CROSS LAMINATED TIMBER

GFA

GEORGIA FORESTRY ASSOCIATION

CLT GUIDE

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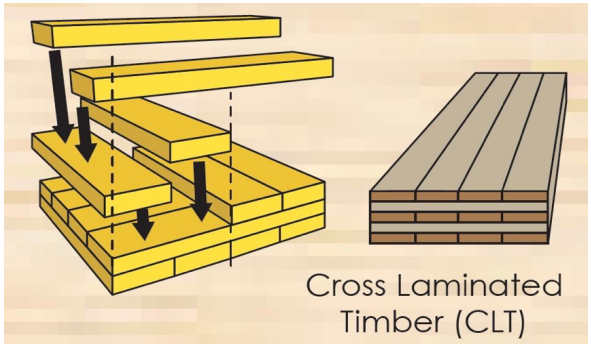
CLT OVERVIEW

What is CLT?

- Cross laminated timber(CLT) is a mass timber engineered building system. CLT is constructed by layering kiln dried dimensional lumber in a crosswise manner, glueing the layers, and pressing them into panels[1].

- It is used in the construction of single and multifamily housing, commercial, and high-rise buildings.
  - CLT was engineered to be a heavy construction alternative to concrete and has the ability to be used in buildings as load bearing structures including walls, floors, roofs, and stairs[1].
  - Similar in design to glulam which has been more commonly used in America for beams and trusses.



- CLT was designed in Europe in the 1990's and has become increasingly popular among architect firms and construction groups. Increased recognition of CLT as a robust and heavy construction material has drawn more interest and research to the product.
- The CLT building system is very cost effective and can provide savings 10-50% on building materials depending on the type of structure being constructed[2]

Advantages

- Cross Laminated timber can achieve strengths equal to or greater than concrete and steel materials, but with less weight.
- CLT structures maintain structural integrity that is equal or greater than traditional materials.
- CLT provides greater carbon sequestration and less of an environmental footprint. Its renewable source makes it a more sustainable option for builders and architects.

Specifications

❖Lumber in CLT is kiln dried to 12%±3% to mitigate panel cracking or separation. It also maintains consistency among the panels produced for project construction.

❖Most CLT is produced in 3, 5, and 7 layer panels.

❖CLT's bidirectional layering gives two-way action strength and dimensional stability.

✦This engineering design causes loads and pressure to be distributed in 2 directions instead of one, eliminating or decreasing the need for cross-bracing.

❖CLT is made to order for each project in manufacturing plants using advanced planers and computer numerical controlled (CNC) milling equipment. The custom nature of its design and precision manufacturing give better performance and overall aesthetics.

❖The customizable dimensions of CLT panels are one of its greatest assets.

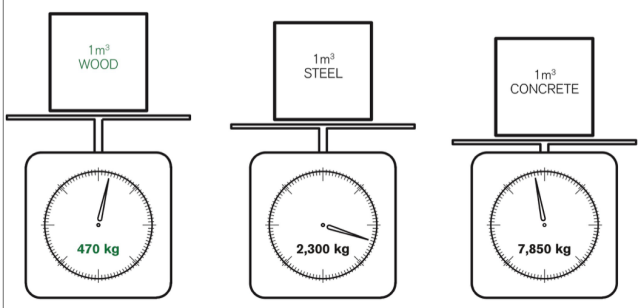


Image: Kim & Itakura Source: Japan Housing and Wood Technology Center

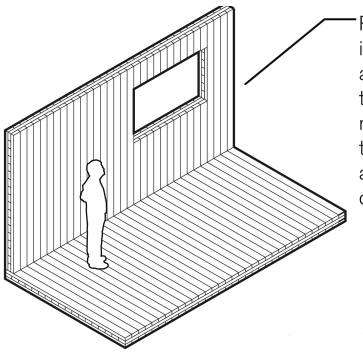
✦Panels can be fabricated for smaller sections of walls, floors, and roofs.

✦Current dimension production in America reaches dimensions of 98' long, 18' wide, and 19.5" thick[2].

✦Dimension size is often determined or restricted by transportation limitations.

- ✦ CLT panels are quickly produced with manufacturing times typically span between 15 to 60 minutes depending on size and prefabrication complexity.

- Window cut-outs, pilot holes, and recessions can be fabricated during production using CNC methods, reducing onsite construction time.



