary water control barrier is the most important control layer, aiming to control the passage of liquid water. More formally, it is the continuous layer comprised of one of several materials that are designed, installed or act to form the rainwater boundary. It must be adequately detailed and is not dependant on a 'perfect' seal at every single point. Where this layer is inadequate, durability issues may arise where any leaks result in water entering the structure. The primary water control layer (exterior cladding) must meet the Verification method requirements for waterproofing in the NCC FV1.1 (Volume 1) or V2.2.1 (Volume 2) and for the NZBC E2/VM1.

Secondary Water Control Barrier/ Water Control Membrane

Many best practice construction systems have two distinct water control layers, an exterior cladding to control rain that is ventilated to the exterior and then a secondary water control layer usually termed the Water Control Membrane.

Air Control Layer

Air control layers reduce the risk of unwanted moisture leaking or diffusing into the building envelope. Potential failures occur due to air leakage from the building interior, carrying moisture into the walls and roof structures where it can condense and cause long-term damage that can affect the durability of a system. As wall or roof system may be closed with no way of accessing them, damage occurring because air leakage is concealed, only becoming evident on internal or external surfaces in the form of mould.

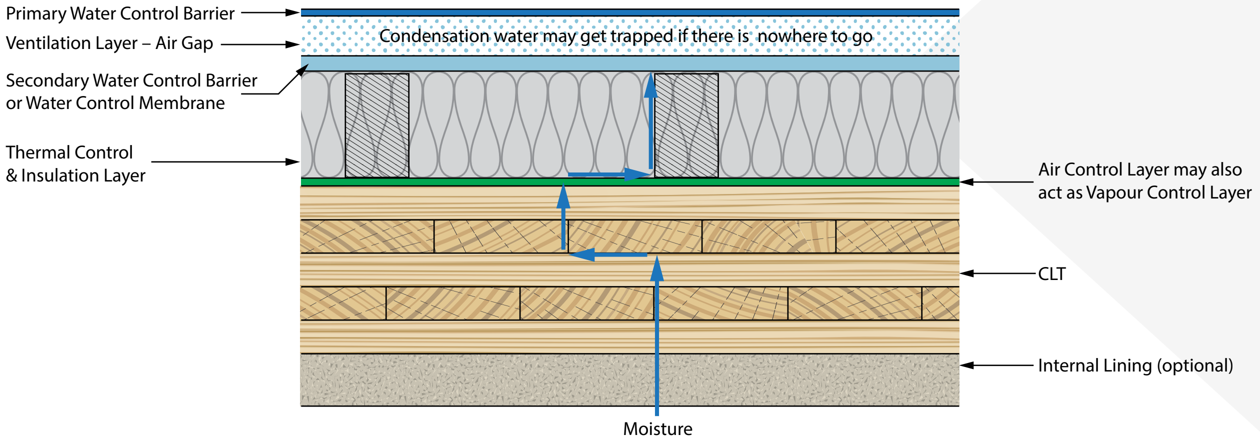

Figure 2 Importance of Air Control layer in Minimising Risk of Condensation

Strategies for an airtight building envelope vary due to climate. In cold climates, they typically include sealing XLam CLT panels with vapour permeable tapes or through the installation of a continuous airtight membrane on the interior or exterior. In most cases, it is recommended that membranes and components be adhered directly to the CLT panel to help ensure air barrier materials are adequately supported and to improve constructability. Continuity of the air barrier around interfaces and details is essential to ensure whole-building airtightness.

Airtightness can also have impacts on acoustic, fire and thermal performance. If a membrane is to be used to obtain airtightness and also serves a vapour control function, careful consideration should be given to the class or permeability of membrane employed, modelling in hyrgothermal simulation calculators can help review suitability. The air barrier system must be durable enough to perform over the design service life of the building enclosure. An air barrier is defined as a membrane or element with an air resistance > 0.1 MNs/m3 in accordance with ISO 5636-5. Note this is not a particularly high barrier, higher value products should be considered.

Figure 3 XLam CLT with Pre Applied Membrane

Figure 4 Taping of XLam CLT Panel Joints

Vapour Control Layer

Vapour control layers control moisture levels in the assembly, to prevent condensation and allow an increased drying potential. Water vapour moves from areas of high humidity to areas of low humidity as a function of the pressure difference between inside and outside. This "vapour drive" is a key consideration in detailing the location of each layer, selection of materials and consideration for the location of a ventilation/drainage layer. It is critical to note that solutions are both project and climate specific.

There are many factors that need to be considered in assessing and managing condensation risk. These include local climate, orientation, building use and ventilation strategy. In addition, the vapour function and permeability of all materials, the location and type of vapour membrane and ventilation strategy must also be considered. Controlling moisture is important to protect occupants from adverse health effects and to protect the building, its mechanical systems, and its contents from potential physical or chemical damage. Vapour control membranes with various permeabilities or variable permeability can respond to the condition of the environment as needed.

