INNOVATION IN HYBRID MASS TIMBER CONSTRUCTION

BROCK COMMONS TALLWOOD HOUSE

CODE COMPLIANCE

INTRODUCTION

Located on a large forested peninsula on the west side of Vancouver, the University of British Columbia is at the forefront of the global movement to revitalize mass timber construction and be innovative in the use of engineered wood products in tall buildings. Among the large wood buildings already on campus are the Centre for Interactive Research on Sustainability, the Earth Sciences Building, and the Bioenergy Research and Demonstration Facility. The newest addition to the portfolio is the 54-m-high (18-storey) Brock Commons Tallwood House, featuring the first North American use of mass timber products in a residential high-rise.

Brock Commons is one of the University's five high-rise, mixed-use, residential complexes that provide housing for students while acting as academic and recreational hubs for the campus community. The hubs are all of similar programming and urban design, however Brock Commons is unique in the use of a hybrid mass timber structure. The foundation, ground floor, and stair/elevator cores are concrete, while the superstructure is composed of cross-laminated timber (CLT) panel floor assemblies supported on parallel strand lumber (PSL) or glue-laminated timber (GLT) columns with steel connections. The building envelope is comprised of prefabricated, steel-stud frame panels with wood-fibre laminate cladding, and a traditional SBS (styrene-butadiene-styrene) roof assembly on metal decking.

Brock Commons was one of the demonstration projects supported by the 2013 Natural Resources Canada and Canada Wood Council competition—the Tall Wood Building Demonstration Initiative—which was aimed at advancing the design and production of wood products in Canada. This pioneering building showcases innovations in engineered wood products and building techniques, and creates unique research and learning opportunities related to the design, construction, operation, and inhabitation of a tall wood building in a North American context.

FRONT & BACK COVER
KK Law

REGULATORY CONTEXT

The University of British Columbia is a single legal entity with sole jurisdiction over its land, buildings, and infrastructures. The Province's *University Act* grants the University's Board of Governors, in consultation with its two Senates, the power to manage, govern, and maintain all development. The campus operates similarly to a small municipality in regulating building and development. As with any municipality, building projects are governed by a number of overlapping policies, codes, standards, and regulations that are established at the local, provincial, and national levels.

The primary regulation governing the construction of tall wood buildings at the University is the *British Columbia Building Code*. The provincial code is modelled on the *National Building Code of Canada*, which regulates the design and construction of new buildings, as well as the alteration, changes of use, and demolition of existing buildings. The current version of the *British Columbia Building Code* allows combustible construction, e.g., wood, for a residential building if it is no more than six storeys and/or 18 m high, has a maximum building area of 1,200 m², and is fully sprinklered.

The project team and the University's Chief Building Official worked with the British Columbia Building and Safety Standards Branch to draft the *UBC Tall Wood Building Regulation*. The regulation exempts the project from some parts of the *British Columbia Building Code*—such as the parts regarding size limitation on combustible construction—and substitutes specific technical requirements that apply to this building only. The intention was to ensure occupant health and safety protection is equal to or better than that provided in the Code for non-combustible construction of this size. The *UBC Tall Wood Building Regulation* was approved by the British Columbia Minister Responsible for Housing on September 29, 2015.

BROCK COMMONS' REGULATORY FRAMEWORK

- *British Columbia Building Code 2012*
- *UBC Tall Wood Building Regulation*
- *British Columbia Fire Code 2012*
- *UBC Policy No. 92 - Land Use and Permitting*—a set of rules for development and building projects, which include:
  - *The University of British Columbia Vancouver Campus Plan*
  - *Land Use Plan, the University of British Columbia, Point Grey Campus*
  - *The University of British Columbia Development and Building Regulations*
- LEED Gold Certification requirements
- ASHRAE 90.1-2010, *Energy Standard for Buildings Except Low-Rise Residential Buildings*

"We started with two considerations—What are the products that are available to build this? And also what are we allowed to do under the building code? These were the two starting points for the design of the building. Everything else fell into place after that."

