

9.0

STRUCTURAL SYSTEM & WOOD

“Unfortunately wood has become a little bit of a forgotten or neglected product here in the west and now there is a resurgence and renewed interest in timber. There are all sorts of possibilities out there.”

– Paul Fast, Structural Engineer, Fast & Epp

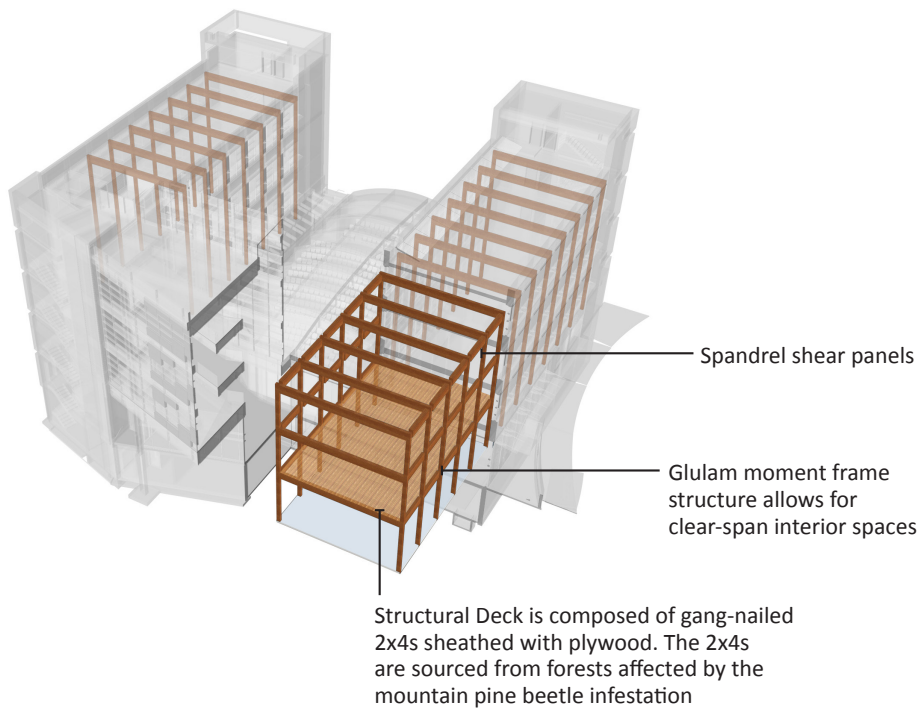


Image 9.1 Wood Structure Diagram

9.1 System Overview

In 2009, the Province of British Columbia passed Bill 9-2009, the “Wood First Act”, with the aim to “facilitate a culture of wood by requiring the use of wood as the primary building material in all new provincially funded buildings, in a manner consistent with the British Columbia Building Code.” CIRS is the first large, multi-story institutional building at the University of British Columbia to be constructed of wood since the passing of the “Wood First Act”. It is a simple structural design comprised of a combination of pre-fabricated glulam members, dimensional lumber, plywood and a minimal amount of concrete. The moment frame structure was designed to create an open, column-free floor plate for flexibility of use and interior arrangements, as well as to allow for large openings in the walls that maximize daylight and views.

Wood is also one of the most sustainable materials in the world. A tree is produced by energy from the sun, it provides valuable functions within ecosystems, it produces oxygen and sequesters carbon during its lifetime and it can be harvested for a durable, beautiful construction material. It is in plentiful supply in Canada, especially in British Columbia.

LESSONS LEARNED

Consider the benefits and challenges of a building material.

Integrated design leads to innovative design

Perception of wood is both a benefit and a challenge

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Image 9.2 Glue-laminated beams in structural moment frames. Photograph by Martin Tessler.

Glued-laminated Structural Members

A Glued-laminated timber or glulam is a type of engineered structural member made by laminating layers of dimensional lumber with a high performance adhesive. The laminating stock or lamstock is typically sourced from smaller, younger trees than would be harvested to produce an equivalent solid timber member. The lamstock has to conform to specific grading requirements before it can be used in a glulam.

