16

This guide was revised in Oct 2018

Please check woodsolutions.com.au/publications to ensure you have the latest edition

# Massive Timber Construction Systems

*Cross-laminated Timber (CLT)*

Technical Design Guide issued by Forest and Wood Products Australia


## WoodSolutions Technical Design Guides

A growing suite of information, technical and training resources, the Design Guides have been created to support the use of wood in the design and construction of the built environment.

Each title has been written by experts in the field and is the accumulated result of years of experience in working with wood and wood products.

Some of the popular topics covered by the Technical Design Guides include:

- Timber-framed construction
- Building with timber in bushfire-prone areas
- Designing for durability
- Timber finishes
- Stairs, balustrades and handrails
- Timber flooring and decking
- Timber windows and doors
- Fire compliance
- Acoustics
- Thermal performance

## More WoodSolutions Resources

The WoodSolutions website provides a comprehensive range of resources for architects, building designers, engineers and other design and construction professionals.

***To discover more, please visit***
***www.woodsolutions.com.au***
***The website for wood.***

*Cover image: Forté, Docklands, Melbourne*
*Design & Construction: Lend Lease*
*Photograph: Lend Lease*

WoodSolutions™
design and build
woodsolutions.com.au

WoodSolutions is an industry initiative designed to provide independent, non-proprietary information about timber and wood products to professionals and companies involved in building design and construction.

WoodSolutions is resourced by Forest and Wood Products Australia (FWPA – www.fwpa.com.au). It is a collaborative effort between FWPA members and levy payers, supported by industry bodies and technical associations.

This work is supported by funding provided to FWPA by the Commonwealth Government.

ISBN 978-1-921763-49-6

**Researcher:**
Timber Development Association (NSW) Ltd
9/281 Pacific Highway
North Sydney NSW 2060

Printed: July 2011
Revised: May 2012, September 2014, September 2015, October 2018

# Table of Contents


**Introduction** 4

**1 What is Cross-laminated Timber?** 5

1.1 History 6
1.2 CLT Benefits 6
1.3 CLT Applications 7
1.4 Compliance to the National Construction Code 8
1.5 Environmental Performance and Occupant's Health Benefits 9

**2 Manufacturing** 10

2.1 Species Selection 10
2.2 Timber Laminates 10
2.3 Panel Assembly 10
2.4 Adhesive 11
2.5 Press 11
2.6 Panel Final Shape and Length 11
2.7 Surface Finish and Appearance 12
2.8 Transport Constraints for Panel Width and Length 12
2.9 Site Access Constraints for Panel Width and Length 13
2.10 CLT Optimisation 13
2.11 Mechanical Properties 13

**3 Design and Compliance** 14

3.1 Standards and Codes 14
3.2 Compliance to National Construction Code 14
3.3 Design 14

**4 CLT as a Building System** 15

4.1 Building Layout 16

**5 The Building Process** 17

5.1 Planning 17
5.2 Site Assembly 17
5.3 Utilities 20

**6 Properties of CLT Assemblies** 22

6.1 Structural Performance 22
6.2 Fire Performance 22
6.3 Structural Performance 24
6.4 Thermal Performance 25
6.5 Durability 25
6.6 Seismic Performance 26
6.7 CLT Manufacturers and Further Information 26

**7 Case Study: Forté** 27

7.1 Design Professionals 27
7.2 About Forté 27
7.3 Environmental benefits 29
7.4 Fire Resistance 29
7.5 Acoustics 30

**8 References & Further Reading** 31

# Introduction

**The next generation of timber buildings are being made from Massive Timber. They are mostly built from engineered timber elements that are generally 75 mm or greater in thickness from:**

- Cross-laminated Timber – CLT
- Glue Laminated Timber – GLT or Glulam
- Laminated Veneer Lumber – LVL
- Nail Laminated Timber – NLT
- Dowel Laminated Timber – DLT

This guide discusses one of the Massive Timbers that is often used called Cross-laminated Timber (CLT). The guide's intention is to introduce CLT, providing general product and performance information, design consideration and building processes. The guide is not a design manual, for more detailed design information refer to producers or suppliers of CLT.

***Figure 1: Cross-laminated Timber panel.*** *Photograph: Stora Enso*

***Figure 2: Forté Living, Australia's first Cross-laminated Timber Building***
*Photograph: Lendlease*

1

# What is Cross-laminated Timber?

**Cross-laminated timber (CLT) is a solid engineered wood product made of at least three orthogonally bonded layers of solid-sawn timber or engineered timber that are laminated by gluing of longitudinal and transverse layers with structural adhesives to form a solid rectangular-shaped, straight, and plane timber panel.**

Dimensional seasoned timber is used; generally finger jointed to form long length boards. Low structural grades are most often used for the transverse layer and higher structural grades for the load direction. The panel can have three to seven layers or more (usually an odd number), which are symmetrical around the middle layer. While softwoods are most often used, it is feasible to manufacture CLT using hardwoods or engineered wood products such as LVL. In some instances, engineered wood products have been combined with CLT to form hybrid panels. These panels have improved air tightness, strength and screwing capacity.

Panel sizes vary by manufacturers, but typical widths are 0.6, 1.2 and 3.5 m; lengths can be up to 18 m. Thicknesses is dependent on the lamination thickness. Generally European CLT is made from 20, 30 or 40 mm lamination or a combination of both while Australian, New Zealand and North American laminations are generally 20, 35 or 45 mm thick or a combination of both. Thickness of the CLT panel typically varies from 60 mm up to 500 mm. The limiting factor on the CLT panel size is usually the ability to transport the product. For imported CLT, the size may also be limited to what can fit into a shipping container.

The cross-lamination provides relatively high strength and stiffness properties in both directions, giving it a two-way action capability, similar to a reinforced concrete slab. CLT has better structural properties than sawn timber and the cross-lamination process in CLT also increases the splitting resistance and connector strength. CLT is also known as X-lam ('cross lam') and 'massive or mass timber'.

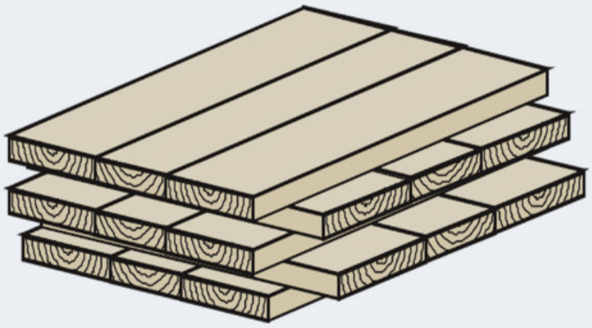


***Figure 1.1: Layers of boards making up CLT.***

***Figure 1.2: 3 layer CLT panel after pressing.*** *Photograph: XLAM Australia*

## 1.1 History

CLT was initially developed in Switzerland and then in Austria in the early 1990s. In 1996, a joint industry-academia research effort in Austria resulted in the development of cross-laminated timber as it is known today.

Construction with CLT increased in the early 2000s. This was driven by the 'green' building movement, better efficiencies in production, and favourable building code changes in some jurisdictions. Leading countries in the use of CLT are Austria, Germany, Italy, France, Switzerland, Sweden, Norway and the United Kingdom, where it is typically being used in housing, multi-residential apartments and educational buildings.

Production is centred in Austria and Germany but there are also plants in Czech Republic, Italy, Finland Switzerland and Sweden. Outside Europe, plants have been established in Australia, Canada, New Zealand and the US.