When designing a CLT assembly, the vapour permeability of the CLT should be considered in relation to the assembly's insulation placement and type, as well as the placement and properties of other air and water control membranes, to avoid water vapour accumulation within the panel and to ensure the panel's long-term durability. The focus therefore for envelopes incorporating CLT is to maximise drying capacity. Vapour control membranes can be classified in accordance with Table 4 in AS 4200.1 2017. Class 4 vapour permeable membranes are recommended to be used where permeance is required.

Class	VCM Category	Vapour Permanence ug/N.s	
		Min (<)	Max(<)
Class 1	Vapour barrier	0	0.0022
Class 2		0.0022	0.1429
Class 3	Vapour permeable	0.1429	1.1403
Class 4		1.1403	No max.

Table 1: Vapour Control Memebrane (VCM) Classification

It is worth noting that a membrane specifically for vapour control is not always required. It is more important to note and fully understand and quantify that membranes that serve other functions such as a water control membrane or air control layer, or both, will have a degree of vapour resistance or vapour permeance. Consideration to ensure the safe drying potential/pathway to the exterior or interior appropriate for all seasons in the particular climate is crucial to protect moisture sensitive building materials. Hydrothermal modelling tools are available to assess risk and aid design.

Thermal Control Layer

Thermal control layers are the least important control layer when it comes to building durability, but receive considerable attention due to the obvious focus as an energy-saving initiative and a desire for increased thermal comfort. In general, air and vapour control layers in heating climates are to be inside of the thermal control layer. This prevents moist interior air from contacting surfaces that are cold, due to being outside or between the thermal control layer and condensing.

The vapour permeability of thermal control layer should also be considered, to avoid trapping of vapour in the construction. This is typically represented by insulation. Total R values achieved by XLam CLT panels in building envelopes can be modelled on the Speckel platform https://speckel.io & https://nz.speckel.io/#/. Placement of the insulation on the external side of the CLT is preferred in most climates as it keeps the CLT warm and dry. The impact of the placement of insulation and climate on the temperature profile of a building envelope and thus vapour management and limiting condensation is highlighted in the following diagrams for temperature climates.