9.2 System Description

The basic vertical structural system is constructed from manufactured rectangular glue-laminated (“glulam”) columns (typically 21.5 centimeters x 65 centimeters) that support glulam beams (typically 21.5 centimeters x 68.5 centimeters) spaced three meters apart and that span approximately ten meters. The beams in turn support a solid wood deck made from standard dimensional lumber (38 centimeters x 89 centimeters (2 inches x 4 inches)) laid on end, gang-nailed together and sheathed in plywood.

The lateral structural resistance is provided by two systems. In one direction, across the short spans of the building, it consists of conventional plywood sheathed shear walls. In the other direction, a wooden moment frame system combines vertical glulam columns with spandrel panels based on a 122 centimeters x 244 centimeters (4 feet x 8 feet) plywood module. The spandrel panels were pre-fabricated as box beams and placed between the structural members on-site. The wood moment frame is an innovative application that allowed for other design opportunities. This system provides the necessary shear resistance for wind and seismic loads in the long direction of the building, while allowing for large amounts of glazing, which maximize the daylight in the space.

The size of the structural members and connections remain consistent, with the exception of areas with increased loads, such as the green roof over the large lecture theatre, where the size of the members was increased. The floor system was sized to support higher live loads of 4.7 kilo-Newton per square meter (100 pounds per square foot), rather than the typical live loads of 2.35 kilo-Newton per square meter (50 pounds per square foot) to accommodate future changes in use. Additionally, the size of the wood members means that the structural frame is considered to be heavy timber construction under the British Columbia Building Code. The Code allows a wooden structure to be used in a building that is required to be non-combustible construction, as CIRS is, if the wood members are sufficiently robust to resist fire damage. The columns and beams are slightly oversized so that the edges char rather than combust in the case of fire and the members maintain structural integrity.

The dimensional lumber is a mix of spruce, pine and fir, sourced from British Columbia. Over 50 per cent of the wood used in the project is certified by the Forest Stewardship Council (FSC), which evaluates forestry practices and wood production. One project goal was to use 100 per cent FSC certified wood, but there was not a sufficient amount available locally to meet the needs of the project. The closest source of a sufficient amount of FSC certified lumber was Chile. The project team determined that the compounding effects of transporting wood from the southern hemisphere, including fuel consumption and carbon emissions, outweighed the environmental benefits of FSC certification. Instead, local non-FSC certified wood was used.

Much of the pine lumber for the decking is sourced from areas attacked by mountain pine beetles, which have devastated forests across Western Canada and some Rocky Mountain states in the United States. Making use of pine from forests affected by the Mountain Pine Beetles prevents a structurally acceptable resource from rotting and releasing the carbon dioxide that sequestered within the tree to the atmosphere.

While the intent was to use wood as the primary structure material, the design team compared the carbon footprints of steel, concrete or glulam for the building structure. Relative to the embodied carbon in a structural material, wood has a clear advantage over concrete and steel as trees sequester carbon dioxide as they grow. The net carbon footprint for the wood structure, including the harvesting, milling and transportation of the timber, was -0.90 Tonnes of equivalent carbon dioxide (CO₂-e) per cubic meter. The project team estimated that the wood used in the building is sequestering the equivalent of 600 tonnes of CO₂-e. This is greater than the 525 tonnes of CO₂-e generated from the manufacturing and transportation of all other building materials used in the construction, making the construction of CIRS carbon negative.

The Forest Stewardship Council is an international third party organization that certifies wood products are created through sustainable practices. The FSC evaluates all aspects of the harvesting, transportation and processing of the wood to ensure that it meets their environmental and social standards.

The Mountain Pine Beetles lay their eggs below the bark, introducing a fungus which prevents the tree from expelling the beetles and blocking the absorption of water and nutrients. The combination of beetle larvae and fungus kills the trees quite quickly and leaves identifying blue streaks in the wood. The wood remains structurally sound but must be harvested within two or three years from the start of infestation before rot begins to compromise the integrity.

Trees sequester carbon during their lifetimes, absorbing it through their leaves in a metabolic process and discharging oxygen. When a tree dies in the woods, the carbon is slowly released back into the atmosphere as the tree decomposes, but when a tree is harvested for construction material the carbon remains sequestered in the wood for the duration of its existence.

