



Innovating with Wood

A Case Study Showcasing Four Demonstration Projects

University of British Columbia Earth Sciences Building

University of British Columbia BioEnergy Research and Demonstration Facility

Confederation College

Port Alberni Secondary School

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du bois



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Your truly,

Michael Giroux
President
Canadian Wood Council

Etienne Lalonde
National Director
Wood *WORKS!*

University of British Columbia – Earth Sciences Building (UBC ESB)

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Background

The success of the University of British Columbia's (UBC) Earth Sciences programs resulted in a need for the department to expand in order to accommodate a growing enrollment of 360 major/honours students, 170 graduate students, and more than 6,400 undergrads each semester. As a university with a history of leadership in the advancement of earth, ocean and atmospheric sciences, the use of wood for the construction of the UBC's Earth Sciences Building (ESB) complemented the relationship between environment and science.

The new 5-storey north wing of the ESB will house the academic research, lecture, and office spaces at UBC's Point Grey Campus in Vancouver. Unlike the 5-storey concrete laboratory wing, the academic wing uses wood as the primary structural material because of its architectural qualities and value as a renewable resource. Located along Main Mall, an important north/south artery on campus, the ESB project is exposed to high volumes of pedestrian traffic. Directly across the street from the ESB is the new Beaty Biodiversity Museum, which, together with the nearby Pacific Museum of the Earth, forms an inspiring collection of buildings and features that showcase wood in construction for both the university and public at large. Securing UBC's position as a global leader in earth, ocean and atmospheric sciences, the ESB is a centre of discovery and learning that embodies the impressive academic and physical scope of the UBC campus.

When complete, the academic wing of the ESB will include offices, lecture theatres and graduate workspaces. It will also have a resource cluster on the 5th floor that will serve as a mini-conference facility and incorporate some of the latest technologies to create a flexible learning environment, making the ESB expansion a project that encourages collaboration in both design and academic functionality. The laboratory wing will be dedicated to labs and lab preparation areas, and will also have office space.

Design Considerations

The Province of British Columbia's Wood First Act (a first in North America), which received Royal Assent in October 2009, promotes climate-friendly construction for provincially-funded projects. Along with being the only major building material that is both a natural and renewable resource, wood has many economic and aesthetic benefits that contribute positively to objectives of the Act. With the passage of the Act, Wood *WORKS!* BC, in partnership with local municipalities, is actively involved with the local government, as well as building and design professionals, to provide technical expertise and support to help navigate through the 'build with wood' requirements for construction projects.



Sustainability and sustainable development were common threads throughout the design and construction of the ESB project. Due to the high performance requirements for scientific research facilities, any opportunity to reduce carbon emissions in the UBC ESB was explored. Contributing to the overall performance of the building, the structural system for the UBC ESB was based on an understanding of the benefits of a reduced carbon footprint as well as a goal of achieving LEED Gold status – an energy and environmental rating system intended to provide building owners and operators with a framework for identifying and implementing solutions for green building design, construction, operations and maintenance.

Using wood as a primary structural material was in-line with the environmental expectations of the ESB project because wood has the lowest embodied energy of any major building material and is proven to emit significantly less carbon dioxide than competing materials during the manufacturing process. The use of wood throughout the construction of the academic wing of the UBC ESB helped minimize the total 'carbon footprint' of the project.

The development of the \$55 million Earth Sciences Building was guided by research, past successes and an appreciation for the building's environmental impacts, during both the construction phase and service life of the building. The innovative approaches to the project's design and construction are outlined in this case study.

The academic wing of the UBC ESB was the first building in Canada to specify solid timber panel systems to such a large extent. To harmonize with the concrete structure of the laboratory wing, careful consideration was given to the overall aesthetics of the building to ensure cohesion between the two wings.

