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Massive Timber Construction Systems

Cross-laminated Timber (CLT)

Technical Design Guide issued by Forest and Wood Products Australia

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Introduction

The next generation of massive timber building systems is transforming how buildings in Australia are designed and constructed.

Products that make up massive timber construction include:

- Cross-laminated timber (CLT)
- EXPAN: post-stressed frames and box beams
- Glulam and laminated veneer lumber (LVL) post and beam systems.

This guide discusses one of these products: cross-laminated timber.

1

What is Cross-laminated Timber?

Cross-laminated timber (CLT) is "a prefabricated solid engineered wood product made of at least three orthogonally bonded layers of solid-sawn timber or structural composite lumber (SCL) that are laminated by gluing of longitudinal and transverse layers with structural adhesives to form a solid rectangular-shaped, straight, and plane timber intended for roof, floor, or wall applications".[1]

CLT panels consist of several layers of timber boards stacked at right angles. They are glued together on their wide faces and usually on the narrow faces as well. The panel can have three to seven layers or more (usually an odd number), which are symmetrical around the middle layer.

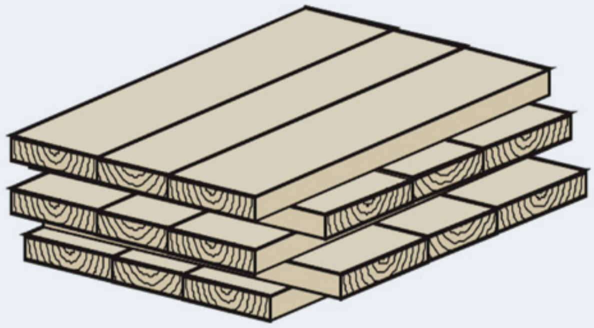


Figure 1: Layers of boards making up CLT

Dimensional seasoned timber is used. Low structural grades are most often used for the interior layers and higher structural grades for the outside layers. While softwoods are most often used, it is feasible to manufacture CLT using hardwoods or engineered wood products such as LVL or Glulam. 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.

The cross-laminating process provides improved dimensional stability and allows for prefabrication of wide and long floor slabs and wall panels.

Panel sizes vary by manufacturers, but typical widths are 0.6, 1.2 and 3 m; lengths can be up to 18 m; and thicknesses up to 500 mm. The limiting factor on size is usually the ability to transport the product. For imported CLT, the size may also be limited to what can fit into 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 timber'.

Archway Early Years Centre
Architect: Kay Hartmann Architects; Engineer: Fluid Structures; Timber Engineer: Techniker; Contractor: Durkan; CLT Supply and Installation: KLH UK; Photograph: KLH UK

1.1 History

CLT was initially developed in Switzerland 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, 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, Switzerland and Sweden. Outside Europe, plants have been established in Canada and New Zealand. Currently, there is no CLT production in Australia.

1.2 CLT Benefits

CLT offers a number of advantages to developers, designers and builders including:

- reduced construction program durations
- off-site manufacturing
- lighter weight structures
- versatility
- waste minimisation
- safer working environments on-site
- less demand for skilled workers on-site
- improved installation speed for follow-on trades, i.e. mechanical and electrical.

CLT-based construction is potentially faster and safer to erect, 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.

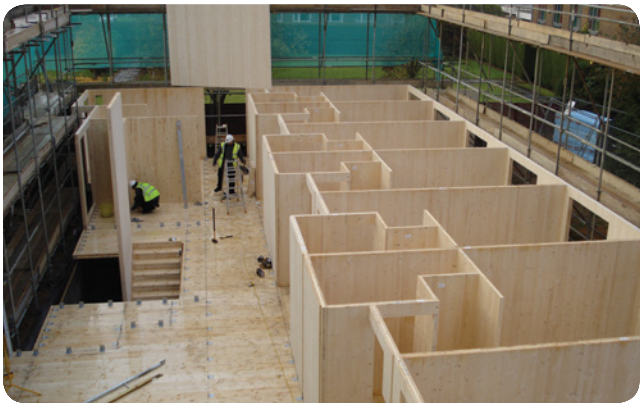
Erecting CLT is a quick and quiet process and takes up less space on-site. This makes it suitable for infill sites and/or additions, increasing development viability of difficult sites.

pliant with the Deemed-to-Satisfy Provisions of the NCC carries no such design risk for fire safety.