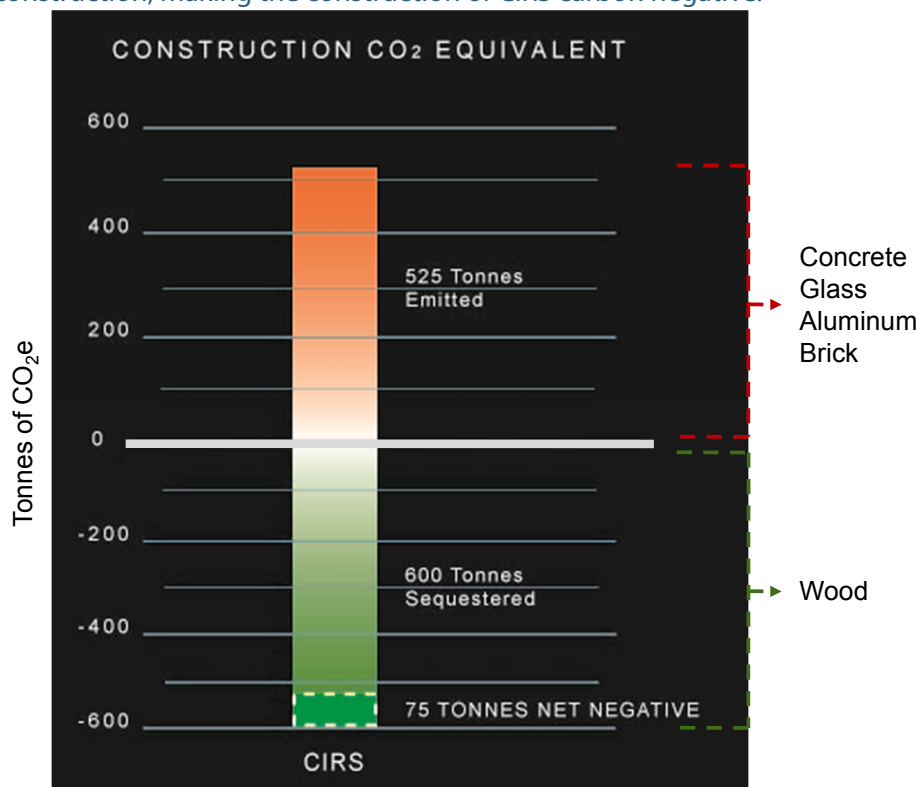


Image 9.3 CIRS Construction Carbon Footprint

AGENTS*Architects: Busby Perkins + Will**Structural Engineers: Fast & Epp**Contractor: Heatherbrae Builders***COSTS***Costs will be added in a future update***9.3 Campus Context****UBC Campus Plan**

The UBC Campus Plan aims to accentuate the University's sense of place by emphasizing the stunning natural beauty of British Columbia and the Pacific coast. To accomplish this new buildings and spaces on campus are encouraged to feature the forest, design for strong indoor-outdoor relationships, and emphasize the celebrated views of surrounding landscape. CIRS exposed wood structure provides a connection to the forest of BC and the moment frame systems allow for large amounts of glazing, framing views to the south, west and north across the peninsula.

UBC Campus Plan Part 2, Campus Plan Sections 7.1 Design Strategies and Guidelines (pg 42)

As part of the living laboratory objectives of the university, new buildings are encouraged to embrace innovation in design and construction. Developing systems and techniques for using wood structures in large multi-story institutional buildings is unique on this campus and provides a rich source of inspiration for future projects. The use of wood is encouraged for structural elements and throughout the interior of buildings for sustainability, acoustic and visual comfort, and connection with the campus forest setting. Additionally, durability, local sourcing of materials (both production and location) and the reduction and management of waste, including construction waste, are emphasized in campus building design and construction to reduce the detrimental effects on the environment.

UBC Campus Plan Part 3 Design Guidelines, Sections 2.1 Sustainability (pg 8-10) and 2.3.5 Architectural Expression (pg 14-16)

UBC Climate Action Plan

The University Climate Action plan sets a goal to reduce greenhouse gas emissions by 33 per cent below 2007 levels by 2015, 67 per cent by 2020 and 100 per cent by 2050. Multiple opportunities for source reduction have been identified, including campus development and infrastructure, energy supply, food, travel and transportation. Reducing and offsetting carbon generated during the construction process, as well as low carbon emission from ongoing building operations, is imperative to helping the University meet these goals.