STRUCTURAL ENGINEER

FACTS

Under the *British Columbia Building Code*, Brock Commons Tallwood House is classified as a Group C (residential) major occupancy, with a subsidiary occupancy of Group A-2 (assembly) in the student amenity spaces. With the exception of the lounge on the eighteenth floor, most of the assembly spaces are located on the first floor within the concrete non-combustible construction.

Hover Collective

SITE-SPECIFIC REVIEW

The development of a site-specific regulation involves a rigorous review process. The purpose of the process is to confirm that all areas of uncertainty are identified and adequately addressed in the resulting regulation. The resulting regulation is applicable only to the specific building site and does not serve as a precedent for future projects.

The project design team developed the design concepts, proposed strategies for mitigating the key areas of technical risks, and obtained peer reviews by third-party structural engineers. The University brought in the Building and Safety Standards Branch, who managed the process of developing the *UBC Tall Wood Building Regulation*, which included design reviews by two expert panels on the topics of structural performance and fire safety, as well as collaborative problem solving involving the Building and Safety Standards Branch, the University's Chief Building Official, and the project design team. An experienced code consultant with relevant experience in combustible construction advised the Building and Safety Standards Branch throughout this process. This process allowed feedback and input from reviews and regulation deliberations to be incorporated in the final design.

The expert panels included professional architects and engineers, fire and code officials, advanced wood construction research organizations, and University faculty. The process produced agreement on matters that required site-specific technical requirements; those that could be handled by the University's Chief Building Official in his monitoring and oversight of the project; and some matters that could be left to the discretion of the project team based on the principles that had been agreed to during the development of the site-specific regulation. The Building and Safety Standards Branch and the project team solicited feedback from these panels regarding specific design strategies and decisions.

STRUCTURAL REVIEW PANEL

- Gage-Babcock & Associates Ltd.
- Read Jones Christoffersen Consulting Engineers
- office of mcfarlane biggar architects + designers
- Equilibrium Consulting Inc.
- Structural Engineers Association of British Columbia
- StructureCraft Builders Inc.
- City of Vancouver
- Part 4 Task Group, Canadian Codes Centre, National Research Council Canada
- Faculty of Forestry, University of British Columbia
- Wood Science and Technology Centre, University of New Brunswick
- FPInnovations
- Natural Sciences and Engineering Research Council of Canada
- Forestry Innovation Investment Ltd.

FIRE SAFETY REVIEW PANEL

- Gage-Babcock & Associates Ltd.
- Sereca Fire Consulting Ltd.
- Building Code Appeal Board (British Columbia)
- Vancouver Fire and Rescue Services, City of Vancouver
- Surrey Fire Service, City of Surrey
- Engineering Services, City of Vancouver
- National Research Council Canada
- Forestry Innovation Investment Ltd.

The structural peer reviews were conducted by two third-party structural engineering firms: one local, with expertise in local and provincial building codes, and one international, with expertise in constructing mass timber buildings. The firms reviewed the proposed design of the hybrid wood structural system, which at the time was composed of GLT columns (PSL columns were added later) and CLT panels with steel connections, a cast-in-place concrete foundation, and first-floor and conveyance cores. The reviews, which consisted of two rounds of reporting based on submitted documentation, confirmed the design approaches and highlighted elements that required further consideration. The final peer-review reports were sent to the expert panels.

