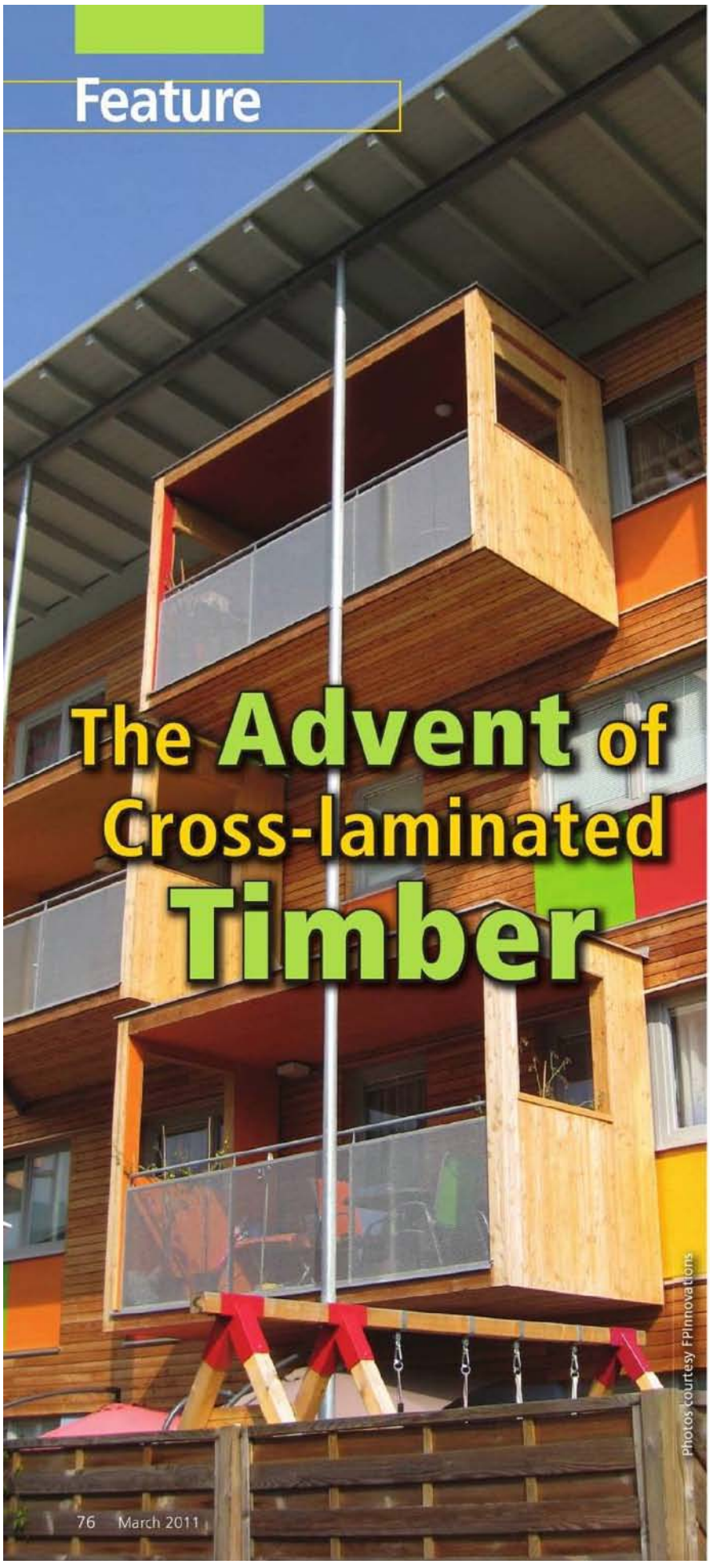
Feature

The Advent of Cross-laminated Timber



Photos courtesy FPInnovations

By David Moses, PhD, P.Eng., PE, LEED AP, and Sylvain Gagnon, Ing.

A relatively new technology is poised to significantly change the way Canadians design and build with wood framing. Cross-laminated timber (CLT) panels, specified in Europe for more than a decade, are now manufactured in Canada (and, possibly later this year, the United States).[1]

CLT panels are large prefabricated wall and floor assemblies used in various building types for residential and non-residential projects. Assembled in a platform-frame fashion, the effect is comparable to suspended concrete slabs spanning between load-bearing concrete walls to resist gravity and lateral loads. These wood panels can also be used in combination with post-and-beam wood frame or steel frame components. Vertically oriented panels can enclose a building, similar to tilt-up concrete construction, while the horizontally oriented panels span across beams to create the floor plates. Another option, sometimes employed for industrial buildings, involves balloon-frame construction. The method takes advantage of the large dimensions of CLT products by hanging floors assemblies from multi-storey wall panels.