UBC Climate Action Plan (www.sustain.ubc.ca/climate-action)

UBC Technical Guidelines, Division 6 (06001, 06100, 06400)

Division 6 of the UBC Technical Guidelines outlines requirements for wood construction in campus buildings. It covers a range of topics including quality control and assurances, provisions for the involvement of professional engineers and trained workers, proper weather protection of materials during construction, performance and prescriptive standards for different types of wood materials, prohibited sources of wood from endangered species and durability of design (designing buildings and structure for 100-year life).

UBC Technical Guidelines, 2010 Edition, Division 6, Sections 06001, 06100, 06400

9.4 Goals & Targets

Table 9.1 lists the project goals and targets specifically related to the structural system. For a complete list of all the goals and targets for CIRS, refer to Section 4.0 Goals & Targets.

| Category | Goals | Targets |
|---------------------------------|--|---|
| Category | Goals | Targets |
| 2- LIFE CYCLE ASSESSMENT | Conduct a life cycle assessment of all building assemblies and products to examine environmental impact, including embodied energy and greenhouse gas emissions - minimize CO2 emissions associated with construction. | |
| 11- RESOURCE EFFICIENT BUILDING | Minimize resource consumption and greenhouse gas impact of building materials and construction. Produce a core building that exemplifies replicable, economical solutions. | Target 50 per cent of typical building ecological footprint and greenhouse gas profile of construction. Maximize the life flexibility and recycling potential of the building. |
| 12 – WASTE ELIMINATION | Zero waste. | Zero construction waste (95 per cent minimum diversion). |
| 13 – BUILDING UTILIZATION | Maximize hours of operation and density of use. | Maximize intensity of use. |

Table 9.1 Goals and Targets for the Structural System.



Image 9.3 Glue-laminate beams with pine beetle kill wood decking. Photograph by Enrico Dagostini.

PROCESS

Design process:

A wood building was an early concept for the CIRS building, the specifics of the system emerged through charrettes and during the design development process.

Construction:

The glulam columns and beams were pre-fabricated offsite and assembled onsite, the rest of the structure was constructed onsite through conventional methods.

Commissioning:

Operations:

RATING SYSTEMS

The timber structure and wood construction helped CIRS to achieve the following LEED credits and Living Building Challenges imperatives:

LEED credits

Materials and Resources credits:

- 5.1 & 5.2 - Regional Materials
- 7 - Certified Wood
- 8 - Durable Building

Indoor Environmental Quality Credits:

- 8.1 & 8.2 – Daylight & Views

Living Building Challenge

11 – Red List

12 – Embodied Carbon Footprint

13 – Responsible Industry

14 – Appropriate Sourcing

15 – Conservation & Reuse

19 - Beauty & Spirit

9.5 Benefits

The structural system and use of wood in CIRS benefitted the project in the following ways:

Reduced Ecological Impact

- Wood, if harvested, processed and transported in an ecologically responsible manner and properly protected and maintained during the life of the building, can contribute to reducing the ecological footprint of the building.

Sequestered Carbon

- Using wood as the main structural material, CIRS sequesters more carbon than was produced during its construction, making it a net carbon negative project. The project team estimated that the wood used in the building is sequestering the equivalent of 600 tonnes of CO₂-e. This is greater than the 525 tonnes of CO₂-e generated from the manufacturing and transportation of all other building materials used in the construction, making the construction of CIRS carbon negative.

Sourced Locally

- Using a regional product reduces transportation costs, fuel consumption and pollution and supports local economies and industry. To procure 100% FSC certified wood-based products would have required purchasing lumber from Chile. The project team determined that the transportation impacts of importing wood from Chile would negate the benefit of using FSC certified wood.

Helped the Mitigation of an Ecological Problem

- Using pine beetle kill wood reduces the environmental and economic impact of the infestation.
- Harvesting pine affected by pine beetles leaves other healthy trees to grow longer, which increases the absorption of carbon dioxide. Harvesting the trees before the onset of rot prevents the release of carbon dioxide to the atmosphere as well as reducing the potential of the dead trees to act as fuel for forest fires.

