Cross Laminated Timber (CLT)
Lesson
Learning Objectives

To provide an awareness of the use of cross laminated timber (CLT) in multi-storey construction.

To develop an awareness of how CLT panels are fixed and produce appropriate details.

To understand the performance of CLT panels in relation to fire, sound, thermal insulation, structural stability and durability.

To understand the processes involved in the erection of CLT buildings with regard to health and safety.

To consider the issues of CLT with regard to current research in the subject.
Why CLT?

FROM THE VIDEO WHAT MAY BE SOME OF THE ADVANTAGES OF CLT?
Considerations for using CLT

In the EU we only harvest about two thirds of annual growth.

Nearly 200 million m³ of wood is added to our forests each year.

For every m² of building constructed from CLT approximately 250kg CO₂ is stored.

- EU27 stocks
- 22.5 billion m³ total stocks
- 660 million m³ annual growth
- 420 million m³ annual felling

A CLT building uses about 0.30 m³ of timber for every m² of floor area provided.

A timber stud and cassette building uses about 0.15 m³ of timber for every m² of floor area provided.

Costs

- Steel frame £190/m²
- Concrete frame £190/m²
- CLT frame £240/m²
CLT Key Points

This is from trade literature so it is not always fully objective and unbiased.

Most of these points here are supported by further research, but it is important to consider information objectively.

No system is perfect but CLT appears so far to perform well.

<table>
<thead>
<tr>
<th>Key points</th>
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<tr>
<td>CL timber panels may be joined using six key connection types.</td>
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<td>Connections are secured with self-drill wood screws of up to 400mm in length and proprietary mild steel angle plates. The tools are lightweight.</td>
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<td>Where walls are bedded on concrete, sole plates are generally unnecessary unless there is a risk of standing water during construction.</td>
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<td>Connection details may need to accommodate hidden service runs.</td>
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<td>Pre-compressed foam tape may be inserted between adjacent panels to produce airtight joints.</td>
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<td>CL timber panels can be used in both platform frame and balloon frame systems.</td>
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<td>The panels have good in-plane shear resistance.</td>
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<td>Shrinkage is not generally a critical factor in design, but creep becomes significant above about 12 storeys.</td>
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<td>For fire resistance, CL panels have a charring rate comparable to softwood.</td>
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<td>Specify plasterboard lining to minimize reaction to fire.</td>
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<td>Disproportionate collapse is unlikely to be a critical factor when designing CL panel structures.</td>
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CROSS LAMINATED TIMBER

PROPERTIES

As a natural renewable product performance can vary slightly, but commercial cross-
laminated timber systems generally achieve:

- **thermal conductivity**: 0.13 W/mK
- **density**: 480–500 kg/m³ (spruce)
- **compressive strength**:
  - 2.7 N/mm² (perpendicular to grain of boards)
  - 24–30 N/mm² (parallel to grain of boards)
- **bending strength**:
  - 24 N/mm² (parallel to grain of boards)
- **elastic modulus**:
  - 370 N/mm² (perpendicular to grain of boards)
  - 12,000 N/mm² (parallel to grain of boards)
Comparison of CLT and other Forms of Construction

<table>
<thead>
<tr>
<th>Material</th>
<th>Floor span capability</th>
<th>Height capability</th>
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<tr>
<td>Steel</td>
<td>7m for metal deck floors</td>
<td>&gt; 100 storeys</td>
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<tr>
<td>Concrete</td>
<td>9m for solid slabs</td>
<td>&gt; 100 storeys</td>
</tr>
<tr>
<td>Masonry</td>
<td>7.5m for hollow core floor</td>
<td>7 storeys</td>
</tr>
<tr>
<td>Platform timber frame</td>
<td>6m for engineered timber joists</td>
<td>7 storeys or 20m</td>
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<tr>
<td>CL timber panels</td>
<td>8m for panels</td>
<td>12 storeys</td>
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Figure 4: Span and height capabilities of mainstream structural materials in multi-storey buildings
Cost and Performance?

CLT floor plank versus pre-stressed hollow core plank

100kg/m²  
span to depth 30  
£110/m²

300kg/m²  
span to depth 40  
£40/m²
Comparison of Materials

Beams of equivalent structural performance

- 50kg
  - 75kg ECO2
  - £65

- 300kg
  - 65kg ECO2
  - £65

- 50kg
  - 20kg ECO2 (80kg SCO2)
  - £85

What then are the advantages and disadvantages of these 3 materials for beams?
Cross Laminated Timber (CLT) panels are produced from mechanically dried spruce boards which are stacked together at right angles and glued over the entirety of their surface.