Panels are prefabricated off-site in a factory, minimizing waste and speeding up construction time. Computer-controlled machinery in the factory trims the panels to exact dimensions and cuts openings for windows, doors, and other installations.

Image: Kim &

Construction Benefits

- Wood's lighter weight requires less concrete in foundation construction leading to more savings and less time spent waiting for foundation to set.
- CLT does not require exclusive training or specialized crews for installation and has a very small learning curve.
- Quick rates of construction between 1,000 and 8,000 ft^2 per day can be attained using crews between 4 to 8 people and typically no more than 2 crane operators[3].
  - The crew used for the Albina Yard project in Oregon had zero CLT experience. The 1st floor installed took 4 hours and after the 4th floor the same installation process took 2 hours[4].
  - Smaller cranes and other installation equipment can be used to move and install the panels due to its lighter weight and places less of a liability on operators.
  - Faster completion times save money and have other benefits especially in urban areas. Road closures due to construction and excess traffic from supply trucks are experienced for lesser amounts of time, benefitting the city as a whole. Depending on the size of the project, months can often be taken off the time needed to assemble the shell of the building.
- CLT is highly adaptable in how its panels can be joined. Plates or metal fasteners are commonly used to join panels together but panels are not limited to this method. Interlocking grooves can also be milled into the panels as either standalone joining method, or as a cooperative method with other metal fasteners and hardware.

Wood Structure

- Wood's greatest strength and stability is with the direction of its grain. Grain pattern on walls runs parallel to the ceiling and floor. The pattern for floors runs parallel to the longest dimension.
  - CLT's outer layers (and odd numbered interior layers) are made to run parallel to the load bearing direction.
- Wood has a much higher strength to weight (STW) ratio than concrete or steel. This ratio gives wood better load bearing capability than an equal amount of the other two materials. CLT's STW ratio is why it can match or outperform other materials structural integrity.

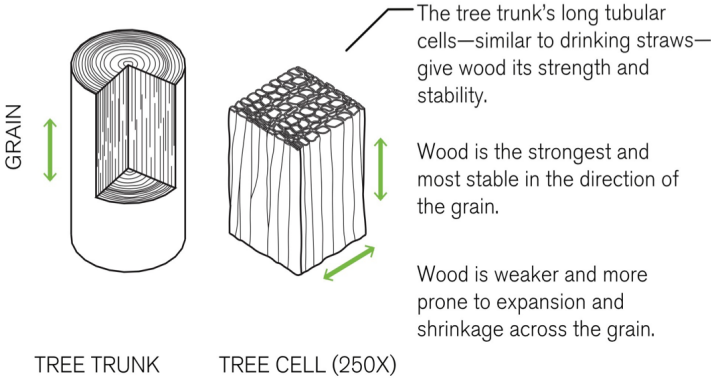


Image: Kim &

MATERIAL	TIMBER	CONCRETE	STEEL
SPECIFIC GRAVITY (kn/ m³)	0.40	2.00	7.66
	2250	10	509
	950	100	445
	2800	7	182

Image: Kim & Itakura Source: Japan Housing and Wood Technology

Wood is Good

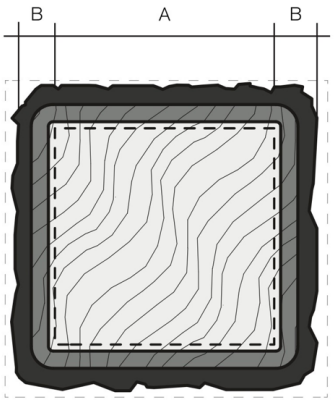
- Wood can be sourced locally, which saves time, transportation costs, and fuel.
- Building with wood helps support and foster local jobs in mills, logging crews, and trucking companies that depend on the resource.
- Timber is a superior material source because 99% of a log turned into a usable material. Little waste is produced and maximum amounts of carbon remain sequestered.
- Wood elements in buildings add warm and inviting feelings to buildings.
- Studies have shown biophilic spaces (such as wood buildings) increase mood and morale in those who live or work in the buildings. Biophilic spaces also can increase brain activity, learning, and overall functioning).
- The benefits of a biophilic space make wood use in work places and schools an enticing and rewarding option.