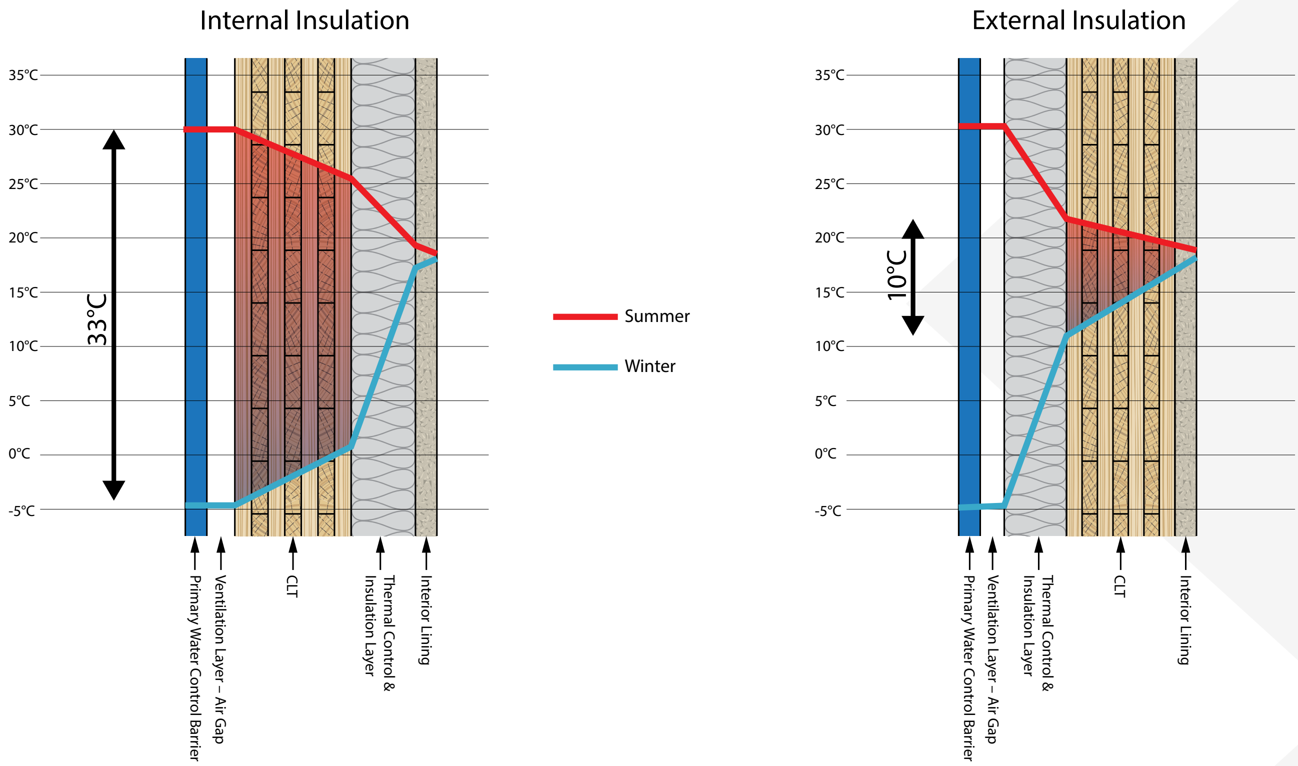

Figure 5 Impact of placement of insulation on temperature

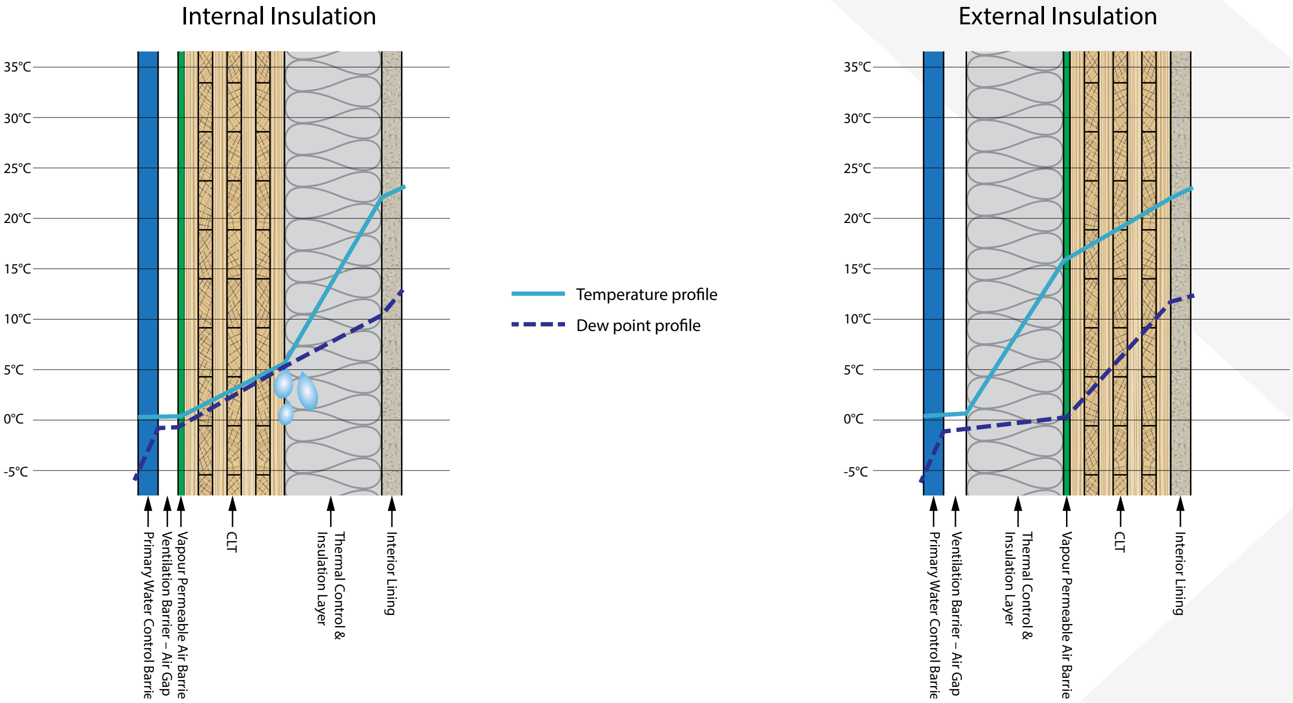

Figure 6 Impact of placement of insulation on formation of moisture in winter

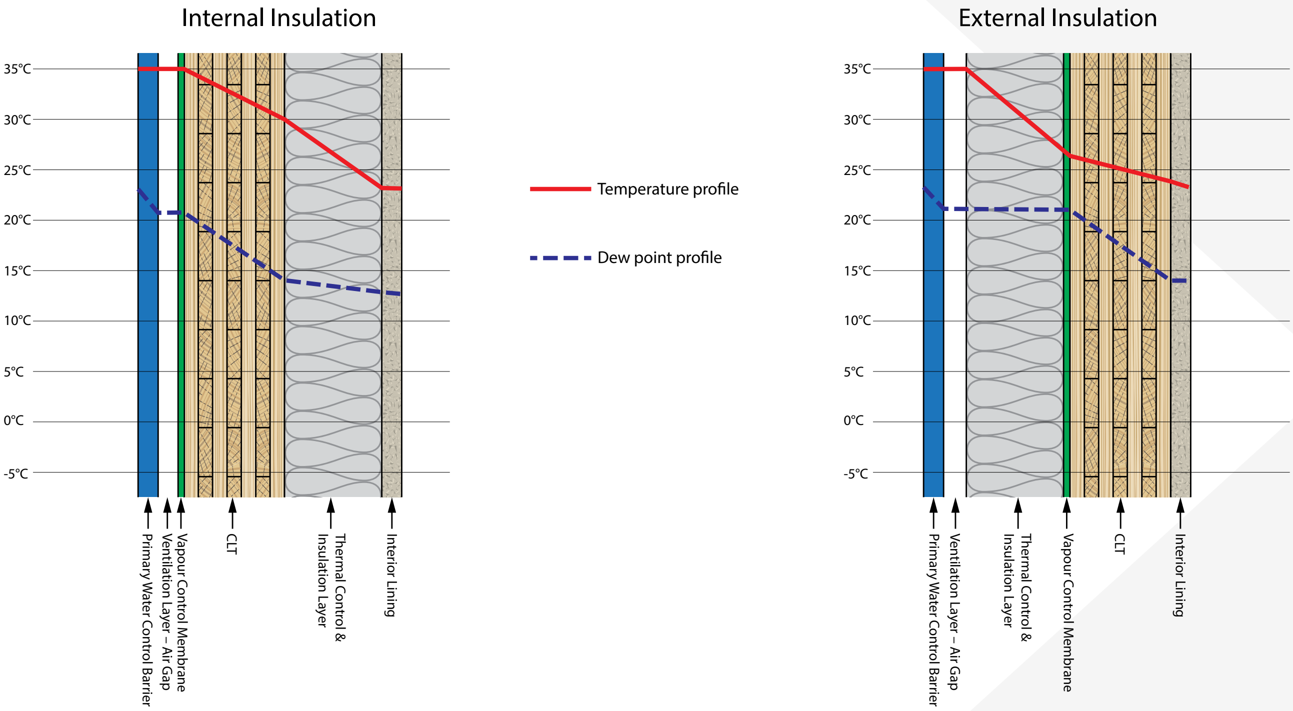

Figure 7 Impact of placement of insulation on formation of moisture in summer

Thermal Performance of XLam CLT

A building's thermal performance is essential to the provision of a comfortable environment for its occupants and in-service energy consumption. The design and manufacture of mass-timber products for use in low and medium rise residential and commercial buildings can enhance thermal performance in comparison to conventional materials, such as stud frame or reinforced concrete. The superior thermal performance of CLT is due to its thermal conductivity, heat capacity, infiltration reduction properties and vapour permeability properties.