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 columns or beams and trusses or EXPAN post-stressed box beam and column system.

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 work occurs off-site at the factory, so there are fewer demands on construction labour on-site. The erection of the structure usually only requires 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 site. CLT construction is timber-based and fasteners are fixed into timber, not concrete, so follow-on contractors require less time.



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; Contractor: Deejak Builders; CLT Supply and Installation: KLH UK; Photograph : KLH UK

1.3 Environmental Performance

CLT manufactured from timber that is certified as harvested from sustainably managed forests is readily available. This 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 benefitted from these environmental considerations. For example, two high-rise residents in London obtained preferential approval from local planning authorities because of CLT's positive environmental characteristics compared to concrete and steel.

CLT also has equivalent or better characteristics than functionally equivalent concrete and steel systems in other aspects of environmental performance, such as thermal performance.

2 Manufacturing

2.1 Species Selection

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

Although technically feasible, hardwoods are not normally used for CLT production as their ability to be fastened requires more work in erection, such as pre-drilling for screws. There has been some early research work on a hybrid softwood and hardwood CLT but it is not in production. Combined CLT and LVL systems are available from Germany and New Zealand.

2.2 Timber Laminates

Individual seasoned dimensional timbers are used, generally softwood. These are usually finger-jointed along their length to obtain the desired lengths and quality. Individual timbers can be edged 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 and 2.95 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 panels can be created up to a thickness of 500 mm if required.

The outer layers of the panels are usually orientated to run parallel to the span direction. That is, for walls that are normally oriented, the outer layers of the CLT panels have the grain direction parallel to vertical loads to maximise resistance. Similarly, for floor and roof CLT panels, the exterior layers run parallel with span 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 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 as there is no current manufacturer of CLT in Australia, all CLT is imported and the easiest and cheapest method of transport is via shipping container.

The most commonly used standard shipping container (and the cheapest for transport) is 12.01 m × 2.33 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 panel packed vertically rather than horizontally (maximum panel width 2.95 m). These are more expensive than standard containers.

The maximum panel length is just less than 12 m – again due to the overall internal length of the shipping container. 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 2.9 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.

It is also possible to ship large CLT panels by break bulk cargo, however, this is normally much more expensive and goods are more likely to be damaged in transit. A discussion with the supplier should be held before considering this option.

2.5 Adhesive

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

Occasionally, melamine urea formaldehyde (MUF) and phenol-resorcinol-formaldehyde adhesives could be used. MUF is low formaldehyde emitting, and phenol-resorcinol-formaldehydes adhesives are ultra-low formaldehyde emitting.

2.6 Press

The right pressure is essential. Hydraulic presses are normally employed, however, the use of vacuum and compressed air presses is also possible, depending on panel thickness and the adhesive used. Vertical and horizontal pressings are also applied.

2.7 Planer and Sander

The assembled CLT panels are planed or sanded for a smooth surface finish.

2.8 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.

2.9 CLT Optimisation

CLT optimisation needs to be considered during the design process. As discussed above, transport constraints affect panel size and costs. Panels are generally produced in the largest length that the manufacturer can make. These ‘master panels’ 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 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.

2.10 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 consultation with each manufacture is required during the design and specification process.

2.11 Appearance

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.

2.12 Density and Mass

The density of a CLT panel is generally around 480 to 500 kg/m3, i.e. close to the density of the base laminate species used. Therefore, the mass of a typical CLT wall panel of 145 mm thickness is 67 to 72 kg/m2.

2.13 Standards and Codes

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

The North American timber industry has developed a national manufacturing standard.1 This standard covers the manufacturing, qualification, and quality assurance requirements for CLT. The development of this consensus American National Standard has been achieved by following procedures approved by the American National Standards Institute (ANSI).

There are no current manufacturing or installation standards for CLT panels manufactured in Europe. The approval process includes preparation of a European Technical Approval Guideline (ETAG) that contains specific characteristics/requirements of the product as well as test procedures for evaluating the product prior to submission to the European Organisation for Technical Approvals (EOTA). The ETA allows manufacturers to place CE (Conformité Européenne) marking on their products.

Most CLT suppliers have independently evaluated design property information available to designers. This information can be used by Australia designers to meet building regulation through an 'Alternative Solutions' compliance path.

3

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.

CLT is a flexible and light-weight 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.