One of the first commercial buildings to use CLT in Canada will be on the University of British Columbia (UBC) campus. Schedule for completion by year's end, this facility will house a biomass-fuelled combined heat and power (CHP) solution.

CLT 101

As cross-laminated timber panels were developed in Europe over a long period, there are many companies who make a wide variety of panel types. The products can be manufactured up to approximately 3 x 18 m (10 x 60 ft) and then cut to size for each project. They are normally produced in thicknesses from about 50 to 400 mm (2 to 16 in.), but thicker panels are available.

The laminates making up the panels are pieces of dimension lumber (*e.g.* 1x4s and 1x6s, or 2x4s and 2x6s) that are either glued using radio-frequency presses or fastened to each other. The lumber is stacked in its flat orientation into layers of three, five, seven, or more on a forming bed and then subjected to uniform pressure using hydraulic or vacuum presses.

The outer layers tend to use higher-grade lumber for strength and appearance, while lower-grade material can be for the transverse layers. Each layer is perpendicular to the adjacent ones

(hence the term 'cross-laminated'). This means when the lumber in each layer tries to expand or contract due to shrinkage or swelling, the others restrain any movement. This contributes to the superior dimensional stability of the CLT panel.

After pressing, completed CLT panels are moved onto a computer numerical controlled (CNC) cutting machine to trim the edges and plane, sand, or wire-brush the faces. The automated machines drill out the panel for connection hardware and cut openings for windows, doors, stairs, and mechanical chases.

The use of CNC technology allows the accurate, efficient cutting and profiling of conventional solid and glue-laminated wood products. CLT panels can be thought of as high-performance products prefabricated under controlled conditions, but they are not generic, assembly-line lookalikes. Fully detailed models of the panels allow designers to customize layouts and window and door openings.

After the design is complete, and once the CLT components have been determined for each project, the cutting patterns can be optimized to reduce waste. Any material cut away from the panel can be collected as wood waste and reused in other ways by the manufacturer (as opposed to conventional, field-built assemblies where site waste must be carefully separated and sent away for reuse or recycling at added cost).

Quality control in the plant is much better than in the field, and the controlled environment eliminates temperature and humidity cycles, while offering protection from water, snow, and ultraviolet (UV) light. Once assembled onsite, the joints are tight—this results in cleaner surfaces for attaching building envelope components.

Construction time onsite is significantly reduced as work becomes assembly rather than carpentry. Panels up to 18 m (60 ft) long and 3 m (10 ft) wide can be used in single elements to simplify installation. The short construction cycle has immediate effects on project costs. It also means CLT panels are exposed to the elements for less time as the roofing and cladding can be installed much faster. Unlike concrete, CLT panels do not require additional protection and heating to cure in cold weather.

Photo courtesy APG Austrian Passive House Group, www.oesterreichhaus.at

The Austria House (Whistler, B.C.) features the first Canadian application of cross-laminated timber (CLT) panels for roof and floor structure and diagonally dowelled solid wood panels for the wall structure.

CLT panels can be assembled in platform-frame fashion, like concrete slabs suspended between load-bearing walls.

Images courtesy FPInnovations

FPInnovations' CLT Handbook *aims to serve as a technical resource for Canadian design/construction professionals who will be using the wood technology for the first time.*

While there are quite a few CLT manufacturing plants in Europe, the first Canadian facilities are expected to open shortly.

This CLT manufacturing plant uses a radio-frequency press.

Additionally, the relatively light weight of the panels reduces the need for heavy lifting equipment onsite.

Material strengths

Cross-laminated timber panels have unique environmental, architectural, structural, thermal, and fire resistance properties and benefits. In Europe, architects have long recognized wood has a lower carbon footprint than other conventional building materials—wood harvesting and processing takes very little energy and the material itself is a carbon sink. The architects who use CLT panels are able to offset the total carbon usage in the manufacturing of the material, construction, and operation of their buildings to make them effectively carbon neutral.