XLam CLT is manufactured from solid finger-jointed radiata pine. Thermal conductivity of Radiata Pine can vary depending on moisture content and orientation of grain, the thermal conductivity of Radiata Pine is 0.12 W/mK at 12% moisture content (NZS 4214:2006). The R-Values for XLam CLT panels at 12% are moisture content given below.

Thermal performance values for various panel thicknesses

Layup	Thickness mm	R Value m^2K/w	Layup	Thickness mm	R Value m^2K/w
CL3/90	90	0.75	CL5/190	190	1.58
CL3/100	100	0.83	CL5/200	200	1.67
CL3/110	110	0.92	CL5/220	220	1.83
CL3/120	120	1	CL7/240	240	2
CL3/130	130	1.08	CL7/260	260	2.17
CL5/140	140	1.17	CL7/270	270	2.25
CL5/155	155	1.29	CL7/290	290	2.42
CL5/170	170	1.42	CL7/310	310	2.58

Total System R values of envelope systems containing XLam CLT panels can be modelled in Speckel. See https://speckel.io/ & https://nz.speckel.io/#/

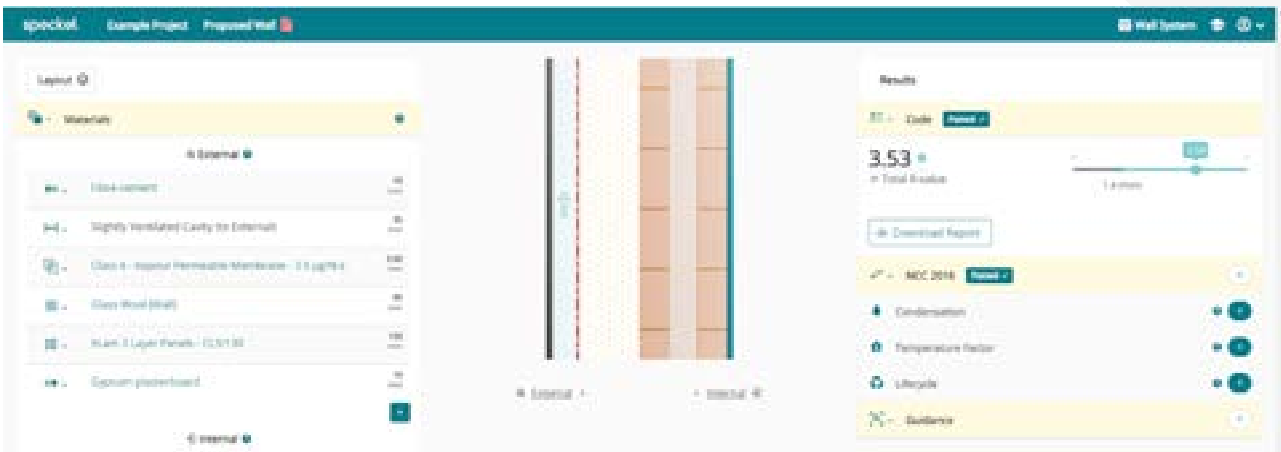

Figure 8: Example of thermal simulation of a wall incorporating CLT in Speckel Tool