Each CLT panel is produced is between three and seven boards thick depending on the amount of structural loading required.

Gluing at high pressure reduces the timbers expansion and shrinkage potential to a negligible level. The result is a rigid structural timber member that can be used both vertically and horizontally to construct a buildings frame.
CLT video – The Wood Innovation Design Centre
Cross Laminated Timber Panels

Individual timbers vary in thickness from 16-51 mm. Widths of individual planks are between 60 and 240mm. Panel sizes range in widths from 0.6 to 3 metres and lengths up to 18 metres with thicknesses up to 500mm.
Model of CLT Frame

Model showing the platform frame and parapet wall construction.

How is structural stability achieved?

How is dimensional stability achieved?
CLT Panel connections

There are basically 6 connection situations with CLT
Detail at Ground Level

Note how a cold bridge is avoided at ground level, with the use of insulation below ground level also.

Note the cavity tray formed to provide damp protection.
Baseplate Fixings

The timber frame contractor then visits site before any timber is delivered to inspect the slab and to set out the ground floor structural walls and partitions. Once this is complete, DPM strips are laid along the line of the walls for the CLT panels to sit on (below).

Base plates are fixed to the slab and levelled in preparation for the glulam columns (below) and smaller fixing plates are positioned along the line of the walls. CLT panels are then delivered to site. Ideally the delivery lorry will park on site and wait whilst each panel is offloaded and fixed into place.
Various Base Fixings

Figure 11 shows typical panel bedding onto a concrete base.

Figure 11: Lowering wall panel onto levelling plates and grout bedding
Photo: Stora Enso/DMH
Fixing Detail and Cross Section

- Horizontal Timber Cladding, fixed to cavity battens
- Vapour permeable membrane
- 25mm Phenolic Insulation Board
- 45mm Cavity Batten, fixed to CLT through insulation board
- Vapour permeable membrane
- Cavity Base Closer
- 50mm Minimum Overlap

XLAM 75mm CLT Wall Panel
13mm Plasterboard
Batten (between metal angle cleats)
How effective are the connections for joining the panels at right angles?

Are these brackets robust enough?
Panel Support

Once a panel is in place, temporary supporting struts will be installed to ensure the panels stability in the interim period whilst the other panels and floor slabs around it are installed and the structure becomes independently stable.

A CLT panel is considered safe once it has been fixed into place and these struts have been fitted.
Doorways arrive partially cut to ensure CLT panel stability during transportation and lifting. These must then be cut out on site.

The example below shows a partially cut door frame; the timber had to be removed to permit the screed and under floor heating to pass through the doorway.
Straight Panel to Panel Connections

Wall panel – wall panel, straight (detail 2)
The connections in Figure 6 may use an engineered-timber jointing piece and offer the potential to embed service runs. Some systems use connections like those shown in detail 4 to join wall panels.

Figure 6: Wall - wall, straight
Panel Connections at Right Angles

Wall panel – wall panel, junction (detail 3)
The outer panel is screw fixed into the end grain of the abutting panel (Figures 7 and 8). Precautions for airtightness and/or sound transmission may be needed.

Figure 7: Screw fixed connections
Photo: Re-Thinking (Milkoot Doon)

Figure 8: Wall – wall, junction
Fixing Panels Together

*Flat washerhead screws*
This 22mm diameter washer headed screw is used for panel-panel joints. They have a high resistance to embedment and their flat head makes a flat connection surface for a better rendering. Sizes: 8, 10 and 12mm diameter; 120mm to 500mm long.

*Countersunk screws*
They “disappear” inside the timber panel and are used when the fixings are to be hidden. Their head can be fully concealed either by plastering the recess created or with timber plugs.
Lifting Positions
Platform Floor Connections

Wall panel – floor panel, platform frame method (detail 5)

These are similar to corner wall connections (Figures 11, 12 and 13). In this situation, the terms ‘floor’ and ‘ceiling’ may be interchangeable.

Figure 11: Wall – floor (ceiling)

Figure 12: Floor panels screwed to walls below
Photo: Stora Enso

Figure 13: Installing angle bracket to fix next level wall
(the sealing strip is for airtightness)
Photo: Stora Enso
Platform Frame Fixing

Load from above

CL wall panel screwed through decking into blocking

Decking

Blocking between I-joists

Continuous ring beam

Where CL timber wall panels are combined with engineered timber joists built into the wall (in a platform frame approach), vertical load can be transferred via solid blocks between the joists (Figure 16). In this detail, the solid blocks and ring beam should be an engineered timber product, e.g., laminated veneer lumber (LVL), parallel strand lumber (PSL) or laminated strand lumber (LSL), in order to minimise shrinkage.