Interior panels can be left exposed as a finish without additional materials (at the discretion of the designer and depending on fire code requirements and the needed acoustic performance). In North America, low- and medium-quality lumber and standing dead timber killed by mountain pine beetles (MPBs) can provide a good resource for CLT manufacture.

Programmatically, the panels lend themselves well to repetitive, shallow floor plates for mid-rise and high-rise buildings. However, they can just as easily be adopted for single-storey or low-rise construction. In North America, CLT lends itself well to making more liveable cities through neighbourhood densification and mid-rise construction.

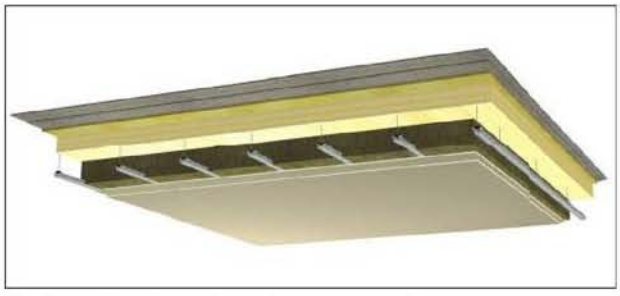
Acoustic performance for sound transmission between walls and floors is fairly good with CLT panels due to their solid mass. Additional sound insulation through a variety of tested European techniques has led to floor systems with STC ratings over 65 dB with careful detailing between walls and floors, and at stairwells.

The thermal mass of CLT panels gives them some ability to moderate temperature. Working as a component of a building envelope system, panelized construction leads to tighter building envelopes with blower door tests resulting in very low air exchanges per hour. In a traditional wood frame wall assembly, airflow is controlled using an air barrier approach with sealed polyethylene, airtight drywall, sealed sheathing, or a sealed sheathing membrane. In a CLT panel wall assembly, the most practical strategies for creating a continuous air barrier are either a sealed exterior sheathing membrane or interior airtight drywall.

The laminates that make up the panels are pieces of dimension lumber (e.g. 1x 4s and 1x6s, or 2x4s and 2x6s). They are either glued using radio-frequency presses or fastened to each other. The lumber is stacked in its flat orientation into multiple, odd-numbered layers on a forming bed and then subjected to uniform pressure using hydraulic or vacuum presses.

Photo courtesy KLH

The panels can also be used in combination with post-and-beam wood frame or steel frame components—the vertically oriented panels enclose the building similar to tilt-up construction.



Horizontally oriented panels span across beams to create the floor plates.

Fire performance of massive wood members is recognized in building codes for heavy timber construction, but CLT is not yet specifically mentioned. In Europe, studies have shown CLT panels exposed to fire will form a char layer—this protects the rest of the panel, allowing it to retain strength and dimensional stability. Unlike conventional construction, solid wood products mean less risk of fire spread through gaps or voids in the building components.

Structurally, CLT panels have strength and stiffness in- and out-of-plane that make them suitable for gravity and lateral load resistance. The excellent axial resistance and in-plane shear resistance of cross-laminated timber allows its use in load-bearing and shear wall construction. The outer layers are oriented to take advantage of the longitudinal tension and compression properties of lumber and to act as bending members for floors and tall walls.

CLT's in-plane strength and stiffness are also beneficial when panels are used as floor and roof diaphragms. In seismically active regions, this can be a significant improvement over conventional framing and systems made with other materials. Ductility (*i.e.* energy absorption) is provided through metal connections. For multi-storey construction, the lighter weight of wood walls compared to concrete and masonry can result in smaller footing sizes, saving cost and materials. Connections between wall and floor panels and to other building components are available via proprietary fasteners or customized options.

Other benefits of the material include vastly reduced construction waste (due to the efficiency of prefabrication), and ease of attachment of services, such as electrical conduit, sprinkler lines, and plumbing systems. In Europe, CLT panels compete against concrete and masonry construction where impact drills must be used to attach pipe hangers. This can be labour-intensive and yield joint damage or injuries to workers. Attaching to wood is much simpler and does not require impact drills.