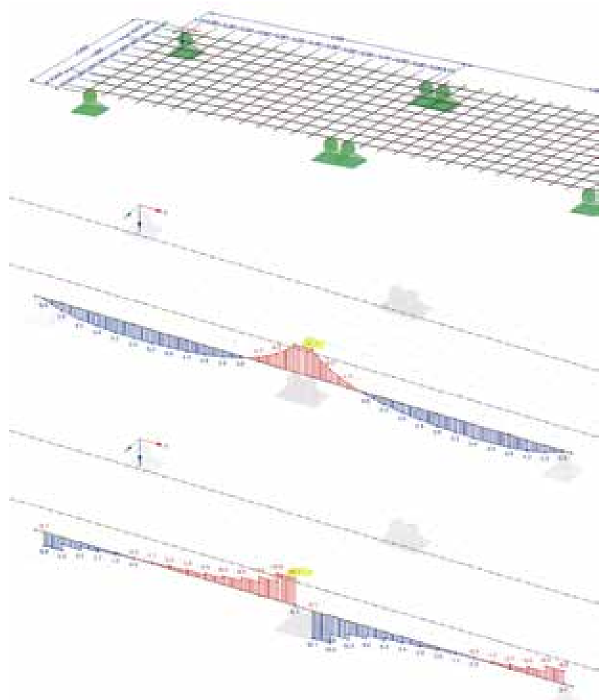
The local peer review focused on the structural concept and code considerations, on strategies to address gravity loads and lateral loads of individual elements and connections, and on the hybrid system as a whole. The analysis validated the designers' applications of the codes and reference standards. The analysis also provided recommendations for areas of further analysis and factors for calculations, and it highlighted specific components that required additional review, such as the consideration of two-way action in the CLT panel design and the proprietary connections for the floor slab diaphragms.

The international peer review was based on load assumptions provided by the structural engineer, and it focused primarily on the mass timber products—specifically the structural capacity components with respect to gravity loads and the ultimate and serviceability limit states. The analysis examined flexural design, shear design, fire design, deflections, and vibration of the CLT panels; stability and fire design of the GLT columns; and differential movement and settling of the GLT columns. The structural conditions of the building elements were found to be acceptable in all cases.

PEER REVIEW FIRMS

- Read Jones Christoffersen—based in Vancouver, Canada
- merz kley partner AG—based in Altenrhein, Switzerland

PANEL STRUCTURAL ANALYSIS



Structural analysis—including reaction at bearings, longitudinal bending forces, and longitudinal shear forces—was performed by merz kley partner AG as part of the third-party structural peer reviews.

KEY DESIGN STRATEGIES

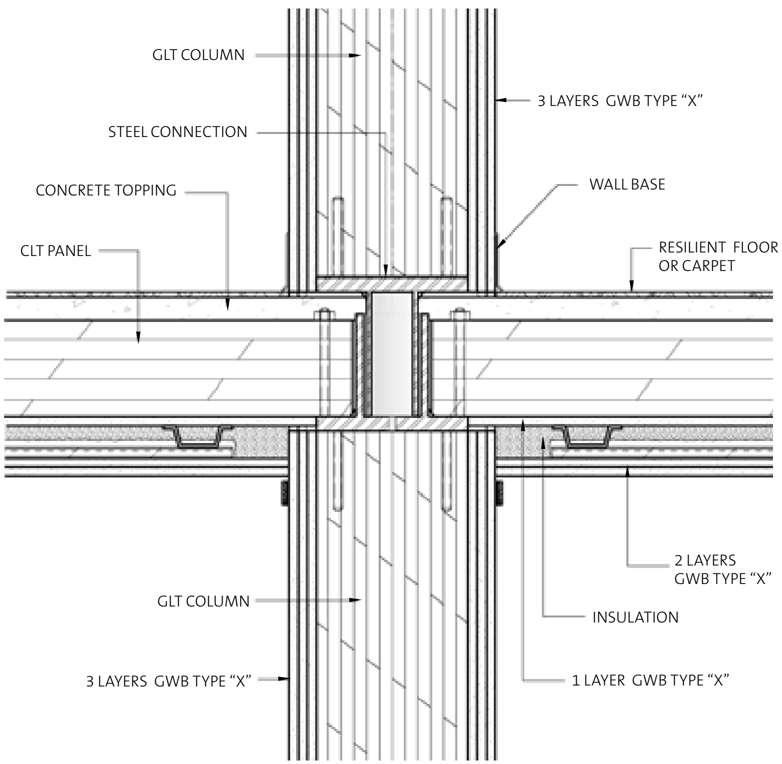
Given the innovative nature of the overall project, a key driver in developing and detailing the design of Brock Commons was the utilization of tried and tested solutions that are code compliant and in accordance with CSA 086-14 *Engineering Design in Wood* or other recognized standards.