## 1.2 CLT Benefits

The cross-lamination provides relatively high strength and stiffness properties in both directions, with a two-way action capability similar to a reinforced concrete slab. CLT has better structural properties than the sawn timber it is composed of, because the cross-lamination process "dilutes" the effect of knots and fibre deviation, while it increases the resistance to splitting and the connector's holding capacity. The cross-laminating process provides improved dimensional stability and allows for prefabrication of wide and long floor slabs and wall panels. Therefore, CLT offers a number of advantages to developers, designers and builders with respect to comparable systems based on non-wood materials, including:

- significant reduced construction program durations
- improved installation speed for follow-on trades, i.e. mechanical, electrical facades and finishes
- high potential for off-site and/or on-site manufacturing, with more accurate tolerances
- lighter weight structures therefore lower requirements for foundations especially on weak soils or vertical extensions to existing buildings
- versatility for architectural design, i.e. overhangs and openings
- waste minimisation
- safer working environments on-site
- less demand for skilled workers on-site

CLT-based construction is typically faster and safer to erect on-site, and results in shorter construction times, which lowers development costs. Foundation costs can also be substantially reduced as CLT based construction is lighter than traditional concrete and steel construction. Erecting CLT is a quick and quiet process and takes up less space on-site and requires less truck movements compared to other building materials. This makes it suitable for infill sites and/or additions, increasing development viability of difficult sites.

CLT's versatility as a building system appeals to architects and engineers. Panels can be used for all assemblies by varying the thickness. Long spans are possible, i.e. up to 7.5 m, with no intermediate support. Longer spans require additional support from beams or trusses. CLT is one-fifth the weight of reinforced concrete so mobile cranes can be employed, saving substantial erection, hire and labour costs.

Most of the processing of CLT occurs off-site at the factory, so there are fewer demands on construction labour on-site. The erection of the structure usually only requires minimal carpentry skills and power tools. Wet trades are largely eliminated, little waste is produced and there is less disruption to site neighbours. As fewer trades are carried out on-site, this contributes to a safer building site. CLT construction is timber-based and fasteners are fixed into timber, not concrete, so follow-on contractors require less time.

## 1.3 CLT Applications

There seems to be no limit to where CLT can be used. To date, CLT has been used in Australia for housing, apartments, offices, educational, student accommodation, hotels, childcare, libraries, community centres, schools and agricultural buildings.

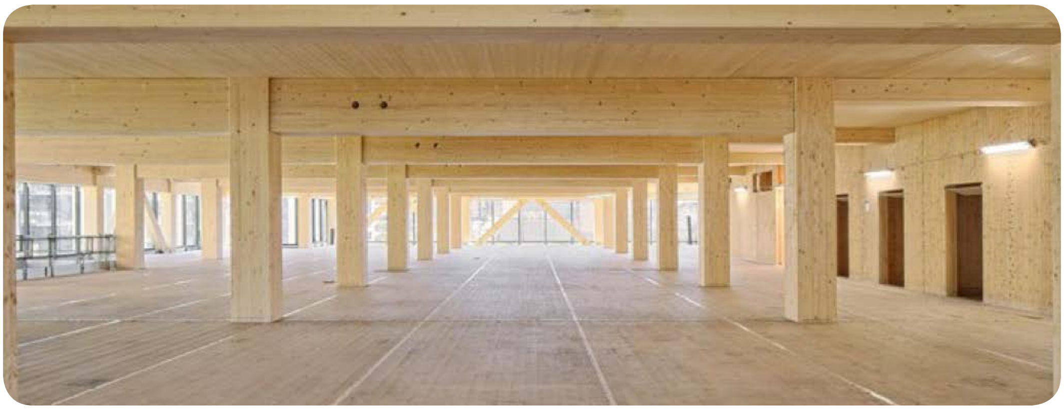


***Figure 1.3: CLT used as a floor and walls inside office building, K5 Brisbane.***
*Photograph: Lendlease*

***Figure 1.4: CLT used for apartment constrcution, AVEO Norwest.*** *Photograph: Strongbuild*

Internationally CLT has been used in similar applications as Australia as well as some unique applications such as wind turbines tower, bridge decks, water reservoirs, pools and so on.

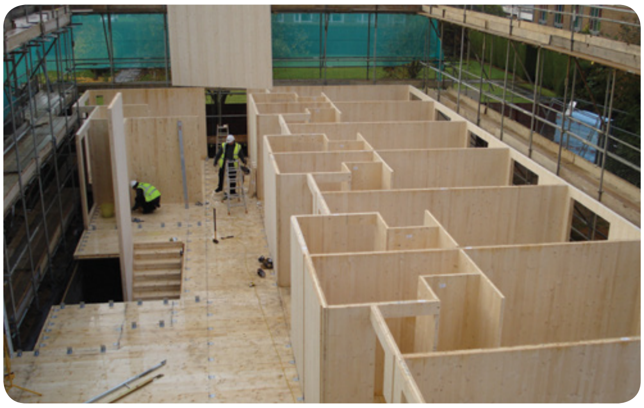
***Figure 1.5: Water reservoir.*** *Photograph: Structurlam*

***Figure 1.6: Mistissini Bridge, Canada using a CLT road platform.***
*Photograph: Nordic Structures*

***Figure 1.7: 100 m wind turbine tower***
*Photograph: Timber Tower*

## 1.4 Compliance to the National Construction Code

The National Construction Code (NCC) has a number of Deemed-to-Satisfy (DTS) buildings solutions for Massive Timber, which includes products such as CLT, Glued Laminated Timber, and Laminated Veneer Lumber. The predominant DTS solution used is termed 'fire protected timber' where the minimum criteria for massive timber to use this DTS solution is that the element is to be not less than 75 mm in each direction and that the element is chemically bonded; the application is for residential or an office buildings up to an effective height of 25 m. For housing and low rise residential buildings there are separate NCC DTS solution placing no limits on CLT use. Where there is no direct DTS solution within the BCA, such as other building types or taller buildings, CLT may still use but via a performance solution pathway.



***Left: 37 Snowfields.*** *Architect: DSDHA; Engineer: Structure Workshop; Contractor: Neilcott Construction; CLT Supply and Installation: KLH UK; Photograph : KLH UK*

***Right: Woodside Lodge.*** *Architect: David Grindley Architects; Engineer: Tapsell Wade & Partners*

## 1.5 Environmental Performance and Occupant's Health Benefits

CLT manufactured from timber that is certified as harvested from sustainably managed forests is readily available. Sustainably sourced CLT has a number of positive environmental characteristics, including:

- carbon absorbed by the sustainably grown trees is stored long-term
- production of CLT results in less greenhouse gas emissions than production of many non-wood building materials.

Many recent CLT structures have benefited from these environmental considerations. For example, two high-rise residential buildings in London obtained preferential approval from local planning authorities because of CLT's positive environmental characteristics compared to concrete and steel. The use of CLT could allow extra points to be obtained from Australia's Green Building Council, GreenStar rating tool, for example 'innovation' or 'structural timber use'.

CLT also has equivalent or better characteristics than functionally equivalent concrete and steel systems in other aspects of environmental performance, such as thermal inertia and insulations, resulting in far more comfortable living conditions.

In addition, using timber has health and productivity benefits for building's occupants. A recent study by Pollinate: Workplaces: Wellness + Wood = Productivity[1] showed employees surrounded with natural wooden surfaces on average reported higher personal productivity, mood, concentration, clarity, confidence and optimism and were more likely to find their workplaces relaxing, calming, natural-feeling, inviting and energising, resulting in significantly fewer sick leave days.