Figure 16: Wall – I-joist, platform frame method
Floor Detail

**Construction**
A - 169 mm CLT  
B - suspended ceiling  
C - 200 mm glasswool insulation  
D - 2 x 15 mm plasterboard

**Performance**
Fire resistance - 60/60/60  
Rw – 63  
Lnw – 40
Floor Fixing
Detail 1

This is a rebated joint with a rebate in both panels that are butted together.

A cover timber is screwed into the rebate joining both panels together.
Floor Panel to Floor Panel Connections

**Floor panel – floor panel (detail 4)**
This connection is usually a half-lapped joint milled in the factory (Figures 9 and 10).

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**Figure 9:** Half-lapped floor joint on concrete substructure
Photo: Stora Enso/OMH

**Figure 10:** Floor – floor

engineered timber jointing piece
Floor Fixing Detail 2

This is a half lap joint. The panels lap over one another and are then screwed together and into the supporting wall below.
In these panels the central layer is substituted by a substructure made of beams, creating a box-shaped cavity within.

This cavity is filled with thermo-acoustic insulation: rock wool, sheep wool or wood fibre. A coat of glue is applied to the beams - as if they were a layer of timber - and a layer of boards is then added on each side, to make a total of five. These panels have even better mechanical, thermal and acoustic properties and employ less timber.

They are used mainly for floors and roofs. Their high stability allows building large spans (up to 10-12m long) in residential and office buildings.
CLT used for Internal Stairs

The section size of CLT makes substantial stair treads and risers.
Platform Construction

Walls/floors

Slab/walls
Platform Construction

The floor panels sit onto the wall panels and are then screwed to the lower wall panels.

The next floor panel sits on top of the floor structure, directly above the wall panel below.
Platform Construction Fixing Detail

2.2 EXTERIOR WALL - EXTERIOR WALL - CEILING

1. Corner joint – screw connection of wall corners according to static requirements or for the compression of joint tapes

2. KLH panel according to static requirements

3. Install joint tape for all panel joints, unless a vapour barrier or windproof layer is installed on the outside

4. Ceiling/walls screw connection with self-drilling wood screws – type, diameter and distance according to static requirements

5. E.g. BMF angle bracket for the statically effective connection between wall and ceiling. Shear forces in the direction of the wall, tension and pressure normal to the wall (wind forces)
Parapet Connection Details

Parapet panel – floor/ceiling panel, balloon-frame method (detail 6)
Cantilevered wall panels, for example parapets, can be formed effectively using continuous (balloon framed) wall panels with the floor structure supported inside the wall on a ledger (either steel or timber) screwed to the wall panel to support the floor panel (Figure 14).

Figure 14: Balloon frame options
Crane Erection of Panels

The large panels require crane erection. They must be guided into place and fixed immediately. Temporary support to the panels may be needed until several panels are fixed together at right angles.
Large CLT Panel Erection
Large Panel Crane Erection
Temporary Support to Panels
CLT Project

Showing some of the erection process of CLT panels
Safety Questions?

What is a minimum safe weight for lifting on site?

Is it legal for a construction company to state they are not employing a woman because she is ‘petite’ and not strong enough?

(discuss these first)

See the slide notes below.
CLT House Erection
Typical Cross Section through CLT wall

The insulation on the outside of the CLT wall enables some of the small thermal mass of CLT to be exploited.

100-150mm of thermal insulation would be needed normally.
Comparing health and safety risks of erecting with CLT *(compete the boxes accordingly)*

| SAFETY ADVANTAGES OF CLT OVER STEEL/CONCRETE FRAMES | SAFETY ADVANTAGES OF CLT OVER MASONRY CONSTRUCTION |
Cladding Principles

Externally the vapour check and insulation as placed next to the CLT frame.

The cladding is fixed through the insulation to the CLT frame.
Fixing of the Cladding
Sheet Cladding Fixings

Insulation between metal studs which are fixed to the CLT via brackets.

The brackets could provide a cold bridge.

The detail shows a low conductivity spacer between the bracket and the wall to reduce this bridge.
Window Detail Cross Section

A clear cross section at a window opening. The internal face will normally be covered with plasterboard.