FIRE RESISTANCE

General

- CLT is like any mass timber and does not easily ignite. High temperatures and relatively long periods of exposure are required to begin the combustion process of solid wood. The combustion of wood involves a slow and gradual process called charring. The char produced functions as insulation, guarding the remaining timber from further fire damage.
- CLT burns at a predictable rate of 1.5 inches per hour. Steel and concrete do not and can collapse or loose structural integrity at an unexpected moment. Predictability adds to CLT safety advantages[5].
  - Fire response teams have measurable time frames for when it is no longer safe to enter a building for search and rescue. This allows greater safety and less risk for first responders.
- CLT has repeatedly been tested for fire performance consistently passed the 2-hour of structural integrity maintenance required for multi-floor buildings.
- Most CLT panels never bear more than 20% of their max rating, but fire testing has been completed with panels carrying the max rated load for integrity assurance[6]
- A 10'x10' 5-ply wall section with a 5/8 inch type X gypsum board layer burned and maintained integrity under a maximum load for 3 hours, 5 minutes, and 57 seconds in a test by the American Wood Council[7].

FIRE RESISTANT TIMBER BEAM: CHARRING DIAGRAM

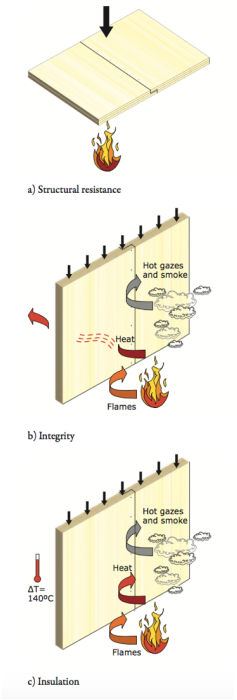


A RESIDUAL SECTION - STRUCTURAL CAPACITY RETAINED
B SACRIFICIAL (CHAR) LAYER - NO STRUCTURAL CAPACITY RETAINED

Image: Kim & Itakura Source: FPInnovations

Elements of Fire Resistance

- CLT's official fire testing has been conducted using ASTM E119 methods, the standard of U.S. building codes.
- CLT's fire resistance is measured in time and is calculated when the panel can no longer meet any of the three requirements under a fire[8].
  - ***Structural resistance***: ability to bear a load during or after a fire.
  - ***Integrity***: ability to prevent flames or gas from passing through a panel or joint.
  - ***Insulation***: ability to prevent temperature rise on the unexposed surface.
- Lumber used in CLT typically falls under a Class B or C fire rating and displays very effective fire resistance in untreated panel.
  - Greater resistance can be reached with additions of gypsum board or gypcrete which has a Class A rating.



WOOD VS. STEEL:
LOSS OF STRENGTH IN FIRE

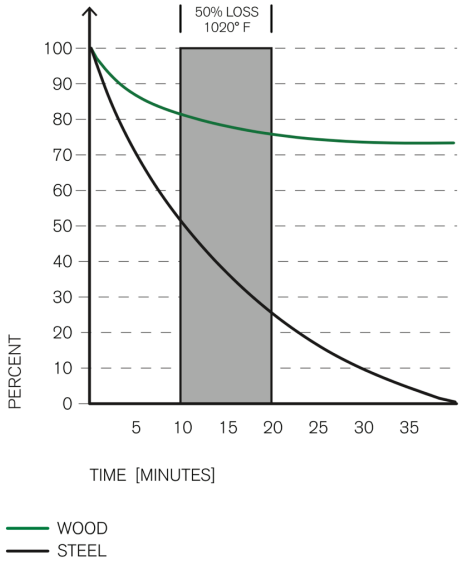


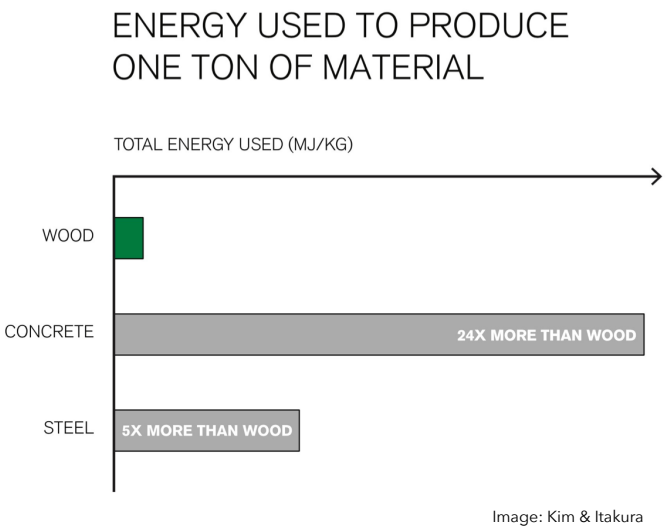
Image: Kim & Itakura Source: National Fire Protection Association