CNC panel cutting machine. Photograph: Hundegger

Lauriston Primary School, Architect: Meadowcroft Griffin Architects; Engineer: Price & Myers; Contractor: Neilcott Construction; CLT Supply and Installation: KLH UK; Photograph : KLH UK

4

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 two, four or eight carpenters and mobile crane operators.

Panels are lifted into place using pre-inserted hooks or slings. Walls are placed on top of a grout bed for CLT/concrete connections and foam tape for CLT/CLT connections where small fixing plates are positioned along the line of the walls. Sealing tapes are sometimes applied to the end grain of CLT panels to reduce potential for moisture effects and to form airtight constructions. Elastomeric supports may also be used to reduce flanking noise.

For general construction, the delivery truck will park on site while each panel is offloaded and fixed into place. Panels are loaded onto the truck 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 common to use the building itself as a temporary storage place. Storage and delivery options should be fully explored to minimise double handling.

The use of CLT increases site safety, reduces demand for skilled workers and usually reduces site waste and disruption to the surrounding community.

4.1 Connections

The basic panel-to-panel connection can be established through half-lapped, single or double splines made with engineered wood products.

Metal brackets, hold-downs and plates are used to transfer forces. Innovative types of connection systems can also be used, including mechanical and carpentry connection systems. Common types of connections in CLT assemblies include:

4.1.1 Wall to Wall Connections (Straight)

Photograph: TDA

4.1.2 Floor to Floor Connections

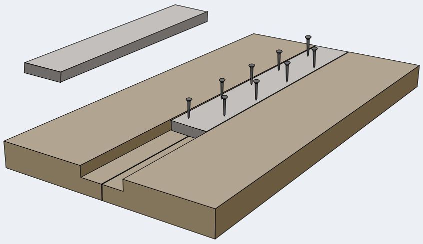


Figure 2: Joint with spine connection.

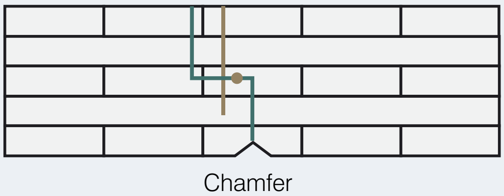


Figure 3: Joint with stepped rebate

4.1.3 Wall to Floor Connections

Photograph: TDA

4.2 Utilities

Electrical, HVAC and water distribution services are typically placed in the suspended ceiling space or in cavities next to panels. Brackets used to support services are usually easier to install as they are screwed into timber instead of concrete, resulting in shorter construction programs.

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

5 Properties of CLT Assemblies

5.1 Fire Performance

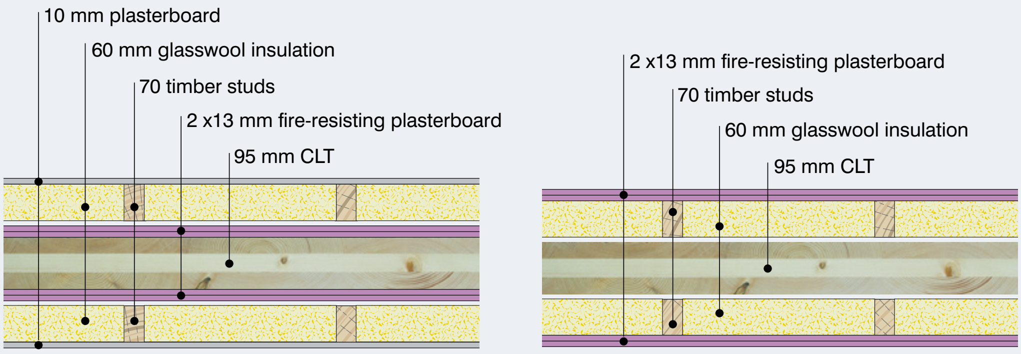
CLT assemblies have excellent fire resistance due to the thick cross-sections that char at a slow and predictable rate when exposed to fire. CLT falls into the same category as massive timber construction, which is different to light weight, timber-framed constructions that are rely on fire-resisting plasterboard for their fire performance. CLT fire performance can also be enhanced by lining assemblies with fire-resisting plasterboard and additional floor layers and/or coverings.

A demonstration test by National Research Council of Italy, Trees and Timber Institute (IVALSA) on a full- scale three-storey CLT building confirmed that CLT panels protected by one layer of gypsum board were able to withstand the burn out of the room contents without fire spreading to adjacent rooms or floors.