The building structure is a hybrid configuration, with a dual approach to handling gravity load and lateral loads. The gravity load system for floors 2 through 18 consists of mass timber floor plates and columns carried by point loads at the column connections. The mass timber structure is supported by the second-floor concrete transfer slab, the first-floor concrete columns, and the concrete foundations. The lateral load system is comprised of the floor panels and the concrete cores, which transfer the loads directly to the foundation. The CLT floor panels are joined together by a plywood spline screwed and nailed to each panel, creating a single diaphragm at each floor to resist lateral forces. The lateral loads are first transferred from the floors to the concrete cores through steel drag-strap connections located at the core edges and along the building perimeter, and then from the cores to the raft slabs in the concrete foundation.

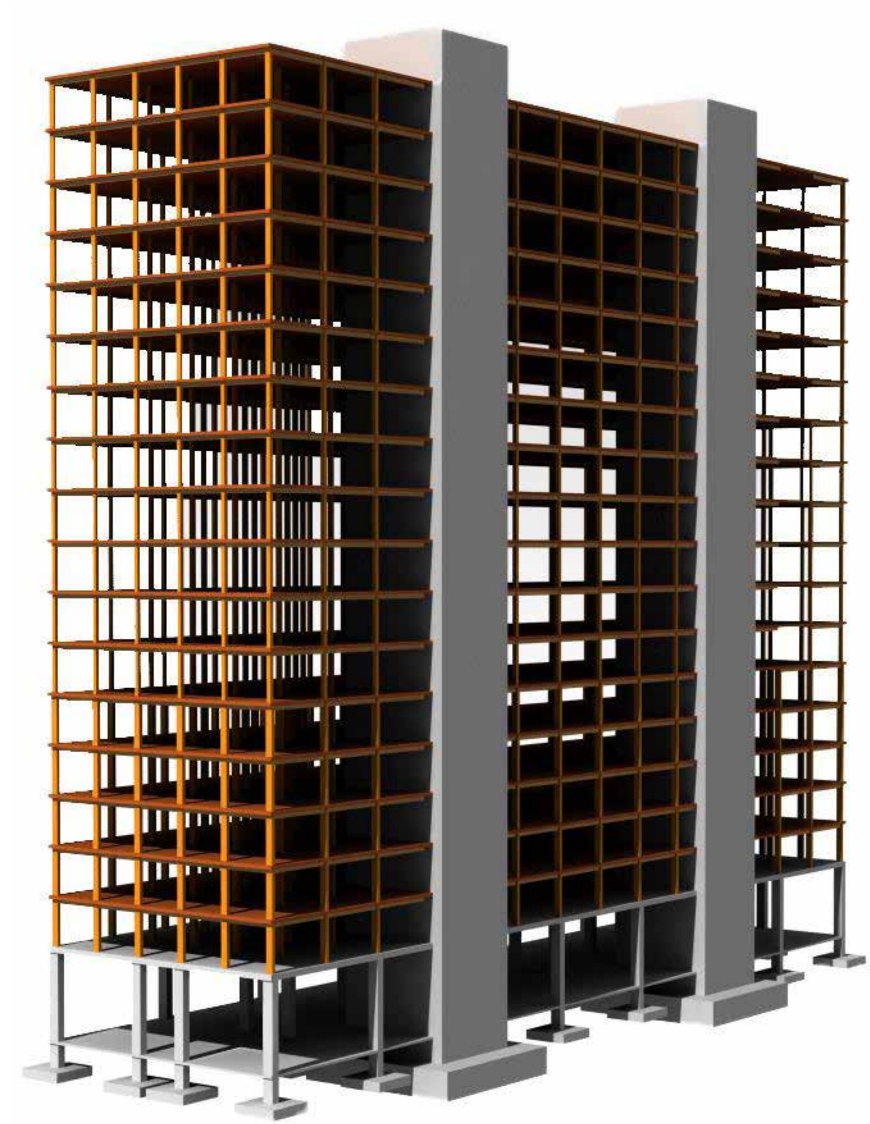
The use of concrete cores enabled the code approval process to proceed quickly because concrete cores are a typical feature in standard high-rise buildings. Mass timber cores would have been much more challenging in terms of design and in demonstrating the levels of performance required for a site-specific regulation. The use of a hybrid mass timber structure also results in a significantly lighter building than a comparably sized concrete structure. The lower mass results in less inertia and therefore lower resistance to overturning during a seismic event. The concrete foundation and ground floor provide a counterweight to resist overturning forces.