Thermal Bridging

A thermal bridge is an area where there is an increase in heat lost or gained by conduction of heat compared to the surrounding build-up, and this normally occurs where there is a change in the insulation level or a junction between building elements. The most prominent bridges occur where there are structural elements penetrating the insulation, or between junctions such as where a floor meets a wall. Some thermal bridging is unavoidable; however, significant heat loss (or gain) can occur that will affect internal comfort and may also reduce surface or interstitial temperatures enough to result in condensation. This can then lead to mould or other condensation related issues like material damage or rot. Thermal bridging should be designed out where possible or minimised. CLT can perform well in reducing thermal bridging effects compared to conventional material, however the design of the connections should still be closely examined.

Vapour Transfer Management

The objective of the modern building envelope is to fulfil the four control layer functions efficiently and effectively. Of these, the control of vapour is perhaps least-well understood and applied. Understanding the vapour transfer mechanism specific to each project will direct the placement of vapour control layers. Moisture may enter the assembly via diffusion or convection through several sources, internally as vapour via cooking, breathing or as water via leaks, or externally from rain or high relative humidity. Understanding the climate indoor and outdoor that the building is subject to is critical to the design of the control layers, construction type and material choices, as the climate will influence which direction the vapour moves through the assembly and the amount of moisture carried in the air.

- In cool Australian and New Zealand climates, the ability of the air to hold moisture is reduced but the likelihood of interior humid air coming into contacting with low temperature surfaces is increased which needs to be managed.
- In tropical & subtropical climates of Australia and New Zealand, substantial amounts of moisture may be present in external air which presents a substantial risk of condensation when the external air comes into contact with cooler surfaces.

Appropriate drying paths must be designed for the moisture sources, with consideration that different build-ups are needed for different climates zones. While this guide contains examples of good detailing practices, this does not replace specialist consultant opinions, which should be sought for individual cases. An important design step is to consider how indoor ventilation and/or conditioning strategies may be applied to control risk, or likelihood of moisture-based issues. Hot-humid climates have an increased risk if dehumidification if not included.

While the CLT itself can serve as a vapour resistive layer due to its low vapour permeability and thickness, in practice, it is recommended to use a project-specific vapour barrier. As moisture vapour molecules are smaller than air molecules, the installation of a vapour barrier is also capable of retarding the infiltration or exfiltration of air movement. Variable vapour control membranes adapt the diffusion properties to suit the relative humidity; in environments of high humidity this increases the ability for the assembly to dry out, while in environments of low humidity it reduces the moisture that diffuses into the assembly. Vapour barriers should be carefully applied, the use of a barrier in a mixed climate may result in seasonal issues. In mixed climates consideration of smart membranes or materials through hydrothermal modelling of performance could be considered.

Hygrothermal Simulations

Hygrothermal simulation programs such as WUFI can provide realistic calculations of the transient coupled one and two-dimensional heat and moisture transport in walls and other multi-layer building components exposed to natural weather by simulating built-in moisture, driving rain, solar radiation, long-wave radiation, capillary transport, and summer condensation of a construction assembly.

As there are many factors that need to be considered in assessing and managing condensation risk including local climate, building use, position, thickness and type of bulk insulation, location and type of vapour membrane and ventilation strategy, it is highly recommended that designers run a condensation risk analysis for project-specific risks. Simple initial condensation simulations (ISO 13788) can be conducted utilising XLam CLT panel build ups on the Speckel platform see https://www.speckel.io/ (Australia) & https://nz.speckel.io/#/ (NZ)