- Structural strength of wood is maintained to a much larger degree for a longer amount of time compared to steel.
  - After 10 minutes of exposure to a fire of 1020 °F steel loses 50% of its strength compared to only a 19% loss in wood. Past 35 minutes of exposure steel loses completely loses its strength while wood maintains over 70% of its strength.
  - Wood is a poor conductor of heat, therefor keeping the interior of a charring beam at a cool temperature while the exterior is burning. Since steel is a good conductor of heat, the core of a steel beam heats quickly causing the entire beam to rapidly lose integrity.
  - Exposed timber begins to ignite at 480°F but maintains it's structural integrity at average structure fire temperatures of 1300 to 1800°F .

SUSTAINABILITY AND ENVIRONMENT

Carbon Benefits

- Wood is far superior to concrete and steel in saving energy in production costs. Concrete manufacturing requires 24 more times the energy input that wood does, and steel requires 5 times more energy[9].
- Growing one pound of wood consumes 1.47 pounds of CO_2 and releases 1.07 pounds of oxygen[10].
  - One tree can consume 48 pounds of CO_2 per year.
- Life cycle analysis (LCA) reveals that during raw material extraction, transportation and manufacturing processes, CLT can store more carbon, emit less GHG and use less fossil energy than steel, concrete and brick[11, 12].
- CLT is carbon negative meaning instead of contributing to carbon emissions, or it saving emissions, it reduces current levels.
  - The carbon used to operate logging, transportation, and manufacturing equipment is less than the carbon that is taken from the environment and sequestered in the wood.



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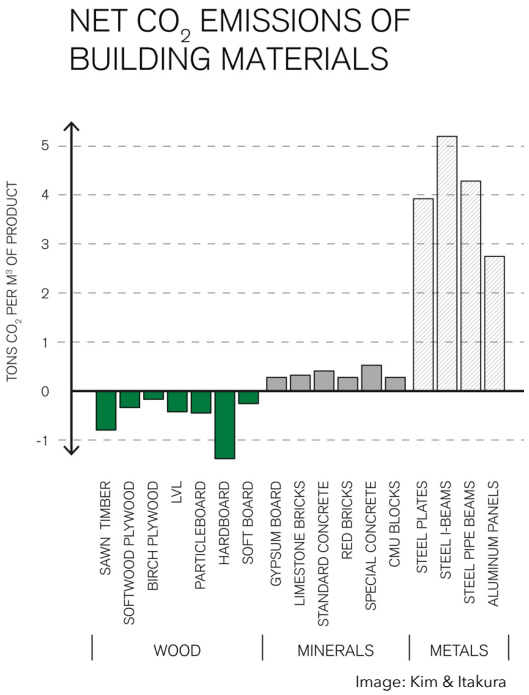


Image: Kim & Itakura

- The average carbon savings of CLT used in a mid-rise building equate to being able to power a home for 55 years.

- Using wood substitutes could save 14 to 31% of global CO_2 emissions and 12 to 19% of global fossil fuel consumption by using as low as 34 % of the world's sustainable wood growth[13].

Renewable Resources

- CLT can utilize low quality sawtimber logs to make interior layers of panels which would otherwise go to waste or be used for paper production bioenergy[4]. These are good uses, but limits the amount of lumber that is yielded from larger trees and brings a lower price in the market for landowners.

- Despite popular misbelief, timber is an increasingly plentiful resource and is not facing any level of scarcity. Overharvesting was an issue in the early 1900's and times previous but has not been a practice since the 1950's.

  - Since the 50's the United States has grown more trees than it has harvested. The level of standing timber is currently 50% higher now than it was in 1952.

U.S. TIMBER GROWTH AND REMOVALS
1920–2006

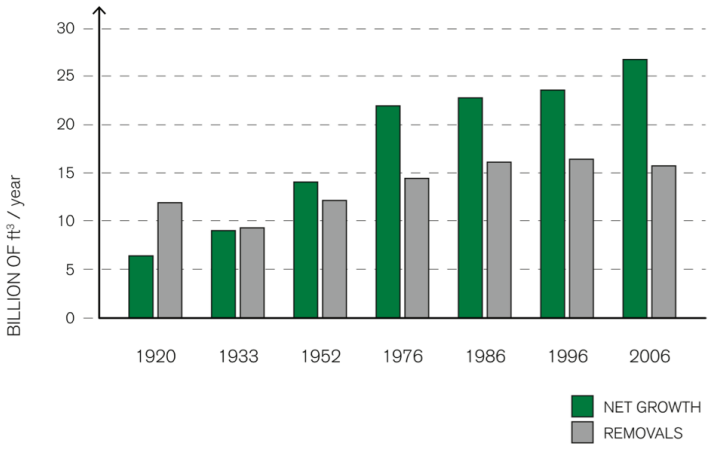


Image: Kim & Itakura

  - This is due to more sustainable practices being adopted and increases in forest management knowledge and technology.