Natural elements that can be brought indoors include stone and wood, water features, plants, natural light and imagery depicting the natural world. The principle brings into focus our innate attraction to nature and implies that we all have an inherent connection to the natural world through centuries of living in agricultural settings.

An additional benefit is the massive timber has a 'buffering' effect on moisture. When the indoor environment is drier massive timber elements releases water vapour and the opposite occurs when the indoor environment is wetter, the massive timber absorbs the water in the air. Therefore the interiors of massive timber buildings will typically remain in the comfortable zone of relative humidity for longer periods.

2

# Manufacturing

## 2.1 Species Selection

The base species of timber used for CLT depends on where it is manufactured. Spruce is the main species used in Europe. Pine and larch can also be used on request. CLT plants in Canada or US use SPF (spruce-pine-fir) or Douglas fir. Production in New Zealand and Australia predominately uses radiata pine.

Although technically feasible, hardwoods are not presently used for CLT production as their ability to be fastened requires more work in erection, such as pre-drilling for screws. With that said, US hardwood producers have manufactured some hardwood CLT for demonstration purpose (Figure 2.1) and there has been an announcement of planned hardwood CLT production in Australia.

***Figure 2.1: London Smile made from American tulipwood hardwood CLT***
*Photograph: Alison Brooks architects*

There has also been early research work carried out on a hybrid combined softwood and hardwood CLT but it is not in production. Combined CLT and LVL systems have similarly been manufactured but tend to be on a project request basis.

## 2.2 Timber Laminates

Individual seasoned dimensional timbers are used, generally softwood. These are usually finger-jointed along their length to obtain the desired panel length and quality. Individual timbers can be edge-bonded together to form a timber plate before further assembly into the final panel.

## 2.3 Panel Assembly

Panel sizes vary by manufacturer and application, but typical widths are 0.6, 1.2, 2.25, 2.4, 2.7, 2.95 and 3.5 m (up to 4 m) while lengths up to 18 m or longer can be manufactured. Standard panel thicknesses are 57 to 300 mm, but some manufacturers can produce panels up to a thickness of 500 mm if required.

The outer layers of the panels are usually orientated to run parallel to the span or load direction. That is, for walls, the outer layers of the CLT panels are oriented in the short direct while for floor and roof CLT panels, the exterior layers run parallel with span direction, long direction.

One of the main differences between CLT manufacturers is their treatment of individual layers. Some manufacturers edge bond the individual dimensional timber together to form a layer before pressing each layer into the final CLT panel. Other manufacturers just face bond individual dimensional timber in layers and press all of them together into the final CLT panel in the one operation.

## 2.4 Adhesive

Generally, the choice of adhesives is dependent on manufacturers. The one-component polyurethane (PUR) adhesives are normally used as they are formaldehyde and solvent free.

Adhesives based on melamine urea formaldehyde (MUF) or phenol-resorcinol-formaldehyde (PRF) are also used. MUF is very-low formaldehyde emitting adhesive while PRF adhesives are ultra-low formaldehyde emitting, both meeting the most stringent low formaldehyde specification. Occasionally a mixture of adhesives are used, for example finger-jointed laminates often use different adhesives than used in the formation of the CLT panel.

## 2.5 Press

The right pressure is essential for both performances and aesthetic. Hydraulic presses are normally employed, however, the use of vacuum and pneumatic (compressed air) presses is also possible, depending on panel thickness and the adhesive used. Some presses also apply vertical and horizontal pressure to close the gaps between each board used to make up the CLT panel.

***Figure 2.2: XLAM Australia's pneumatic CLT press.*** *Photograph: XLAM*

***Figure 2.3: XLAM New Zealand's Vacuum Press.*** *Photograph: XLAM*

## 2.6 Panel Final Shape and Length

Computer numerical controlled (CNC) routers are generally used to cut the CLT panel to final length and width. Sometimes manufacturers also pre-cut openings for windows, doors, connections and service channels or ducts.


***Figure 2.4: XLAM Australia's CNC.*** *Photograph: XLAM*

## 2.7 Surface Finish and Appearance

The assembled CLT panels are sometimes planed or sanded for a smooth surface finish but this is not carried out by all manufacturers.

CLT panels can be specified for appearance grade on the outer layer of the panel for situations where they will be seen on completion of the building. CLT panels with appearance grade outer layers are more expensive and generally where required are arranged with the manufacture. Appearance specifications vary so consultation with manufacturers is required before selecting an appearance specification.

Some manufacturers also have wire-brushed surfaces that remove the early wood leaving a textured surface. Again, consultation with manufacturer is required.

***Figure 2.5: Wire-brushed surface of CLT.*** *Photograph: PlanetArk*

## 2.8 Transport Constraints for Panel Width and Length

Transportation may impose panel size limitations, so a discussion with the supplier is recommended before starting a building design. For example, imported CLT is generally transported via shipping container. The most commonly used standard shipping container (and the cheapest for transport) is 12.1 m × 2.35 m (internal length × width). The next most common is 5.89 m × 2.33 m (internal length × width).

The most efficient way of importing CLT is to use 2.25 m wide panels, are they can be packed horizontally into a standard container. CLT panel widths greater than 2.25 m have to be imported using open-top, out-of-gauge containers with the panels packed vertically rather than horizontally and they typically accommodate panel width up 2.95 m. Wider or longer panels require shipping using flat rack or MAFI containers. Open-top, flat rack or MAFI containers are more expensive than standard containers.

For standard containers, the maximum panel length is just less than 12 m, due to the overall internal length of the shipping container. Also, the maximum width is generally 2.25 m to allow the panel to negotiate the container's door opening. The length of panel requires consideration of using the maximum length of the panel as well as maximising the container used to transport the panels. For example, there is generally no cost penalty for 8 m long panels as they are cut out of a larger 'master panel' (see section 2.10 CLT Optimisation), which are normally 16 m in length. Therefore, two 8 m panels can be cut out of one 16 m master panel; however, 8 m panels are not an efficient size for standard containers. They are too long for 6 m containers and too short for 12 m containers.

For CLT manufactured in Australia, there are fewer size constraints and are directly dependent on road transport constraints. Ideally, panel sizes that don't require car escorts or special time of the day to travel cost less for transportation.

## 2.9 Site Access Constraints for Panel Width and Length

The constraints on the building site are often overlooked. Crane placement, trees or other buildings often interfere with the handling of large panels. Consideration should be given to these issues as well as transportation constraints.

## 2.10 CLT Optimisation

CLT optimisation needs to be considered during the design process. As discussed above, transport and site constraints affect panel size and costs. Panels are generally produced in the largest length that the manufacturer can make. These panels are termed 'master' or 'mother' panels and are optimised so that the least amount of material is wasted, as CLT cost is based not on the finished panel volume but the volume of CLT required to complete the order. Therefore, the most economical project will be delivered by considering transport constraints and the best use of master or mother panels.

Most CLT suppliers offer both optimisation and shop drawings services for a fee, or as part of the supply price of the product. The suppliers use their experience to calculate the most economical use of the master panel while considering transport constraints, usually resulting in project savings.

## 2.11 Mechanical Properties

As with other engineered wood products such as LVL and I-beams, the mechanical properties of CLT are timber species and manufacturer dependent. Mechanical properties are provided by each manufacturer on a proprietary basis, so reference should be made to each manufacturer's documentation during the design and specification process.

3

# Design and Compliance

## 3.1 Standards and Codes

There is currently no Australian Standard that covers CLT manufacturing or installation.