The composition, sizing, and spacing of individual mass timber components were designed to handle the anticipated loads—including gravity loads, shear loads, and lateral loads due to wind or seismic events—as well as vibrations and deflection. The approaches were validated through the performance analysis in the peer-review process.

A typical structural bay is 4×2.85 m. The CLT panels come in four sizes to allow for overlap of the bays and staggering of the panel layouts between floors: 2.85×6 m (spans 1.5 bays), 2.85×8 m (spans 2 bays), 2.85×10 m (spans 2.5 bays), and 2.85×12 m (spans 3 bays). The panels are 169 mm thick, with outer layers of machine-stressed lumber and inner layers of SPF lumber and CSA-standard wood adhesive. The characteristics of the three types of columns within the building vary depending on the location and loads: 265×215-mm GLT columns on floors 10 and above, 265×265-mm GLT columns on floors 2 to 9, and 265×265-mm PSL columns in high-stress positions in the center of the floor plates on floors 2 to 5.



Detail of typical column and floor intersection and encapsulation, by Fast + Epp.



Render of hybrid mass timber and concrete structure, by CadMakers Inc.

STRUCTURAL ELEMENTS STANDARDS

CLT panels

North American standards

- APA PRG 320-2012—*Standard for Performance-Rated Cross-Laminated Timber*
- CSA O86-14—*Engineering Design in Wood*
- CSA O112 Series (R2013)—*CSA Standards for Wood Adhesives*

European standards

- EN 14080:2013—*Timber Structures. Glued Laminated Timber and Glued Solid Timber. Requirements*
- EN 1995-1-1:2004—*Eurocode 5: Design of Timber Structures—Part 1-1: General—Common Rules and Rules for Buildings*

Timber columns

North American standards

- CSA O80 Series 08 (R2012)—*Wood Preservation*
- CSA O86-14—*Engineering Design in Wood*
- CSA O112 Series (R2013)—*CSA Standards for Wood Adhesives*
- CSA O122-06 (R2011)—*Structural Glued-Laminated Timber*
- CSA O177-06 (R2011)—*Qualification Code for Manufacturers of Structural Glued-Laminated Timber*

European standards

- EN 14080:2013—*Timber Structures. Glued Laminated Timber and Glued Solid Timber. Requirements*
- EN 1995-1-1:2004—*Eurocode 5: Design of Timber Structures—Part 1-1: General—Common Rules and Rules for Buildings*