- Adhesives used in the U.S. for binding the CLT layers are formaldehyde free and better for the environment.

- CLT buildings can be LEED certified when utilizing lumber sourced from certified tree farms or used from damaged trees.

THERMAL EFFICIENCY

- CLT averages savings of 50% in additional insulation costs compared to other pane building system.
- The precision fabrication and CNC milling of panels gives very tight tolerances between joined walls leaving little room for air leakage.
  - Additional usage of foam tapes or sealants with installation boosts protection of air drafts
- CLT panels require approximately 1/3 of the energy needed for heating and cooling.
  - The average building uses 31% of its energy on heating and cooling, leading CLT to give ~20% savings on power bills alone.
- The structure of wood alone provides it with excellent insulation properties. CLT's thermal performance increases as more layers are used in the panel.
- CLT panels are not limited to just retaining heat and air. The thermal mass of CLT allows the absorption of heat during the day and the release of heat at night.
  - This property reduces heating and cooling peak loads leading to lower energy use and a greater level of comfort residents.

MOST OF A BUILDING'S ENERGY IS CONSUMED IN HEATING AND COOLING

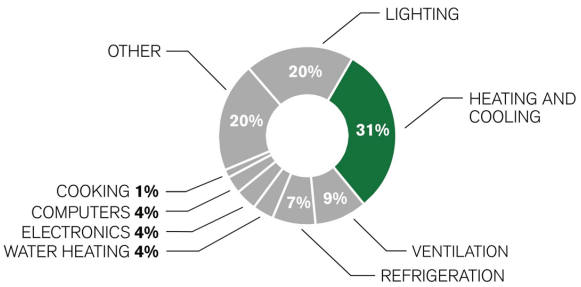


Image: Kim & Itakura Source: U.S. Department of Energy

Wood's cellular structure contains air pockets that limit its ability to conduct heat. The precise manufacturing of CLT and other engineered timber limits air leakage. The result: a comfortable interior that requires less energy to maintain.

WOOD IS THERMALLY EFFICIENT

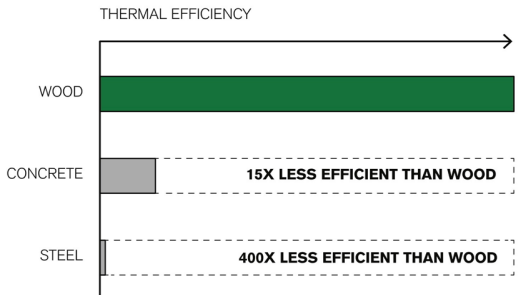


Image: Kim & Itakura Source: ReThink

SEISMIC PERFORMANCE

- CLT's design gives panels dimensional stability and strength, contributing to their ability to resist lateral loads and forces. The stiff nature of the panels decreases the ductility of the panels and decreases energy dissipation in the wood.
- Energy dissipation is crucial to with standing seismic forces and activity. This issue is fixed in CLT structures by using systems of connectors that increase its ductility.
  - Steel brackets, hold downs, half-lapped joints, screws, and self-tapping screws give CLT the ductile and energy dissipating qualities needed of superior performance.

SOFIE Test

- Italy's SOFIE project conducted seismic testing on a 7-story CLT building in Japan using the largest shaker table in the world to simulate the effects of an earthquake[7].
  - The building was subjected to 14 consecutive tests all varying in the acceleration rates, from 0.35 g up to 1.2g, and magnitudes from 5.8 to 7.2 on the Richter scale. 10 out of 14 tests were above the minimum 0.35g acceleration.
  - After all tests the building was still standing and had no permanent deformities. The only damaged portions of the building were panel connections, which were able to be repaired. All CLT portions maintained perfect structure.

- The max inter-story drift was 1.5 inches with a max lateral drift of 11.3 inches at the top of the building. Seismic dampening levels of 12% were achieved, which meets U.S. requirements in high seismic areas found on the west coast[6].