Although CLT has widely been used in Europe it is only recently (late 2017), that a Standard on the manufacturing of CLT was published, *EN 16351:2015 Timber structures - Cross laminated timber*[2].

Prior to this, the generally approval process in Europe has been based on a European Technical Approval (ETA) Guideline that contains specific requirements for the product as well as test procedures for evaluating it prior to submission to the European Organisation for Technical Approvals (EOTA) in order to allow individual manufacturers to place CE (Conformité Européenne) marking on their products. The ETAs provided by European CLT producers and related documents provide a lot of information for designers.

Since European CLT varies from manufacturer to manufacturer, it is expected that the European Standard will take some time before it is widely adopted. During this time European CLT producers are likely to continue with the ETA approach.

The North American timber industry has as well developed a national manufacturing standard. This Standard covers the manufacturing, qualification, and quality assurance requirements for CLT - *ANSI/APA PRG 320-2012 Standard for Performance-Rated Cross-Laminated Timber*[3]. Japan has also issued a product standard (JAS3079) in 2013.

## 3.2 Compliance to National Construction Code

**Structural Design**

The reference document in the NCC for timber structural design is AS1720.1[4]. This Standard may be applicable to CLT use, irrespective to what country the CLT was manufactured in, through the AS 1720.1 clause 1.3.1 (h) Other timber products and grade. This clause allows any timber product including CLT to be used within AS 1720.1, where the properties of the product are established by testing and evaluation methods consistent with AS/NZS 4063 Standard series. The only other provision is the modification factors for duration of load effect for strength and stiffness should be determined by authoritative research and the durability of adhesives used for manufacture should be appropriate for the exposure condition. Where CLT does not meet the conditions of this clause, it will require a performance solution approach.

**Fire Performance**

The NCC requires certain applications within a building to have a Fire Resistance Level. The NCC Provision A2.3 refers to NCC Specification A2.3 where a number of methods are detailed on how Fire Resistance Levels can be determined, i.e. by Standard Fire Test, an assessment based on a Standard Fire Test, calculations or by a referenced Standard. For CLT, the only options available to demonstrate compliance are test results or an assessment based on a Standard Fire Test. A Standard Fire Test is the test method described in AS 1530.4[5].

Regrettably the reference Standard for calculating Fire Resistance Levels for timber AS 1720.4[6] is not applicable to CLT as the Standard's scope is for Glue Laminated Timber, Plywood and Laminated Veneer Lumber compliant to their Australian manufacturing Standard only.

Where evidence is provided by fire test done by other International Standards that are similar to the Australian Standard test method, this information may be used as evidence for a performance solution or data for an assessment by an Accredited Testing Laboratory.

## 3.3 Design

Although CLT is a relatively simple building system it is new and uncommon to many designers, particularly when used in building applications that traditionally don't use timber based systems. To alleviate this most CLT suppliers in the Australian marketplace have proprietary documentation to assist designers as well as design services. Most CLT suppliers also have preliminary design guidelines and/or software tools to size CLT elements. WoodSolutions Guide No 44 *CLT Acoustic Performance*[7] provides a summary of CLT-based wall and floors systems that were tested using Australian acoustic products and methods.

# 4 CLT as a Building System

The high level of prefabrication and simplicity of handling CLT panels in construction enables a rapid erection time and reduces overall construction program durations. Openings for windows, doors, staircases and other utilities can be pre-cut using CNC machines at the factory.

Buildings are usually assembled on site. The prefabricated CLT panels are transported to the site, where they are connected with mechanical fastening systems such as self-tapping screws and brackets. It is also possible to assemble elements or modules of the building off-site and deliver completed segments of the building to the site. This speeds up the construction process even further.

***Figure 4.1: Site assembled CLT core.*** *Photograph: Lendlease*

CLT is a flexible and lightweight building system, allowing for long spans and use in all assemblies (such as floors, walls or roofs) with a high degree of finishing preinstalled at the factory. Its ability to be used as a panelised and/or modular system makes it ideally suited for additions to existing buildings. CLT can be used jointly with any other material, such as light timber frames, heavy timbers, steel or concrete, and it accepts varied finishes.

***Figure 4.2: Monash University Business School vertical extension.*** *Photograph: XLAM*

## 4.1 Building Layout

Each building material has its own efficient span and spacing and CLT is no different. For the most cost-efficient CLT building, it is necessary to consider efficiencies of the CLT in the layout of walls and support, etc, before committing to a design layout. Often, CLT is considered as an alternative construction method in a building that was first designed for concrete. In this case, the concrete building would in most cases be cheaper as the span and spacing are optimised for concrete not CLT.

Therefore, for a CLT design to be cost effective it needs to be designed initially with CLT in mind. The largest constraint on CLT design is generally the transport limitations discussed earlier that may restrict panel sizes, although this has recently been alleviated to some extend by local production. For example if an imported CLT floor panel is considered; where supports are greater than 6.0 m, it may not be possible to achieve continuous span floors as the CLT panel would need to be greater than 12.0 m, beyond a shipping container size. This results in simply supported floors that are deeper and more expensive. Consequently for imported CLT floor panels keeping the floor supports at 6.0 m or less results in design efficiencies.

The fundamental design of a CLT building is conceptually similar to the design of a lightweight timber frame platform construction systems, where wall support vertical loads and provide bracing. Floors take floor loads as well as acting as diaphragms to transfer loads to bracing elements or the core. Deflections and vibrations of floor elements need to be considered as they might often be the limiting factor in structural design. Connections are generally considered to be semi-rigid.

The basic rules for structural layout are:

- The building should have a modest ratio of height to footprint dimensions. Slender shapes are possible with some precautions.
- The arrangement of structural elements is similar to a series of ‘stacked boxes’ where the walls provide sufficient bracing and resistance to vertical loads.
- The floors act effectively as horizontal diaphragms with high in-plane rigidity and resistance to out-of-plane buckling.
- CLT panels offer a lot of space to position connections offering design efficient both in the vertical and horizontal directions.

Experience has shown the most efficient CLT structure occurs when the selection of the supplier is made early. Juggling issues such as panel size constraints, differences in CLT properties, etc, are reduced once a CLT supplier is selected.

# 5 The Building Process

**The CLT panels are divided into 'elements'. These elements are usually numbered and shipped according to an assembly plan. Installation typically needs a mobile crane, light power tools and a small crew of riggers and/or carpenters and mobile crane operators.**

## 5.1 Planning

The accurate planning of the supply, delivery and construction phases is important to get all the benefits that CLT structures brings to a project. Efficiencies in erection are achieved when due consideration and time is given to accurately planning and documenting the sequence of delivery, on-site handling operations and assembly methods. The following is a non-exhaustive list of considerations for the planning for a CLT structure:

- Design CLT elements to be the largest size possible to reduce crane movements on site. CLT's lightweight panels can be fabricated and delivered to site as large elements.
- Reduced site storage by just-in-time delivery scheduling, therefore a factory loading order that considers the unloading sequence and pre-fitting of lifting devices is recommended. CLT suppliers can provide an analysis of the construction sequence and lifting requirements as part of their services.
- Pre-install connectors and other items on the ground or off-site.
- Pre-fitting of linings on both CLT surfaces, slots and holes is easy and quick, as well as moisture protections.
- Assemble items on the ground or off-site.
- Practise the lifting sequence virtually before building on site. Virtually modelling the building's assemble identifies road blocks and allows correction before being on-site.
- CLT's interface with concrete slows things down by half. Think about better ways to connect timber to concrete.
- CLT's reduced weight decreases crane loads compared to other panel construction materials, allowing for smaller crane requirements and shorter use periods.
- Early provision of a stable structure without the need of temporary props allows the follow-on trades to commence earlier.
- Should any unforeseen change need to happen on site, e.g. the position of an opening, then CLT allows quick and easy modification with hand-held carpentry tools.