CLT construction typically has fewer concealed spaces within wall and floor assemblies than framed construction, which reduces the risk of hidden fire spread.

Generally, CLT incorporates a layer of fire-resistant plasterboard either in the wall or ceiling assembly, as this reduces 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 Table1 below). The composition of most building systems is likely to be determined by their acoustic performance and, as a result, will include insulation and separation of layers or toppings to meet or exceed the required acoustic requirement.

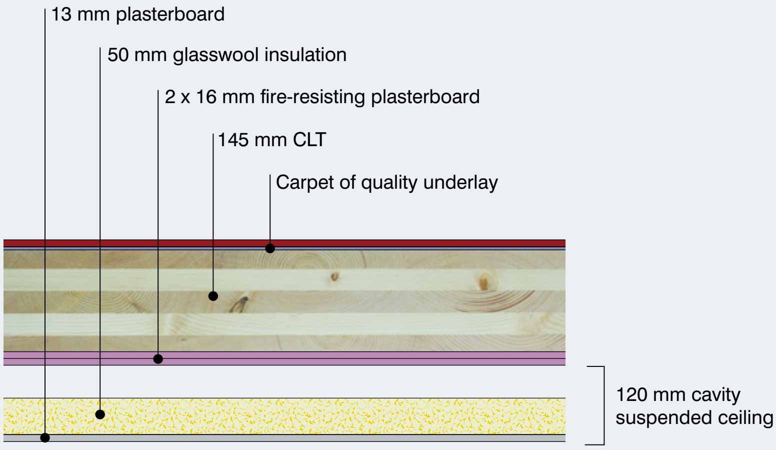
As CLT is timber, there are some instances where its inclusion in building components will not meet the deemed-to-satisfy fire performance requirements in the Australian National Construction Code (NCC). Where this occurs, an alternative compliance path is required. A number of structures have taken this path to date and have obtained approval. For further information, refer to Wood Solutions Technical Design Guides #4, #2, #3, #17, #18 and #19.



Fire resistance - 90/90/90
Rw (C; C_{tr}) – 62 (-1, -12)

Fire resistance - 90/90/90
Rw (C; C_{tr}) – 65 (-1, -12)

Figure 3: Common fire and sound resistant systems for Compartment Walls.
Note: Fire and sound ratings are based on SmartStruct/KLH systems. Other CLT based products may have different results. Also system performance is always improving always refer to supplier for the latest information.



Fire resistance - 90/90/90
Rw (C; C_{tr}) – 61 (-5; -11)
Ln,w (C_i) – 43 (6)

Figure 4: Common fire and sound resistant systems for floor system.
Note: Fire and sound ratings are based on SmartStruct/KLH systems. Other CLT based products may have different results. Also system performance is always improving always refer to supplier for the latest information.

5.2 Acoustical Performance

The acoustic performance of CLT is excellent and is 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 suspended ceiling below the CLT. Floor acoustics performance can be increased in a number of ways. In Europe, a concrete screed is typically 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.

5.2.1 Flanking Noise

As with all building structures, some corrective measures during construction are needed to reduce flanking noise. Polyurethane sealant damping strips or laminated natural rubber 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.

Polyurethane damping strips under CLT walls. *Photograph : Rothoblaas*

5.3 Thermal Performance

CLT has the same fundamental thermal properties as the timber it is made from. Timber has a low thermal conductivity, reducing problems such as thermal bridging from the internal to the external environments and vice versa, heat transfer and energy wastage. CLT also provides 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 sources often suggest that CLT provides a degree of thermal mass for a building – due to increased density compared to framed construction – that can be associated with reduced heating and cooling energy. In terms of heat capacity and thermal resistance, timber is rated as average among major building materials. Values for CLT are improved simply by its thickness. External walls usually have a weather-protecting layer of masonry or commercial facade. Here, bulk insulation is used, generally in the external wall cavity, 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.

Due to a high degree of manufacturing precision, good air tightness may be achieved with CLT. Foam tape is normally used at the joints for this purpose. Edge bonding of the individual dimensional timber in each layer also helps.