CLT IN ACTION

Current World Applications

Cross Laminated Timber has already been used to impressive and advanced buildings in the United States and around the world. Modern structures such as parking garages, high-rise office buildings, and museums have been constructed both exclusively of CLT, and in conjunction with other materials traditional materials.

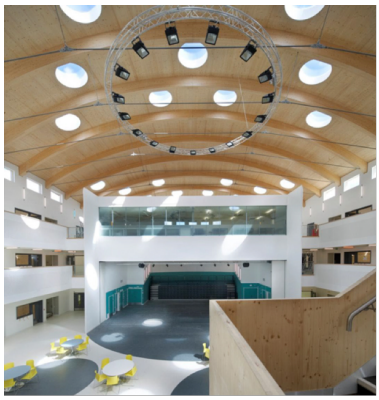
Building Case Studies

Murray Grove/Multifamily Housing/London

The Murray Grove high-rise building was designed by Waugh Thistleton Architects as a nine story multifamily housing unit. Waugh Thistleton used the Austrian CLT producer KLH to fabricate the wood panels used in its construction[14]. The 25,307 ft^2 building used 33,549 ft^3 of CLT saving the carbon equivalent of using a roof-top wind turbine for 210 years. The structural frame only took 27 days to finish with a 4 person crew using cordless drills and a mobile crane. The total project took 49 weeks and saved 22 weeks compared to a concrete building.

Albina Yard/Mid-Rise Office/Portland, OR

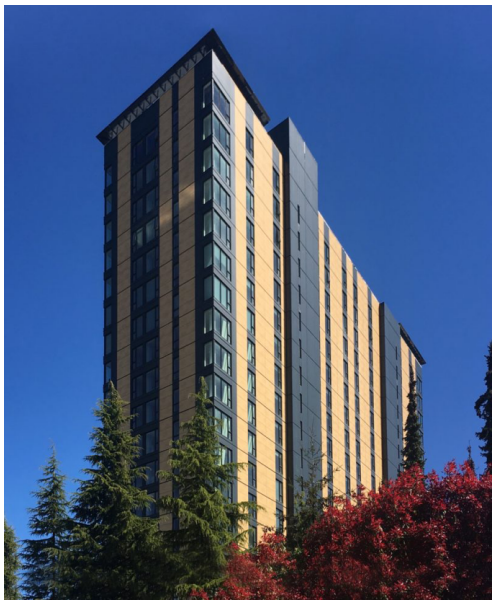
Albina Yard is a 4 story office complex designed by LEVER Architecture and manufactured by D.R. Johnson Wood Innovations. The 16,000 ft^2 office building opened September 2016 and was the United State's first office to use mass timber. Albina Yard utilizes CLT and glulam for its frame, roof, stairs, and floor.



Norwich Open Academy/Education Building/ United Kingdom

Is a 3 story 102,000 ft^2 school that used 127,000 ft^3 of CLT giving a yield of 1.25ft^3/ft^2. Open Academy was produced for $29 million at $284/$ft^2$. Installation for the massive building containing classrooms, labs, and an auditorium took only 18 weeks using a crew of 8 people and 2 cranes. CLT construction saved an estimated 14 weeks of installation compared to traditional materials. The school has a circular design with classrooms surrounding the central lecturing hall and has the capacity for 950 students and 100 staff. Open Academy pulled off an interested design feat by using flat CLT panels to form curved and double curved surfaces[15].

Brock Commons/Student Residence/Vancouver



Tallwood House in Brock Commons at the University of British Columbia is set to be the world's tallest wood building upon completion in 2017. The 173 foot $53 million project designed by Architekten Hermann Kaufmann is now awaiting interior construction to wrap up[16]. The frame and external structure was completed in less than 70 days, which is 4 months faster due to the use of CLT and mass timber. The 162,700 ft^2 Tallwood House will use 69,676 ft^3 of CLT in its construction and will be home to roughly 400 students. Tallwood is providing rooms ranging from single bed studios to suite style 4 bedroom arrangements. A canopy fabricated from CLT will run the entire length of the building, sitting beneath the metal decking roof. Tallwood is calculated to have a carbon benefit 2,825 tons, or the equivalent of taking 490 cars off the road for an entire year.

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Kim & Itakura: Graphics courtesy of Yugon Kim and Tomomi Itakura, partners at architectural design firm IKD