The application of solid timber panels on a glulam frame had rarely been used on large scale projects prior to the academic wing of the UBC ESB. Office spaces, which carry relatively light live loads and have 'normal' vibration and sound performance requirements had different engineering considerations than

the academic teaching and research areas which have relatively high loads. Buildings can be designed to support any load, regardless of the material specified. Factoring this into the design logistics of the academic wing of the UBC ESB, offices in the building were designed for a 65psf live load whereas the designs for the academic teaching and research areas used a 100psf live load.

The structural design of the UBC ESB was not limited to loading considerations. Some of the additional engineering factors considered included:

- Review of available products with various suppliers.
- Review of product certification, testing and fabrication procedures.
- Cost and engineering analysis of different options (panel make-ups and types).
- Extensive vibration, sound transmission and fire performance analysis.
- Review of available literature in Europe for panels and connection options.
- Design of load transfer details to manage shrinkage, custom seismic connection solutions and all non-standard wood-to-wood connection details.
- Coordination of service-related cuts, routings and openings in panels.
- Design and review of full-scale testing for vibration and strength.
- Additional site services including site visits and information transfer to contractor.
- Review of erection and weather protection requirements with contractor.
- Cost comparison of various systems/connections with considerations to local market.

Below are some of the key elements that were evaluated by the design team:

Vibration – The wood-concrete composite floor system was chosen for the UBC ESB in part because it provided a significantly higher level of vibration performance than the lighter wood-only panel options.

Acoustics – A sandwich composed of 89 mm of laminated strand lumber, 25 mm of foam board insulation and 100 mm of reinforced concrete, the wood-concrete composite system's acoustic performance offers excellent sound absorption.

Fire Resistance/Building Code – Under the prescribed fire safety requirements for the British Columbia Building Code (BCBC), having the academic wing built entirely of heavy timber or wood-frame construction was not permitted. In order to allow for the use of wood as the main structural element, an engineering assessment was carried out and documented in a Building Code Alternative Solution, which was peer-reviewed as part of the building permit approval process.

The fire hazard assessment essentially looked at how the wood construction might perform in fire, in both the pre-flashover and post-flashover environments. Flashover is the point in a fire when all the combustibles within a room ignite and begin to burn; this is considered the most dangerous stage of a fully developed fire. In the pre-flashover stage, the concern was that wood, being a combustible material, might become fuel for the fire, in addition to the contents (the primary fuel source), resulting in a more rapid fire growth that would cause flashover to occur sooner and increase the potential for fire spread. To address this potential hazard, the ESB was designed with an automatic sprinkler system, and a fire retardant coating was applied where necessary to alter the surface burning characteristics of the wood interior finishes to more closely meet the standard required in a non-combustible building. Further, taking advantage of the highly compartmentalized nature of the wing, a fire risk analysis was presented to show that the risk of fire growth and spread



would inherently be limited by the many separate, individual offices and rooms. In the post-flashover stage, the concern was the potential for failure due to excessive charring and reduced strength. To address this, the wood structure was engineered to account for the charring of the wood members for the required fire-resistance period so that the resistance provided by the reduced cross-section (unburned portion) of the wood members would continue to resist the gravity loads expected during the fire.

With the design requirement of a structural fire resistance rating of 1 hour for this 5-storey project, the traditional heavy timber construction equivalency to $\frac{3}{4}$ hour combustible construction in 1- to 3-storey buildings did not apply. A key component in the fire safety design of the heavy timber element, which is traditionally not explicitly addressed by the building code, was the fire performance of the steel connections. The minimum fire resistive properties of steel connectors were considered critical since the loss of the load-bearing capacity of the structure at the early stage of a fire would be significant if the steel connectors failed. To ensure the connectors would continue to transfer loads in the heavy timber wood-frame system during a fully-developed

fire, concealed connections were needed. This is why the concealed Sherpa® connectors were specified. Where there were other exposed steel elements that were part of the wood structure's load path, appropriate 'passive' fire protection, in the form of an intumescent coating, was also specified.