## 5.2 Site Assembly

For general construction, the delivery truck or trailer will park near the structure while each panel is offloaded and fixed into place. Panels are loaded onto the truck or tailer in the reverse sequence that they will be required for installation. Where it is not possible to install CLT panels immediately, they can be off-loaded and stored off the ground, under a waterproof covering. Due to the light weight of the panels, it is also possible to use the building itself as a temporary storage place, e.g. lift a bundle of panels on the floor where installation is progressing and let the truck leave. Storage and delivery options should be fully explored to minimise double handling.

***Figure 5.1: Trailers used to store panels before installation on site.*** *Photograph: TDA*

Panels are lifted into place using pre-inserted hooks or slings for walls, while floors are usually lifted with screws driven into the panel surface and specific hooks that clamp onto their screw head.

Walls are usually placed on top of a grout bed for CLT/concrete connections and foam, cork or elastomeric strips for CLT/CLT connections where fixing plates are positioned along the line of the walls. Elastomeric supports may also be used to reduce flanking noise.

Sealing tapes are sometimes applied to the end grain and connections of CLT panels to reduce potential for moisture uptake and to form airtight constructions.

***Figure 5.2: Slings and brackets used to support CLT panels during lifting.***
*Photograph: WoodSolutions*

The panel-to-panel connections can be pre-cut and established through half-lapped, single or double splines made with engineered wood products, or made with steel connectors; plates, angles and screws.

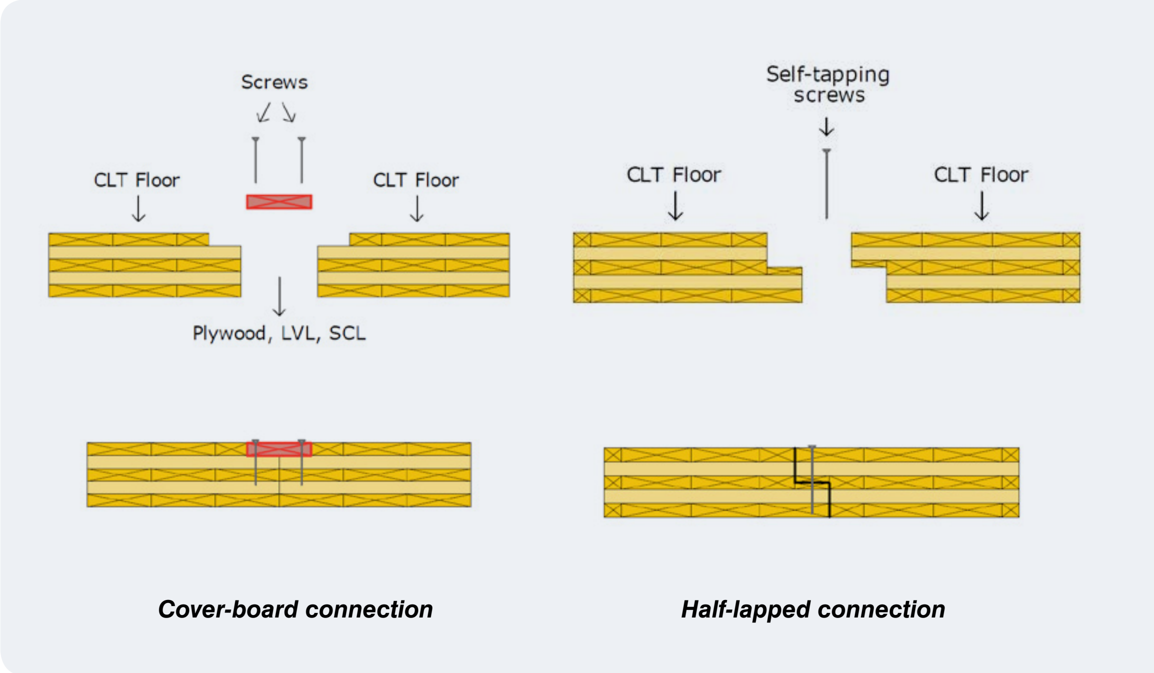



**Figure 5.3: Methods to join CLT floors panels together.**
*Source: CLT Handbook: Cross-laminated Timber (U.S. Edition 2013) FPInnovation*

Metal brackets, hold-downs and plates are typically used to transfer forces. Innovative connection systems can also be used, including glued-in rods or plates, mechanical (clips, dovetail plates, etc) and carpentry connection systems.

**Figure 5.4: Wall to floor connection.** *Photograph: TDA*

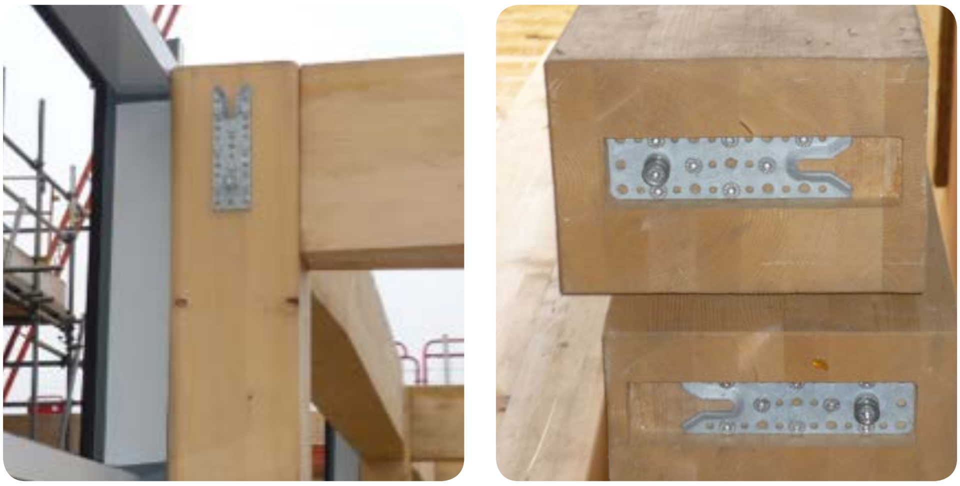


**Figure 5.5: Specialist Timber Connector.** *Photograph: TDA*

Floor and walls are brought together with clamps for their final placement.

***Figure 5.6: Special clamp used to align CLT floors.*** *Photograph: WoodSolutions*

## 5.3 Utilities

Electrical, HVAC and water distribution services are typically placed within suspended ceilings, false walls or specific cavities. Brackets used to support services are usually easy to install as they are screwed into timber with lightweight tools, instead of fixed to concrete with expensive anchors and heavy tools, thus resulting in shorter construction programs and optimised costs.

Using CLT panels also for the lift shafts and staircases is normally the preferred option, as the panels are strong and stiff enough to provide sufficient resistance to lateral loads and avoids the need to introduce wet trades into the project.