Steel connections

North American standards

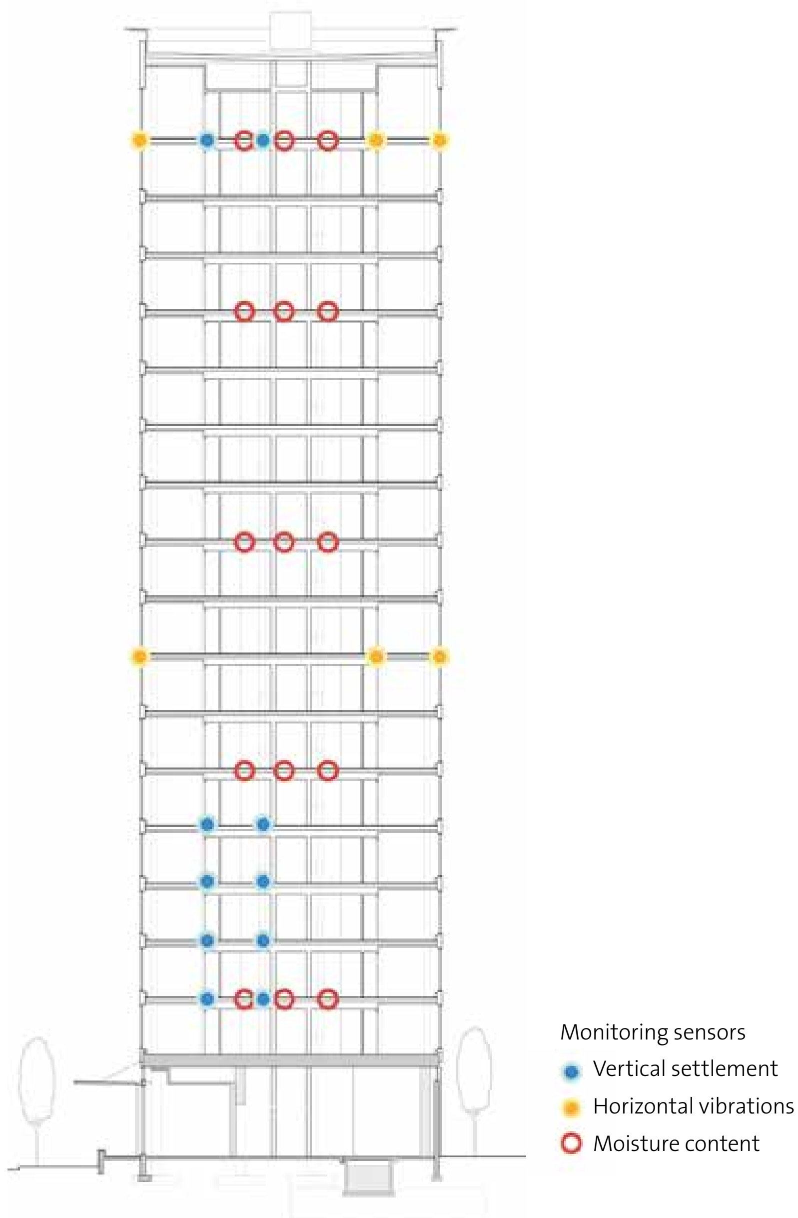
- ASTM A123/A123M-13—*Standard Specification for Zinc (Hot-Dip Galvanized) Coatings on Iron and Steel Products*
- ASTM A153/A153M-09—*Standard Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware*
- ASTM A307-12—*Standard Specification for Carbon Steel Bolts, Studs, and Threaded Rod 60,000 PSI Tensile Strength*
- ASTM A563-07a (2014)—*Standard Specification for Carbon and Alloy Steel Nuts*
- CSA G40.20-13/G40.21-13—*General Requirements for Rolled or Welded Structural Quality Steel / Structural Quality Steel*
- CSA W47.1-09—*Certification of Companies for Fusion Welding of Steel*
- CSA W59-13—*Welded Steel Construction (Metal Arc Welding)*

The use of North American and European standards allowed the University to solicit tenders and source products from both continents.

PERFORMANCE TESTING, MODELLING, AND MONITORING

Because this type of hybrid construction is new, there are few actual performance data on which to base design decisions and code regulations. As part of the demonstration nature of Brock Commons, a monitoring system was installed to collect data on the performance of engineered wood products and hybrid structural systems in a high-rise building. The data from Brock Commons, and the research that will be conducted with it, are expected to contribute to the creation of performance and building safety standards for future tall wood buildings.

Three specific aspects of building performance are being monitored: moisture content of the CLT panels, vertical settlement (including elastic shortening, moisture-related shrinkage, and creep), and horizontal vibrations due to wind (and, potentially, earthquakes).



Monitoring sensors are located across the entire building to provide data on its performance. Rendering by Acton Ostry Architects Inc.

FIRE PROTECTION

The fire-protection strategy for Brock Commons is three-fold. First, there is no significant exposure of the wood structure. Second, the building is fully sprinklered. And third, a 30-minute, on-site, backup water supply is provided.