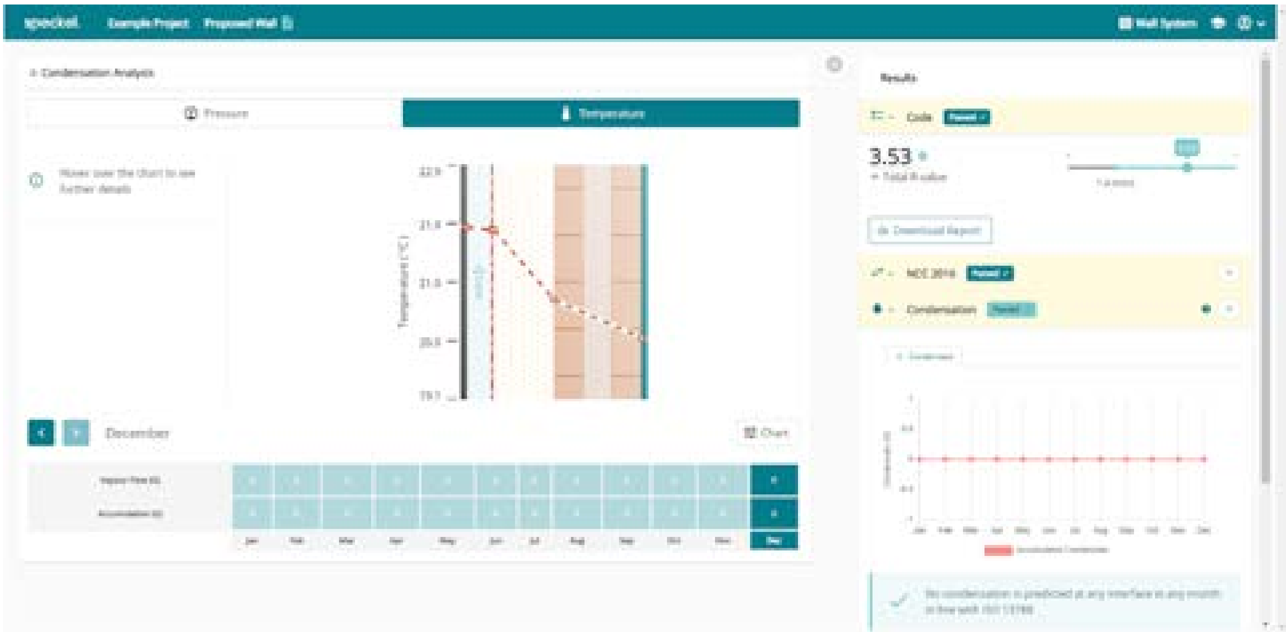

Figure 9: Example of condensation simulation of a wall incorporating CLT in Speckel Tool

Construction Phase Moisture Control

To minimise swelling or shrinkage of the CLT panel during operation, the target moisture content of XLam's CLT panel is 12%, the anticipated equilibrium moisture content that the most conditioned buildings are expected to experience in-service. The initial moisture content of installed XLam CLT panels, prior to applying linings, can affect long term hygrothermal performance and durability. Timber treatment will not prevent moisture absorption where CLT panels are exposed to weather onsite (rain, high humidity and extreme sunlight combinations). The maximum acceptable moisture content for wood products at the time of installing interior linings is generally accepted to be 18%.

The best solution to moisture intrusion is prevention; however, wood poses a challenge because it is naturally hygroscopic. Therefore, it is best-practice to define a comprehensive water-management plan to protect the mass timber during manufacturing and construction until the building is enclosed by the envelope. This includes durability strategies for transport and construction to protect the XLam CLT panel from all moisture sources as much as possible, include sealing edges, just-in-time delivery, capping joints, and active moisture removal or drying. These strategies protect the CLT as well as the building membranes, as most membranes are not designed to withstand prolonged direct exposure to the elements particularly UV visible light, therefore exterior cladding should be installed without delay.

Recommendations to limit exposure to construction moisture:

- Site-stored panels and elements should be supported at least 200mm clear of the ground, and continually covered by tarpaulins. Avoid using polythene covers which can induce sweating. Where covers are used they should allow for air exchange.
- Joints between XLam panels should be taped following installation to prevent moisture tracking into the end grain of the timber.
- Where prolonged exposure to moisture is anticipated, seal end grain at panel edges and openings at the building envelope to inhibit moisture penetration. This can be in the form of a paint-on sealer or a flashing tape.
- For exposure periods of greater than 4 weeks XLam recommends applying a water-repellent sealer to all exposed surfaces which can provide protection to the timber for up to 12 weeks.
- All XLam CLT panels and elements should be protected as soon as is reasonably practicable after installation from both weather and UV. Exposure to high levels of moisture followed by exposure to the sun and other heat sources can create a moisture gradient across the elements resulting in warping, twisting or bowing.
- Visual grade panels and elements should not be exposed to weather or direct sunlight. Breathable building wraps should be applied to the visual surface following installation. Wraps should be unmarked to eliminate differential light penetration, and fixed with stainless steel or plastic fixings to avoid rust staining.
- Weather, temperature and moisture content readings should be taken weekly, and before and after each weather event. Should the moisture content of any XLam panel or element exceed 18%, XLam should be notified.
- Following any weather event, all horizontal panels should be swept clean of ponding water and all protection measures should be checked and any inadequacies rectified.

Good Detailing Practices

Wood naturally absorbs and releases moisture, and while this is a beneficial feature for buffering internal humidity, it also requires educated management to deal with related susceptibilities within the building envelope. As improper moisture management may lead to structural deterioration and impact the health of the occupants, it is essential to detail appropriately when using mass timber construction systems.