A range of claddings and sills are available
Roof Fixing Details

3.2 EAVES DESIGN WITH CANOPY OR INTERMEDIATE BEARING (MIDDLE WALL)

1. Screws absorb shear forces parallel to bearing or wind suction forces
2. Use fully threaded screws for high forces towards the inside
3. The bearing surface must be set at a normal angle in the direction of the main loads

3.3 EAVES DESIGN WITHOUT CANOPY (INDEPENDENT OF PANEL BEARING DIRECTION)

4. If the main bearing direction of the panel is parallel to the bearing, any lateral projections are only possible subject to cross-bearing capacities (middle layers) – static verification required
Roof Details

There is a potential cold bridge where the wall meets the roof, as the wall and roof insulation don’t meet. The use of insulated plasterboard internally to the ceiling and walls would avoid this cold bridge.
CLT Interior
CLT Interior
A 121-unit residential block, that when complete will be the largest cross laminated timber (CLT) building in the world, has started on site in Dalston Lane, Hackney in London.

Designed by Waugh Thistleton Architects for property developer Regal Homes, the 16,000 sq m development includes 3,460 sq m of office space. Above a basement and ground floor of concrete, the building’s structure, designed with engineer Ramboll UK, is constructed from timber.

The 10-storey building will use 3,852 cu m of CLT, more than has been used on any other project in the world. “We believe that by volume of CLT used it will be the largest building in the world,” says Dave Lomax, project architect at Waugh Thistleton.
Construction of the world’s tallest wooden apartment block, a 14-storey, 49m high structure, starts in Bergen, Norway, later this month.

The building uses metre-thick columns of glulam to carry all the vertical load and two concrete decks on top of the 5th and 10th floors, and also employs cross-laminated timber (CLT). Both materials are produced to very high quality and millimetre precision. The main load bearing is handled by glulam alone; CLT carries the staircases, elevator shaft and some inner walls but is not connected to the glulam.
Construction of the 14 Storey Block in Bergen
Multi Storey CLT

What are the drawbacks of building a multi storey structure out of CLT as compared to a steel or a concrete framed building?

*Consider issues like robustness, stability, rigidity, fire resistance, sound insulation etc.*

Can these drawbacks be reasonably overcome?
Environmental Considerations

As CLT is available readily manufactured from wood certified as harvested from sustainably managed forests, it possesses a number of positive environmental characteristics. These include:

Long-term storage of the carbon absorbed by the sustainably grown trees

Production of CLT results in far less greenhouse gas emissions than many non-wood materials

Many of the recent structures built from CLT benefit from these environmental considerations.

For example, two high rise residential projects in London used the fact that wood stores carbon and that substantial greenhouse gas emissions were avoided by substituting CLT in place of concrete or steel to get preferential approval from local planning authorities.
Fire Performance

CLT assemblies have inherently excellent fire-resistance due to the thick cross-sections which, when exposed to fire, char at a slow and predictable rate.

CLT fire performance can also be enhanced by lining with fire resisting plasterboard and additional floor layers and/or coverings.
Fire Safety

A demonstration test conducted by IVALSA on a full scale, three storey CLT building confirmed CLT panels protected by one layer of gypsum board was able to withstand the burn out of the room contents without fire spread to adjacent rooms or floors.

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

**Construction**
A – 13 mm plasterboard
B – 95 mm CLT
C – 60 sound absorbing material
D – 95 mm CLT
E – 13 mm plasterboard

**Performance**
Fire resistance - 90/90/90
Rw - 60
Thermal Properties

European sources often suggest that due to increased density compared to framed construction, CLT provides a degree of thermal mass for a building, which can be associated with heating and cooling energy reductions. In terms of heat capacity and thermal resistance wood is average among building materials. Values for CLT are improved simply through the virtue of 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 envelop thermal efficiency.

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.
ADVANTAGES

• As a renewable material, stores carbon throughout its usable lifespan
• Avoids thermal bridging (in parapet walls or flat roof solutions)
• Good delivery of airtight envelope
• Greater load distribution can reduce thickness of transfer slabs
• Light weight reduces load on foundations so less need for materials with high embodied energy (eg concrete)
• Need for robust upfront design may improve overall design and efficiency
• Robust finished wall will take sundry fixings
• Simple and fast onsite construction process
• Suitable for non-visible as well as exposed finishes
• Vapour-permeable wall construction

LIMITATIONS

• Requires accurately set out groundworks
• Requires completed designs ahead of start on site, to allow for offsite manufacture
• Requires external cladding or render to provide weatherproof envelope
• Use limited to above damp-proof course or equivalent level
Sources of Information

Building with Cross Laminated Timber. www.brettsperholz.org

Architecture Design Scotland. Huntley Crescent, Raploch, Case Study. www.huntleycrescentraploch.co.uk


KLH. Component Catalogue for Cross Laminated Timber. www.klh.at

Tutorial

A tutorial exercise on a CLT building will be given out which will look at the construction in more depth.