The wood structural elements, as well as most of the steel connections, are encapsulated with multiple layers of Type X gypsum board to achieve a 2-hour fire resistance rating. The one exception is the exposed wood structure in the eighteenth-floor lounge, which is fully sprinklered. Additional fire-separation measures are provided by the interior wall and floor assemblies, which are designed to achieve specific levels of fire separation through layers of Type X gypsum board and concrete toppings (for floors): a 2-hour fire resistance rating for floor assemblies, suite-to-suite demising walls, and vertical shafts; and a 1-hour fire resistance rating for suite-to-corridor walls. The exit stairs are located within the concrete cores and are therefore of non-combustible construction. Similarly, the mechanical and electrical service spaces are housed on the non-combustible concrete ground floor.

The active fire-protection system includes an automatic sprinkler system, a standpipe system, and a water curtain. The systems are connected to the municipal water supply and are backed by an on-site water reservoir and pump connected to emergency power. Fire extinguishers are also provided on each floor, which is standard practice.

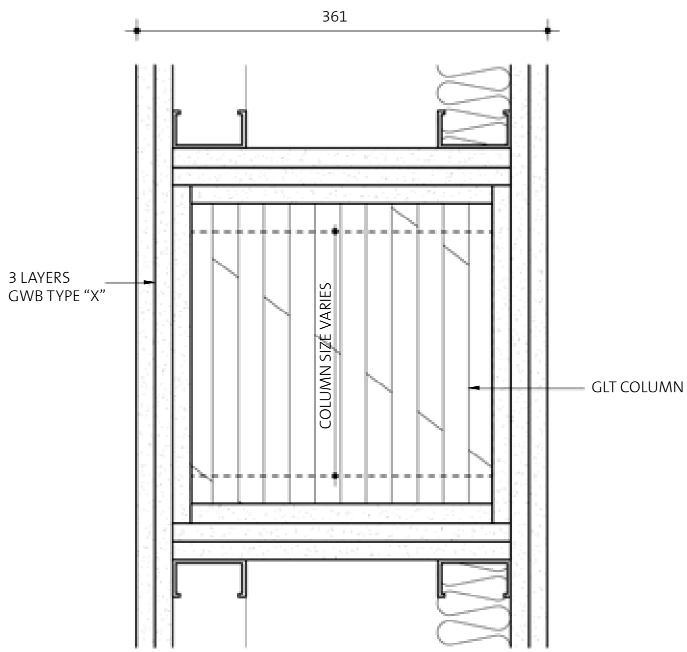
The automatic sprinkler system serves the interior of the building. Sprinkler heads in the residential units are recessed to mitigate the possibility of being accidentally hit and damaged or set off. Non-freezing sprinkler heads are used in exterior, unheated areas, including the space below the exterior CLT canopy on the ground. The sprinkler systems are electrically supervised and monitored by the fire department. Expansion joints were installed where the sprinkler risers exit the concrete cores, to ensure the system remains operable in case of building movement.

The standpipe is a standard system within North American high-rise buildings. It is composed of pressurized pipes housed within the stair core, with special connections on each floor at which fire departments can attach their hoses. The water curtain is used on the ground-floor exterior glazed curtain wall, in areas that are in close proximity to the adjacent parkade.