The BCA and NZBC includes minimum requirements for good detailing practices to prevent damage, illness or injury caused by surface water, external moisture entering a building and the accumulation of internal moisture within a building. Therefore, it is a legal obligation to manage these requirements in any structure. For the use of CLT, these requirements can be met through best-practice moisture management and by adhering to the following design approaches:

- Maintain the temperature of the CLT above dew point temperature.
- Avoid any vapour-impermeable materials in the building envelope where, if at risk of being at dew point temperature, there is no provision for the safe removal of moisture through draining and drying.
- Management of internal humidity levels through effective ventilation (as opposed to reliance on infiltration and exfiltration).
- Continuity of the air barrier and water-resistive barrier membrane from the exterior surface of the CLT into and through the rough opening is critical to protect the CLT and to seal the window/opening.
- Membranes used as the sill flashing should be thick, robust and vapour impermeable and resistant to ponding water, as the CLT surface will typically be flat.
- The use of a back-dam or sill angle is preferred to air and water sealing of the sill, and no fasteners should penetrate the sill membrane into the CLT, unless inboard of the air and water seal.
- The membranes used at the jamb and head of the window into the CLT rough opening should be vapour permeable. It is suggested that the same vapour permeable self-adhered membrane recommended for the exterior of the walls be used in this instance. The window is to be sealed to this membrane using a compatible sealant, tape, or self-adhered membrane.
- At the windowsill, the installation of a supplemental flashing "skirt" to divert water from the rough opening and over the exterior insulation is preferred over allowing water to drain behind the exterior insulation. This skirt is typically installed at the time of window installation, with the release liner left intact until the exterior insulation is installed.
- Consideration should be given to the gravity, wind, and seismic loads to ensure the claddings, insulation, air barrier and water-resistive barrier membrane will perform in service without excessive deflection, cracking, or detachment from the structure.
- Consideration should be given to how the fire performance requirements are being met and the impact this will have on condensation management. Non-combustible linings and insulation may be required as well as cavity barriers. The impact of these requirements on the envelopes ability to dissipate moisture needs to be considered.
- Consideration should be given to how the cladding, insulation air barrier and water-resistive barrier membrane will be installed.
- Membranes should not be walked on excessively or have other heavy duty loads.

Recommended Envelope Build-Ups

Each building envelope design needs a climatic-based, project specific solution. This guide provides typical locations of the control layers in roof and wall build-ups for envelopes which include XLam CLT panels. The build ups are general in nature, and projects must use climate-specific and construction-specific hygrothermal assessments. In all instances, the CLT is taped and forms the airtight barrier. Generally the vapour barrier and insulation should be permeable to moisture as this allows for the passage of moisture and drying to both sides.

Exterior-insulated is the preferred design approach for CLT wall assemblies in most Australian and New Zealand Climate zones this also allows the CLT to be left exposed on the interior, where allowed by the fire safety provisions. Exterior insulation keeps the CLT warm and dry; the CLT on the interior provides sufficient vapour resistance to outward vapour drive, eliminating the need for further vapour control. The use of vapour permeable exterior insulation and a self-adhered vapour permeable membrane on the exterior of the CLT is the most durable approach, as it allows for outward drying of CLT or the drying of small leaks in service.

The use of either vapour impermeable exterior insulation or a vapour impermeable membrane will significantly reduce outward drying and therefore should only be used with extreme caution. Caution must also be taken where the indoor RH is expected to be elevated such as in densely occupied housing, museums, and swimming pools and in tropical climate zones. The use of a drained and ventilated rainscreen cladding is recommended for all building types and will also help to dissipate inward solar-driven moisture. Vertical strapping is recommended for cladding support, and where horizontal strapping is required for cladding support, it should be installed on the exterior of the vertical strapping. Interior-insulated CLT wall assemblies are not generally recommended for building enclosures except for unique indoor climatic situations and with special attention to the selection of materials and details.

The following details are provided as typical examples and need project specific modelling before being specified in project details. The impact on other building attributes and building regulatory requirements such as thermal, fire, acoustic and structural properties should be reviewed before finalising the design.