Brought Warmth to the Building Interiors

- Using wood as the building structure and finish creates the perception that the building spaces are warm. It catches and reflects light in a unique way and has a softer appearance than other manufactured materials, such as steel and concrete.
- People are comfortable with wood and tend to perceive wood structured spaces as friendly, relaxing and more humane than other building materials.

Maximized daylight and views

- The moment frame structure, consisting of columns and spandrel panels allows a significant amount of glazing in the exterior walls to reach the underside of each floor. Large windows allow daylight to penetrate farther into the building and facilitate more access to views to the exterior.

9.6 Challenges

The structural system and use of wood in CIRS was challenging to implement in the following ways:

Procuring FSC Wood

- The project was not able to meet the project goal to acquire 100 per cent of the wood used in the building from both local and FSC certified sources.

Developing Cost Effective Fire Suppression

- A secondary fire suppression system is required by BC building Code for wood construction. This secondary system affected the overall construction budget and raised the cost compared to the benchmark typical lab building.

Integrating Flexible Interior Partitions

- The exposed timber construction on the underside of each floor plate creates a ceiling of varied heights which limits the future flexibility of a moveable wall system in certain areas of the building.

Overcoming Misperceptions of Wood

- Wood is often perceived as a less desirable structural material than steel and concrete because it is perceived to be less durable and more costly. Convincing project stakeholders that wood can be both durable and cost effective can be challenging.

Compensating for Potential Shrinkage

- Wood is an organic material that absorbs and dispels moisture. Used as a structural material in the controlled climate of a building, the wood structure will shrink as the moisture content reduces over time. As such the structure will experience some movement. Interior finish materials and exterior cladding systems may be impacted by the shrinkage.

Protecting Material during Construction

- A wood structure must be properly protected from environmental conditions during construction. Moisture may be absorbed by the interior wood components before the building envelope is enclosed. As the wood dries, the moisture will be released to the interior spaces of the building, which could potentially affect the durability of the building construction.

RELATED SECTIONS

3.0 Vision & Leadership

4.0 Goals & Targets

7.0 Building Design

8.0 Design Process

10.0 Building Materials

16.0 Lighting

18.0 Building Rating Systems

20.0 Construction

RESOURCES

- *Diagrams links*
- *Drawings links*
- *Perkins + Will:*
www.perkinswill.ca
- *Fast & Epp: www.fastepp.com*
- *Heatherbrae:*
www.heatherbrae.com
- *Forest Stewardship Council Canada: www.fsccanada.org*
- *Wood First BC: www.for.gov.bc.ca/mof/woodfirst*
- *UBC Campus Plan*
- *UBC Climate Action Plan: www.sustain.ubc.ca/climate-action*
- *UBC Technical Guidelines*

9.7 Lessons Learned

The experience gained through the use of wood materials and structural system for CIRS provided valuable lessons to apply to future projects. Some of the key lessons are:

Consider the Benefits and Challenges of a Building Material

- Wood is a highly sustainable construction material that can contribute to creating an ecologically respectful building. The organic properties of the material must be understood and incorporated into the design to add to the durability of the project. Finding local, FSC wood products proved to be challenging, but using wood from forests affected by the mountain pine beetle utilized a local product with an important environmental benefit. The project also found that by using wood as the primary structural material, the amount of carbon sequestered in the structure was greater than the carbon emissions related to the construction of the building.

Integrated Design leads to Innovative Design

- The structural solutions involving wood require collaboration among all design team participants. The innovative solution of creating a wooden structural moment frame allows for flexibility of the interior spaces and contributes to the efforts to achieve the project goal of daylighting interior spaces of the building. The slightly increased size of the structural members allowed the use of a wood structure in a non-combustible building that would typically be made of steel or concrete.

The Perception of Wood is both a Benefit and a Challenge

- Although wood is positively perceived as a comfortable, warm and organic building material, wood may also be perceived by project stakeholders as a less durable or more costly material. Project teams must work with project stakeholders to overcome any obstacles around the perception of wood.

9.8 Future Learning

Additional lessons learned over the operational life of the building will be added at periodic intervals