***Figure 5.7: Lift shaft in Stadthaus, Murray Grove.*** *Architect: Waugh Thistleton; Engineer: Techniker; Contractor: Telford Homes; CLT Supply and Installation: KLH UK; Photograph: TDA*

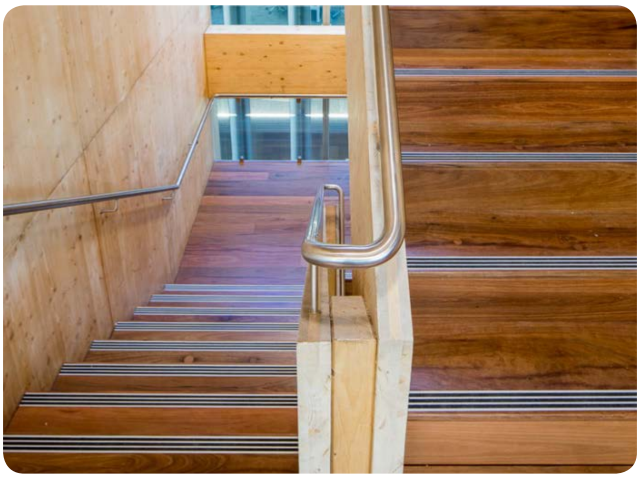


***Figure 5.8: Fire stair in International House, Sydney.*** *Photograph: Lendlease*

***Figure 5.9: Figure 4.8: Lift installed in CLT shaft in International House, Sydney.***
*Photograph: Lendlease*

# 6 Properties of CLT Assemblies

## 6.1 Structural Performance

CLT panel's strength and stiffness are predominately produced from the outer load direction laminations. Transverse and central laminations primary function is to hold the outer lamination apart and provide the panel's stability.

Timber boards used to manufacture CLT are generally not homogeneous throughout the panel and the layup, thickness and grade vary from manufacturer to manufacturer. As stated above there is no Australian manufacturing standard for CLT, therefore CLT panel properties are proprietary in nature. Reference to the supplier for their individual properties is required.

Many of the CLT suppliers have preliminary size information that can be used to initially design CLT buildings.

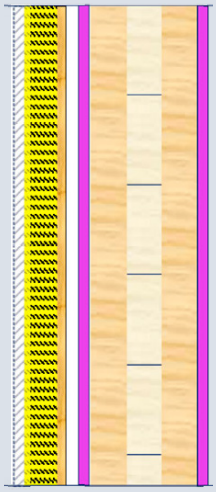
## 6.2 Fire Performance

CLT assemblies have excellent fire resistance due to the thick cross-sections that char at a slow and predictable rate when exposed to fire. CLT construction typically has fewer concealed spaces within wall and floor assemblies than framed construction, which reduces the risk of hidden fire spread.

The NCC has a number of deemed-to-satisfy fire solutions suitable for CLT use. The predominate DTS fire solution is for walls within buildings with an effective height of 25 m or less, sprinkled and protected by fire protective coverings. This solution is generally termed fire-protected timber and currently is applicable for residential and office buildings. Within this provision, two timber systems are recognised Massive Timber and Timber Framed. CLT fits in the Massive Timber provisions. CLT fire rated solutions may also be used for other NCC DTS solutions for low-rise timber buildings as well as housing.

Generally, the NCC's Fire Protected Timber DTS solution requires a layer of fire-resisting plasterboard as the fire protective covering. Fire-resisting plasterboard is not the only fire protective covering that can be used. Any non-combustible covering that resists the temperature rise on the timber surface for a period of time can be used. The time for this temperature rise varies depending on location and application within the building. Refer to WoodSolutions Guide No 37[8] and No 38[9] for more information on this NCC DTS. The fire resistance level required for fire protected timber systems are no difference to that required by other materials.

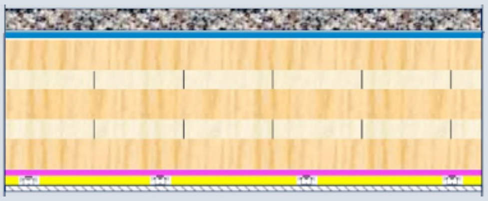
The fire protective covering used to protect CLT can also be used to reduce the thickness of the wall or floor CLT panel required for the fire design. Standard fire tests have been conducted on wall and floor systems, see Figure 6.1 for common solutions.

| Configuration | |
| --- | --- |
|  | Lining<br>Stud frame<br>75mm glasswool insulation<br>Gap<br>16mm fire-rated plasterboard<br>90mm Cross-Laminated Timber (CLT)<br>16mm fire-rated plasterboard |

| System | Test | Lining | Stud Frame | Thickness (mm) | $R_w$ | $R_w + C_{tr}$ | STC |
| --- | --- | --- | --- | --- | --- | --- | --- |
| W02-05 | T1617-89 | 2x13mm standard plasterboard | 70mm timber stud 20mm gap | 238 | 58 - 59 | **52** | 58 - 59 |
| W03-04 | T1617-44 | 2x13mm standard plasterboard | 64mm steel stud 20mm gap | 232 | 59 - 60 | **52** | 60 - 61 |
| W03-05 | T1617-46 | 1x13mm sound-rated plasterboard | 64mm steel stud 20mm gap | 219 | 58 - 59 | **50** | 59 - 60 |
| W03-06 | T1617-47 | 2x13mm sound-rated plasterboard | 64mm steel stud 20mm gap | 232 | 60 | **53 - 54** | 60 - 61 |

***Figure 6.1: Typical CLT fire and sound rated wall system***

**Configuration**



Floor
40mm screed
10mm rubber underlay
140mm Cross-Laminated Timber (CLT)
16mm fire-rated plasterboard
67mm furring channel ceiling with Resilient mounts
50mm glasswool insulation
13mm standard plasterboard

| System | Test | Floor Covering | Thickness (mm) | $R_w$ | $R_w + C_{tr}$ | STC | $L_{n,w}$ | IIC |
|---|---|---|---|---|---|---|---|---|
| F11-01 | T1617-52 | Bare screed | 286 | 60 - 61 | **52 - 54** | 60 - 62 | **53 - 55** | 55 - 57 |
| F11-03 | T1617-53 | 7mm laminate timber floor 3mm foam underlay on Screed | 296 | 60 - 61 | **51 - 54** | 60 - 61 | **52 - 53** | 54 - 57 |

***Figure 6.2: Typical CLT fire and sound rated floor system***

As CLT is timber, there are some instances where its inclusion in buildings will not meet the Deemed-to-Satisfy fire performance requirements in the NCC, for example exposed CLT used for walls within the fire protected timber DTS. Where this occurs a Performance Solution compliance path is required. A number of structures have taken this path to date and have obtained approval. For further information, refer to WoodSolutions Guides No 2[10], No 3[11], No 17[12], No 18[13] and No 19[14].

## 6.3 Acoustical Performance

The acoustic performance of CLT is excellent because of timber's natural damping ability and, if considered with reference to the mass per unit surface area, it is better or equivalent to other forms of panel construction. As with other forms of construction, the CLT systems are not entirely reliant on the CLT itself to deliver the required performance. That is, overall performance depends on providing independent leafs of construction via two CLT panels, or a CLT and framed construction with cavities generally having insulating materials included.

Floor construction generally includes a separated ceiling below the CLT panel. Floor acoustics performance can be increased in a number of ways. In Europe, concrete screeds, battens, dry sand or gravel and other proprietary materials are sometimes used, that may include floor heating. These systems generally easily exceed the NCC minimum requirements, with the ultimate choice of system dependent on the level of acoustic performance required for the project. Refer to Figure 19 and 20 for typical wall and floors system incorporating CLT as well as WoodSolutions Guide No 44[7].

As with all building structures, some corrective measures during construction are needed to reduce flanking noise. Polyurethane sealant damping strips or laminated natural rubber or cork in the junction of the floor-to-wall will reduce flanking noise as well as make the structure air tight. Having discontinuous walls across stories and discontinuous floors across units helps prevent flanking noise. Installing floating floors may also assist. All these acoustic strategies are consistent with any building system, irrespective of the material of construction used.