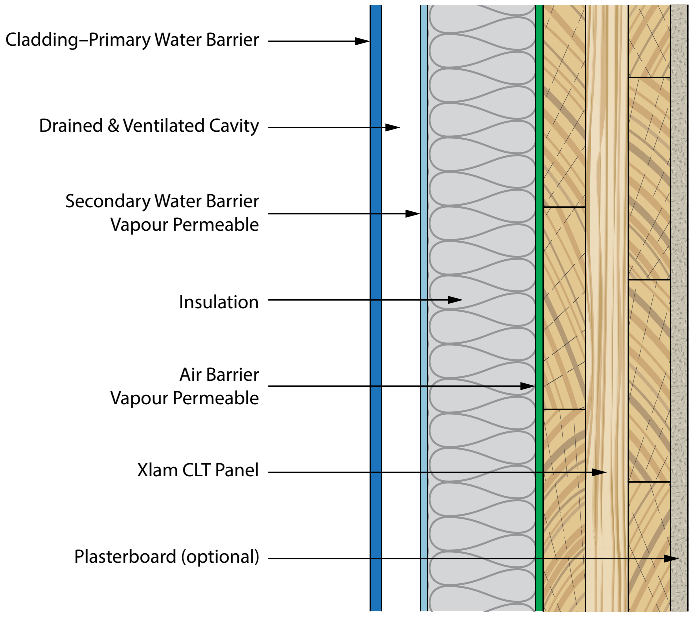

Fig 10 Typical Detail for External Walls

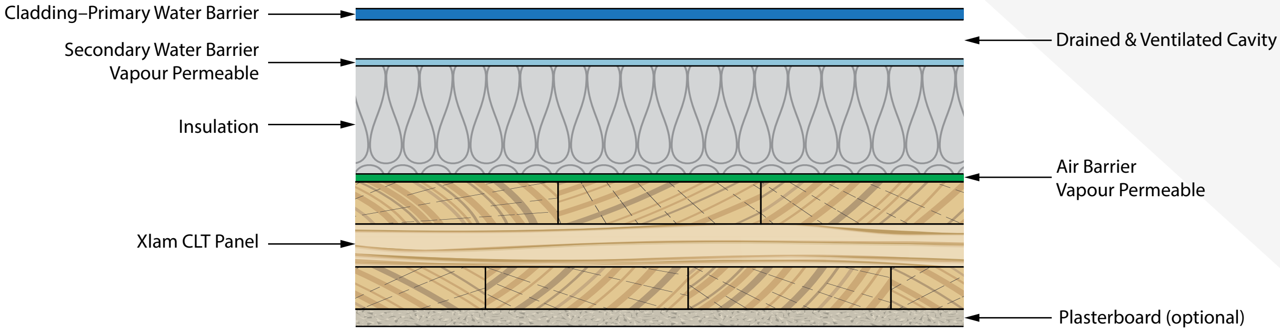

Fig 11 Typical Detail for Roofs

General Design Considerations

- Keep the CLT warm & dry, this generally entails having the insulation on the exterior of the CLT.
- Provide water barriers and ventilated cavities to ensure no free water encounters the CLT and any water which enters the system past the primary water barrier can be drained away.
- Ensure all materials allow for the transport of moisture and drying of CLT in both directions.
- Design to achieve required ground clearances.
- Clad XLam in external locations where it would be otherwise exposed to weather.
- Isolate CLT from moisture by using adequate set-downs, separation gaps, barriers, and flashings.
- Take particular care in detailing external decks, balconies, thresholds, and balustrades to eliminate any possibility of moisture reaching XLam panels.
- Where practicable, lift the bottom edge of wall panels clear of concrete floor slabs with a continuous cementitious grout to minimize end grain absorption of ponding water, particularly where water staining may affect visual surfaces.
- Overlay XLam to wet area floors and decks with a durable sheet substrate as a base for waterproof flooring systems. Seal the substrate joints with a flexible sealer compatible with the floor finish adhesive. This is a precaution both against the penetration of moisture and to prevent any natural movement of timber in the XLam floor surface layer from affecting the floor finishes.
- Specify corrosion-resistant and compatible metal fixings.
- Manage moisture within the external building envelope to avoid the buildup of condensation.
- Ensure the building is adequately ventilated. Occupants generate a significant amount of indoor moisture which can lead to interstitial condensation. Where there is a potential for highly humid conditions within the building envelope, such as swimming pools, saunas, and the like, specific hygrothermal design is required.
- Check fire performance strategy and how this may impact on pathways for moisture egress, and thermal bridging particularly the requirements for cavity barriers, non-combustible external linings and insulation.

References and Further Reading Materials

ABCB National Construction Code, 2019, Volume Two, Part 3.8.7 Condensation Management

ABCB National Construction Code, 2019, Volume One, Part F Condensation Performance Requirements

AS/NZS 4200.1:2107 Pliable building material and underlays – materials

DA07 Criteria for Moisture Control Design Analysis in Buildings, AIRAH 2020

ABCB National Construction Code, Handbook Condensation in Buildings, 2019

FPI Canadian CLT Handbook 2019, Chapter 10

New Zealand Building Code Handbook Clause E3 Internal Moisture

New Zealand Building Code Handbook Clause E2 External Moisture

ISO 5636-5 Determination of air permeance (medium range) — Part 5: Gurley method

ISO 13788 Hygrothermal performance of building components and building elements - Internal surface temperature to avoid critical surface humidity and interstitial condensation - Calculation methods (ISO 13788:2012)

WuFi Data Base https://wufi.de/en/

Proctor https://proctorgroup.com.au/

Proclima https://proclima.com.au/

Speckel https://www.speckel.io/ (Australia) & https://nz.speckel.io/#/ (NZ)

XLam Operation & Maintenance Guide

If you need any further information on the use of XLam panels, please contact technical@xlam.co.nz or technical@xlam.com.au and we would be happy to assist. We can provide information and introductions to external consultants who can assist in your project.

Disclaimer

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