5.4 Durability

As the species used for CLT production is generally softwood, which is of low natural durability when used in exposed applications, it is not recommended to directly expose the panel to exterior conditions. Normally, CLT buildings have a skin of masonry or commercial facade material such as aluminium or fibre cement. A cladding of naturally durable or appropriately preservative-treated wood product is preferable.

5.4.1 Termite Resistance

Because the timber used in CLT is not modified during the manufacturing process, its termite resistance performance is considered the same as would apply to the same timber species used in timber-framed construction. If termite protection is required, the building should be protected in accordance to AS3660 Termite management – New building work.

5.4.2 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.

5.5 Seismic Performance

The National Research Council of Italy Trees and Timber Institute (IVALSA) has tested three- and seven-storey, full-scale CLT buildings in Japan.2 Japanese research facilities have the largest shaking table in the world, where full- scale buildings have been exposed to large simulated earthquakes. The CLT buildings performed remarkably well, even when subjected to severe earthquake motion like that of the devastating Kobe earthquake (magnitude of 7.2).

In the case of the seven-storey building, there was no residual deformation at the end of the test. The maximum inter-storey drift was 40 mm (1.3%), 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. Such behaviour was mainly influenced by the mechanical connections used.

Further work has also been done on seismic performance by FP Innovations in North America.3

5.6 CLT Manufacturers and further information

The supply of CLT into the Australian market is rapidly changing. For updated information and details of manufacturers and suppliers of CLT, refer to the Supplier's listing on the WoodSolutions web site: www.woodsolutions.com.au.

6

Case Study: Forté

Completed Forté apartments. *Photograph: Lend Lease*

6.1 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

6.2 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. Once 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.

Forté under construction. *Photograph : Lend Lease*

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

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 are 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.

6.3 Environmental benefits

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

A full life cycle assessment by staff of RMIT University compared Forté with a standard apartment building constructed with reinforced concrete.4 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 construction5 equates to 216 tonnes of stored carbon that absorbed 792 tonnes of CO2 during its growth (based on 12% moisture content and carbon content of 50.5%, by weight.4 In comparison to a standard concrete and steel building, Forté reduces CO2 emissions by more than 1,451 tonnes,5 the equivalent to taking 407 cars off the road for a year. (This calculation is based on information from the Australian Bureau of Statistics6 and the Australian Government greenhouse gas emissions calculator 2008, estimating average CO2 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.

6.4 Fire Resistance

Fire resistance is a key issue, as some timber applications do not meet the deemed-to-satisfy requirements of the NCC. 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.

6.5 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.

Cross Section Model of Floor Construction used in Forté.
Photograph: TDA

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References & Further Reading

References

1. American National Standard/APA, *Standard for Performance-Rated Cross-Laminated Timber, 2012*
2. 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/
3. 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
4. Durlinger, B., Crossin, E. and Wong, J. (2013) *Life Cycle Assessment of a cross laminated timber building.*
5. Andrew Nieland, Lend Lease (2013). *Building with Cross-Laminated Timber: is this our future?*
6. Australian Bureau of Statistics. *Year Book Australia 2012.*

Further Reading

Australian Standards:

AS3660 Termite management - New building work

Wood Solutions Technical Design Guides

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

#2 Timber-framed Construction for Multi-residential Buildings Class 2, 3 & 9c: information about complying with the fire and sound performance requirements in the BCA for Class 2, 3 and 9c buildings.

#3 Timber-framed Construction for Commercial Buildings Class 5, 6, 9a & 9b: information about complying with the fire performance requirements in the BCA for Class 5, 6, 9a and 9b buildings.

#6 Timber-framed Construction - sacrificial timber construction joint: common details for using sacrificial timber blocks to maintain a Fire Resistance Level.

#17 Alternative Solution Fire Compliance, Timber Structures: information about using alternative solutions to allow the use of timber in structural applications not covered by the Deem-to-Satisfy Provisions of the NCC; includes a case study of a five storey residential apartment (Class 2) building.

#18 Alternative Solution Fire Compliance, Facades: Information about using timber facades not covered by the Deem-to-Satisfy Provisions of the NCC; includes a case study on the use of combustible facades.

#19 Alternative Solution Fire Compliance, Internal Linings: information about using timber linings not covered by the Deem-to-Satisfy Provisions of the NCC; includes a case study on the use timber linings in a school building corridor.

#20 Managing Construction Fire Guide: Information on the consideration need to prevent fires during construction; the guide covers all material types.

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