Moving forward

FPInnovations is a not-for-profit group that includes members of the forest operations, wood products, and pulp and paper industries, along with the Canadian Wood Fibre Centre of Natural Resources Canada (NRCan). It drafted CLT plant qualification and product standards and passed them to the American National Standards Institute (ANSI)-accredited APA–Engineered Wood Association committee to be used as 'seed documents' for the development of a single North American product standard. This would then be the basis for an International Organization for Standardization (ISO) standard that would harmonize North America with Europe. (An ISO task group was formed under the ISO Technical Committee on Timber Structures for this purpose.)

It is anticipated manufacturers will use the proposed standards to gain acceptance of proprietary CLT products by code-recognized

Opening in a CLT floor for mechanics.

Like the multi-family building in Judenburg, Austria, pictured on page 76, this five-storey residential complex in Berlin, Germany, benefits from CLT use.

Located in Växjö, Sweden, the Limnologen Project is an eight-storey building made out of CLT.

evaluation services such as Canadian Construction Materials Centre (CCMC) and the International Code Council Evaluation Service (ICC-ES).

A North American advisory committee on CLT has also been formed to advance the implementation of cross-laminated timber technology. In turn, this group formed a research/standards subcommittee so the related activities could be streamlined. Based on the initial assessment, seismic and fire design issues have been identified as the most important ones to address. The American Wood Council (AWC) and Canadian Wood Council (CWC) have already initiated the process of implementing CLT in the material codes. These forthcoming documents should deal with:

- grade of softwood to be used;
- certain lay-up requirements;
- quality control during fabrication;
- structural design standards; and
- plant quality standards.

Each manufacturer will be required to meet minimum standards, but the companies will be allowed to develop their own systems, much like in Europe. Some manufacturers may choose to use other wood products such as laminated veneer lumber (LVL) or oriented strandboard (OSL) in their panels; others may follow some of the European systems and employ internal wood dowels, keyways, grooves, spaces between laminates, or varying laminate orientation.

Regardless of the provider, the end-products share certain characteristics. They are all prefabricated and manufactured in a controlled environment and processed using automation and CNC equipment. Further, all CLT products are easily assembled on construction sites, and can be used as monolithic walls, floors, ceiling, elevator shafts, and stairwells.

Guidelines will be released for architectural detailing, engineering, and construction. Research is ongoing related to all the issues normally associated with any new product in the building code:

- strength and seismic performance;
- connections;
- fire resistance;
- thermal behaviour;
- acoustic and vibration performance; and
- durability.

Much of this research has already been carried out in Europe and Canada.

Resource for further work

While Canadian design/construction professionals await these new standards, a comprehensive overview of the use of cross-laminated timber has just been released by FPInnovations. Unveiled in early 2011 at a symposium sponsored by the Wood Enterprise Coalition of British Columbia, the *CLT Handbook* draws on European experience and FPInnovations' multi-disciplinary research program that was launched under the auspices of NRCan's Transformative Technologies Program in 2005.

Another look at the construction of Limnologen.

CLT panels can be used in both horizontal and vertical applications.

The peer-reviewed reference provides immediate support for the design and construction of CLT systems as alternative solutions in building codes, along with technical information related to:

- manufacturing;
- structural design;
- seismic performance;
- connections;
- duration of load and creep;
- vibration performance;
- fire performance;
- acoustic performance;
- building enclosure design; and
- environmental performance.

"The *CLT Handbook* will be instrumental in guiding building and design specialists as they seek use of this innovative new wood building material in non-traditional applications," explained Mary Tracey, executive director of WoodWORKS! BC and executive member of the Wood Enterprise Coalition (WEC).

"The possibilities are exciting, and we look forward to realizing the full potential of cross-laminated timber as a renewable alternative building material in Canada as we see construction of the first Canadian projects using CLT," she said.

Conclusion

Major changes to the line of forest products do not happen very often. Further, experience over the last century or so has shown new products—such as OSB, I-joists and structural composite lumber (SCL)—take time to develop and to gain market acceptance. Manufacturers, trade associations, and researchers in Canada and the United States are working hard to provide support to designers and builders who want to use CLT products in their projects in the near future. The forest products industry is actively conducting research and developing the materials, standards, and guidelines to bring cross-laminated timber panels to the North American market in a very short timeframe.

Notes

[1] An earlier version of this article, "A New Generation of Solid Wood Panels," appeared in the Fall 2010 edition of the Canada Wood Council (CWC) magazine, *Wood Design and Building*.

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