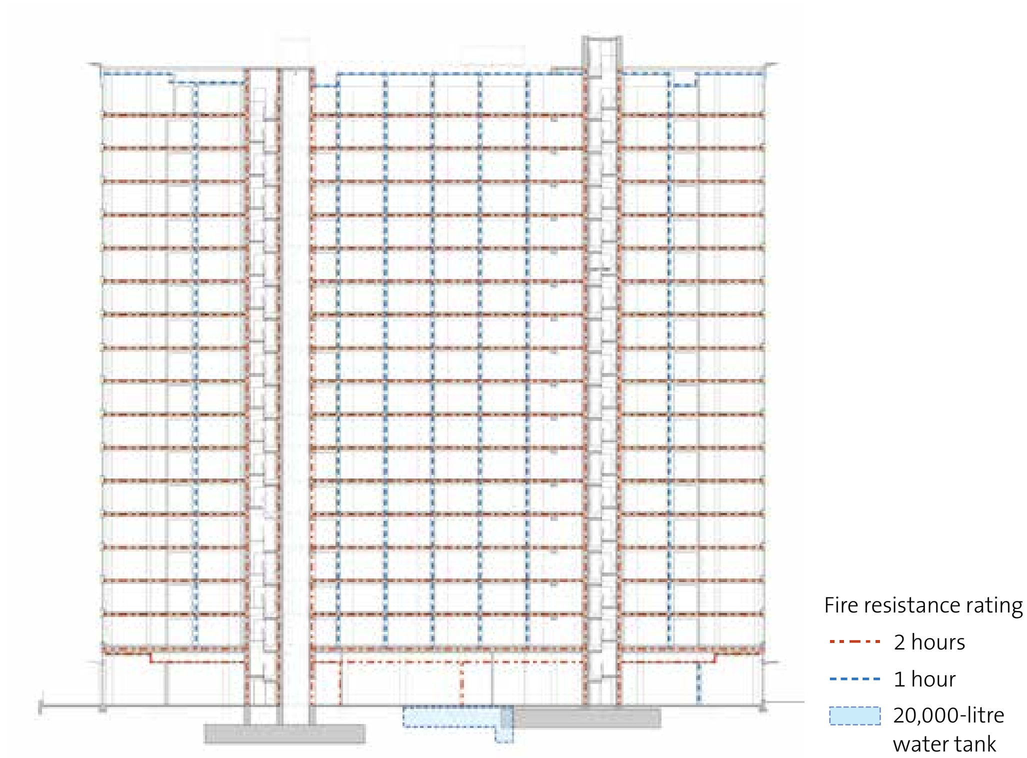
A 20,000-litre tank, with a dedicated fire pump, is located on site as a backup water supply for the fire-protection systems. The capacity represents approximately 30 minutes of water supply for the entire sprinkler system, and increases the reliability of the automatic sprinkler systems to almost 100%.

FACTS

- Sprinklers are designed according to the National Fire Protection Association's NFPA 13 (2013)—*Standard for Installation of Sprinkler Systems,* and according to the requirements of the *British Columbia Building Code*
- The standpipe system is designed according to the National Fire Protection Association's NFPA 14 (2010)—*Standard for the Installation of Standpipe and Hose Systems*



GLT and PSL columns are encapsulated by multiple layers of Type X gypsum board. Detail by Acton Ostry Architects Inc.



Fire protection measures. Detail by GHL Consultants Ltd.

LESSONS LEARNED

Recognizing early on that a hybrid mass timber high-rise would entail a strict approval process and specialized design considerations, the University of British Columbia employed the following strategies in designing the Brock Commons Tallwood House:

- The owner engaged the right expertise within the design team. This was important for allowing the building regulation requirements to be considered and proactively addressed at the appropriate time and within the design development process, not just as validation at completion.
- A code consultant with expertise in wood construction, fire science, and the requirements of the *British Columbia Building Code* regarding combustible construction was engaged. The code consultant ensured that code compliance was a part of every design consideration.
- The project team engaged strategic external stakeholders and experts to provide additional advice in highly technical or specialized areas, to critique the design, and to provide constructive feedback to the design team.

The University of British Columbia's unwavering commitment to using mass timber products was critical to keeping the project team focused on finding simple and effective solutions to the challenges of delivering a residential high-rise constructed of wood.

KK Law

CASE STUDY

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RENDERS & TECHNICAL DRAWINGS
Acton Ostry Architects Inc.
Fast + Epp
CadMakers Inc.

OTHER CASE STUDY RESOURCES (WWW.NATURALLYWOOD.COM)

Brock Commons Tallwood House: Design & Preconstruction Overview
Brock Commons Tallwood House: Design Modelling
Brock Commons Tallwood House: Construction Overview
Brock Commons Tallwood House: Construction Modelling
Brock Commons Tallwood House: Performance Overview

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