***Figure 6.3: Polyurethane flanking strip under CLT floor.*** *Photograph: Rothoblaas*

## 6.4 Thermal Performance

CLT has the same fundamental thermal properties as the timber it is made from. Timber generally has a low thermal conductivity, high thermal inertia and strong moisture buffering ability. It also reduces problems such as thermal bridging from the internal to the external environments or the reverse, resulting in reduced heat transfer and energy wastage.

CLT-based exterior walls will also provide a degree of insulation higher than that provided by exposed solid masonry construction, which can reduce energy use in buildings such as apartments that are not constantly occupied. European studies and built experience suggest that CLT provides a degree of thermal mass for a building; due to increased wall system density compared to framed construction.

External walls usually have a weather-protecting layer of masonry or commercial façade, such as cementitious panels, wood based panels or metal cladding. In the cavity between the exterior weather protecting envelop and CLT, insulation is placed to obtain the desired level of building envelope thermal efficiency. As with all building materials and systems, care is required to consider where condensation may occur within the external wall cavity and therefore vapour permeable materials are always preferred. Where dew point calculations are undertaken, the dew point should occur on the outside of the vapour permeable membrane, never in the CLT or interior of the building.

Due to a high degree of manufacturing precision, good air tightness may also be achieved with CLT. Foam tape is normally used at the joints for this purpose.

## 6.5 Durability

As the species used for CLT production is generally softwood, which is generally of low natural durability when used untreated in exposed applications, it is not recommended to directly expose the panel to exterior conditions. Normally, CLT buildings have a weatherproof layer of masonry or commercial facade. A cladding of naturally durable or appropriately preservative-treated wood product may also be used.

### 6.5.1 Termite Resistance

CLT's termite resistance performance is considered the same as would apply to the same timber species used in timber-framed construction. CLT is predominately made from termite susceptible timber species but some CLT producers can preservative treat the CLT on demand. If termite protection is required, the building should be protected in accordance to the principles contained in AS3660[15].

### 6.5.2 Decay Resistance

Again the base timber species used predominately for CLT production are non-durable. CLT made from spruce or Douglas fir are difficult to preservative treat to Hazard Level 3 or higher. Australia and New Zealand produced CLT are normally from pine timber such as radiata that can have the base lamination preservative treated to Hazard Level 3 or higher if required.

### 6.5.3 Weather Protection

Due to the quick erection time of CLT-based systems, the short-term exposure of CLT to weather will not usually have a long-term effect. The work sequence should be planned to reduce weather exposure of the panels as much as possible and this should be maintained until the building is closed in. During construction, wall elements can be protected with vapour barriers or the building's scaffolding can be wrapped to form this protection. Other strategies could be employed, such as a coating system for the construction period only.

As CLT buildings are generally air tight, and consequently water tight, strategies to deal with storm water during construction are required. Ponding water should be brushed off as early as is practical. As discussed above, long-term direct weather exposure of CLT is not recommended.

## 6.6 Seismic Performance

In 2008 the National Research Council of Italy, Trees and Timber Institute (IVALSA) tested three and seven-storey, full-scale CLT buildings in a Japanese research facility that has the largest quake simulation 'shaking table' in the world[16]. Each building was exposed to large simulated earthquakes subjected to severe earthquake motions, like that of the devastating Kobe earthquake with a magnitude of around 7.0.

In the case of the three-storey building, which was tested 26 times, damages to connections where achieved as predicted and no unforeseen damages was observed in the CLT panels, thus allowing for a 'Zero Damage Design' approach to be developed. This means the structural safety and serviceability of the building is maintained and repairs are possible in those joints that are deemed to be yielding under the design quake loads.

Based on the previous experiences, in the case of the seven-storey building there was no residual deformation after 14 test quakes, again the Zero Damage Design approach was validated. The maximum inter-storey drift was 40 mm (1.3% of ceiling height), while the maximum lateral deformation at the top of the building was only 287 mm. The CLT buildings showed ductile behaviour and good energy dissipation, as expected. Such behaviour was both influenced by the cross-lamination effect and by the design of the connections, which can be repaired or re-integrated after a quake event while the CLT panels are only damaged for a few millimetres around the connectors by embedment (crushing). Further work has recently been done on seismic performance in North America[17] and Japan.

***Figure 6.4: 7 storey CLT building on a shake table***
*Image: National Research Council of Italy, Tree and Timber Institute (IVALSA)*

## 6.7 CLT Manufacturers and Further Information

CLT availability into the Australian market is rapidly changing with local and imported product available. There are currently two manufacturers of CLT in Australia, one on the east coast and another on the west coast. Imported CLT is predominately supplied from Europe and New Zealand.

As manufacturers and suppliers of CLT are rapidly changing updated information and details are available from the Suppliers listing on the WoodSolutions web site: www.woodsolutions.com.au

# 7

# Case Study: Forté

***Figure 7.1: Completed Forté apartments.*** *Photograph: Lend Lease*

## 7.1 Design Professionals

- Architects: Lend Lease
- Structural Engineers: Lend Lease
- Services Designers: Lend Lease
- Fire Safety Engineers: Scientific Fire Services
- Acoustic Engineers: Renzo Tonin
- CLT Supply: KLH UK
- Building Surveyor: City of Melbourne – Melbourne Certification Group

## 7.2 About Forté

Forté Living is a 10-storey apartment building made from cross-laminated timber. At 32.2 m, it is currently the world's tallest timber apartment building and also the first Australian building constructed with CLT.

The building is made from 759 CLT panels made of European spruce (*Picea abies*), weighing 485 tonnes. The European spruce was harvested and panels manufactured in Austria, before being shipped to Australia in 25 shipping containers.

The timber structure was connected with 5,500 angle brackets using 34,550 screws.

Forté's ground and first-storey floor slab were constructed from geoploymer concrete. This was due to the larger spans required in the retail space and the need for general good practice to have the timber away from the ground.

Once the concrete had set, the CLT panels were transported from their storage site a short distance away. The panels were raised into their final position and connected together with screws and metal brackets. The first panels erected were those forming the stair and lift core, which were stood vertically. When these core panels were in place, others were laid on their sides to form internal and external walls. The panel width forms each storey height of the building.

Panels were laid on top of the walls to form floors. This process was repeated until the full height of the building was reached. The roof was constructed the same way as each floor.

***Figure 7.2: Forté under construction.*** *Photograph : Lend Lease*

***Left: Figure 7.3: Interior view of Forté prior to internal linings being affixed. Steel elements projecting into corridor are pre-fabricated bathroom pods.*** *Photograph : Lend Lease*

***Right: Figure 7.4: Completed Interior of Forté Apartment.*** *Photograph : Lend Lease*

The exterior of the building is clad with metal commercial façade consisting primarily of AluBond®; however, parts were also covered with Lysaght® products and recycled hardwood timber. These finishes provide the rain-screen protection to the CLT structure.

The balconies are an extension of the CLT flooring of the main building structure. The CLT is covered with concrete screed and a waterproof membrane is finished with tiles. The CLT used in each apartment's balcony floor is exposed on the underside, with a timber stain and seal polyurethane used to protect the timber.

The interior of the apartments is lined with plasterboard and painted. Other than a featured internal CLT wall, there is no indication that the building is constructed from timber.

The featured CLT wall is sealed with a clear coat to blend in with the light colours used elsewhere in the interior. An Australian hardwood blackbutt engineered wood floor is used throughout the living areas.

## 7.3 Environmental Benefits

All CLT used in Forté is harvested from sustainably managed spruce forests in Austria while the blackbutt floor is from sustainably managed forests in Austarlia.

A full life cycle assessment by staff of RMIT University compared Forté with a standard apartment building constructed with reinforced concrete. The carbon footprint of Forté, including the transport from Austria, was 22% lower if carbon storage in the timber was included and 13% lower if carbon storage was not included. If the carbon footprint of the building materials alone were considered, the carbon footprint of the Forté building was 30% lower than the concrete-reinforced building.

The 485 tonnes of CLT used in the building construction equates to 216 tonnes of stored carbon that absorbed 792 tonnes of $CO_2$ during its growth (based on 12% moisture content and carbon content of 50.5%, by weight. In comparison to a standard concrete and steel building, Forté reduces $CO_2$ emissions by more than 1,451 tonnes, the equivalent to taking 407 cars off the road for a year.

(This calculation is based on information from the Australian Bureau of Statistics[6] and the Australian Government greenhouse gas emissions calculator 2008, estimating average $CO_2$ emissions for a passenger car in one year at 3.56 tonnes.)

The building also achieved Australia's first 5-star Green Star Multi-Unit Residential As Built rating.

## 7.4 Fire Resistance

Fire resistance is a key issue. When this building was constructed, the CLT system used did not meet the deemed-to-satisfy requirements of the NCC, requiring a performance solution. CLT walls are generally comprised of CLT panels 128 mm thick with 13 mm fire-resisting plasterboard direct fixed to both sides. The bare timber walls used as a feature in the Forté apartments are 128 mm thick CLT. All required walls achieve the required deemed-to-satisfy fire rating FRL of 90/90/90.

The floors are generally 146 mm thick with two layers of 16 mm fire-resisting plasterboard, again direct fixed. The floors exceed the required deemed-to-satisfy fire rating FRL of 90/90/90.

The external walls use a combination of fire-resistant plasterboard and the calculated char capacity of timber itself. Fire safety engineering analysis considered them to achieve the deemed-to-satisfy fire rating from the inside. However, the analysis showed it did not meet the deemed-to-satisfy requirements for a fire exposure from outside in some circumstances. The outer layer of CLT to one elevation where the building is exposed within 6 m of another allotment is thickened to provide the resistance to fire from that direction.

Penetrations through all fire-rated elements are dealt with by the usual methods, however, extensive testing according to the Australian Standards was done to demonstrate compliance with the Standard and applicable requirements of Part A of the NCC – Volume One.

Sprinklers have also been used. They were not included as deemed-to-satisfy but allowed consideration of particular concessions according to Victorian variations to the NCC. It is also noted that sprinklers provide social sustainability to the occupants of the building through minimising any disruption or relocation if there is a fire.

## 7.5 Acoustics

The system used in Forté meets and exceeds building code deemed-to-satisfy minimum requirements. The floors use a combination of products to deal with airborne sound as well as impact noise. The floors in the living area are engineered timber and any hard surface floors require greater impact noise consideration.

Forté uses a number of techniques – such as concrete screed topping, direct fixed and/or resilient mounted plasterboard and suspended ceiling and resilient mat – to improve airborne and impact noise, similar to standard construction. A thicker than normal concrete screed was used to match the floor height of the pre-fabricated bathrooms that were also used on this project.

Bulk insulation has been placed in the cavity of the suspended ceiling and direct fixed plasterboard. Wall systems use the addition of frames lined with plasterboard to provide acoustic isolation between apartments.

***Figure 7.5: Cross section model of floor construction used in Forté.***
*Photograph: TDA*

8

# References & Further Reading

## References


1. Pollinate: *Workplaces: Wellness + Wood = Productivity*.
2. EN 16351:2015 *Timber structures - Cross laminated timber*.
3. CLT - ANSI/APA PRG 320-2012 *Standard for Performance-Rated Cross-Laminated Timber*
4. AS 1720.1. *Timber Structures Part 1: Design Methods.*
5. AS 1530.4 *Methods for fire tests on building materials, components and structures Part 4: Fire-resistance test of elements of construction.*
6. AS 1720.4 *Timber Structures Part 4: Fire resistance for Structural Adequacy of Timber Members*.
7. WoodSolutions *Guide No 44 CLT Acoustic Performance.*
8. WoodSolutions *Guide No 37 Mid-rise Timber Buildings Class 2, 3 and 5 Buildings.*
9. WoodSolutions *Guide No 38 Fire Safety Design of Mid-rise Timber Buildings Basis for the 2016 changes to the National Construction Code.*
10. WoodSolutions *Guide No 2 Timber-framed Construction for Multi-residential Buildings Class 2 & 3.*
11. WoodSolutions *Guide No 3 Timber-framed Construction for Commercial Buildings Class 5, 6, 9a & 9b.*
12. WoodSolutions *Guide No 17 Alternative Solution Fire Compliance, Timber Structures.*
13. WoodSolutions *Guide No 18 Alternative Solution Fire Compliance, Facades.*
14. WoodSolutions *Guide No 19 Alternative Solution Fire Compliance, Internal Linings.*
15. AS3660 *Termite management – New building work.*
16. Ceccotti, A. (2010) *Cross Laminated Timber Introduction to Seismic Performance, Trees and Timber* Institute IVALSA-CNR National Research Council, Italy. Available at www.bcwood.com/resources/cross-laminated-timber-symposium-presentations/
17. Popovski (2010) *Seismic Performance of CLT Construction. FP Innovations*. Available at www.cecobois.com/index.php?option=com_content&view=article&id=315&Itemid=199.


## Further Reading

The WoodSolutions Guides are available to download for free from www.woodsolutions.com.au in the resources section.

*No 2 Timber-framed Construction for Multi-residential Buildings Class 2 & 3*

*No 3 Timber-framed Construction for Commercial Buildings Class 5, 6, 9a & 9b*

*No 17 Alternative Solution Fire Compliance, Timber Structures*

*No 18 Alternative Solution Fire Compliance, Facades*

*No 19 Alternative Solution Fire Compliance, Internal Linings*

*No 37 Mid-rise Timber Buildings Class 2, 3 and 5 Buildings*

*No 38 Fire Safety Design of Mid-rise Timber Buildings Basis for the 2016 changes to the National Construction Code*

*No 44 CLT Acoustic Performance*


# Discover more ways to build your knowledge of wood

If you need technical information or inspiration on designing and building with wood, you'll find WoodSolutions has the answers. From technical design and engineering advice to inspiring projects and CPD linked activities, WoodSolutions has a wide range of resources and professional seminars.

**www.woodsolutions.com.au**

Your central resource for news about all WoodSolutions activities and access to more than three thousand pages of online information and downloadable publications.

**Technical Publications**

A suite of informative, technical and training guides and handbooks that support the use of wood in residential and commercial buildings.

**WoodSolutions Tutorials**

A range of practical and inspirational topics to educate and inform design and construction professionals. These free, CPD related, presentations can be delivered at your workplace at a time that suits you.

**Seminars and Events**

From one day seminars featuring presentations from leading international and Australian speakers to international tours of landmark wood projects, WoodSolutions offer a range of professional development activities.

**What is WoodSolutions?**

Developed by the Australian forest and wood products industry for design and building professionals, WoodSolutions is a non-proprietary source of information from industry bodies, manufacturers and suppliers.

Wood
Solutions™
design and build
woodsolutions.com.au