Availability – Canada is leading the world in attaining third-party sustainable forest management certification. The preference for using timber in the UBC ESB project allowed for the use of locally sourced wood, which encouraged local employment – building on British Columbia's historical connection with the timber industry. While cross-laminated solid wood panels were selected for the project, a number of other engineered wood products including glue laminated timber, laminated strand lumber (LSL) and laminated veneer lumber (LVL) could have also been used, with little or no impact on the design or performance of the overall structure. At the time of construction, there was uncertainty as to whether sufficient volumes of cross-laminated timber (CLT) panels could be supplied in time for the construction of the floors. LSL panels were therefore chosen in a wood-concrete composite application because they were readily available in the Canadian market. CLTs were specified for the roof

and extensive exterior canopy since they were expected to become locally available later on in the construction schedule. The ESB project provides a snapshot at a pivotal time in the Canadian timber industry by showcasing different solid wood panel products, both established and new, in a large institutional building application with high performance standards.

Appearance – The use of wood throughout the project provided warmth that complemented the urban surrounding. The aesthetic appeal resulted in an ‘A-HA Moment’ – a term coined by the UBC to define a special place that inspires minds, a place for open thinking and new ideas, and a sudden realization that anything is possible. Whether it is the undertones that make for a welcoming aura or the bright highlights, wood is one of the only building products that can be left exposed without compromising the interior finish or quality of the overall project. Breathing a sigh of relief, the natural aesthetic appeal of wood reduces the amount of off-gassing from finishing elements that may have otherwise released potentially harmful vapours into the surrounding environment.

Construction Methodology

Several design milestones were achieved in the construction of this project, including the application of the LSL/HBV composite flooring system, CLT and a variety of novel connection details.

Composite Floor System: The floors are constructed predominantly of a composite system called the Holz-Beton-Verbund-System™, commonly referred to as the HBV-System. First adopted in European construction, the HBV-System is well regarded for its engineered technology and, when used in flooring applications, is suitable for achieving long spans.

The composite floor system in the ESB construction consists of 89 mm thick LSL panels topped with foamed board insulation and 100 mm of reinforced concrete. The composite action is achieved by securing perforated steel HBV-shear

connectors into slots cut into the face of the wood panels. These plates extend past the layer of the insulation to support the reinforcing bars for the concrete topping. The insulation provides an acoustic break and also acts as a barrier to prevent moisture infiltration while the concrete sets. This assembly is over 50% lighter than a solid concrete floor structure, allowing for larger spans which increases the ‘loose fit’ opportunities for designers.

The ends of the 22-foot long wood-composite floor panels are supported by steel beams above the first floor of the ESB project, and on glulam beams to create the ceilings for storeys 2 through to 4.



The combination of solid, cross-laminated wood and wood-concrete composite panels make the academic wing of the UBC ESB an innovative project in Canada – raising the bar for the use of wood in large scale, high performance projects. Glulam, LSL, CLT components and connectors were supplied through Structurlam Ltd, of Penticton, BC. Weyerhaeuser produced all of the LSL panels for the project.

Extensive structural, economic and feasibility research for the HBV-System was coordinated by the engineer consulting company and the architects to ensure that this wood technology would best suit the design and structural requirements of the ESB. In addition, FPIInnovations (a not-for-profit



research organization that advances the product and market opportunities for the forestry sector through a framework of environmental sustainability) conducted vibration testing on the ESB construction project. The vibration test on the overall structure was conducted to ascertain the lateral stiffness of the structure. The results of this research were reported in the case study entitled 'Three Innovative Mid-Rise Wood Buildings'.

Ambient vibration testing (AVT), which uses natural excitations such as wind and heavy traffic to induce vibrations in a structure, allowed researchers to determine natural frequencies and dampening ratios of the structure. AVTs are reliable, relatively easy to conduct, and have been widely used to evaluate wind and seismic designs for steel-concrete buildings, towers and bridges. Vibration tests performed on the ESB project included an impact test on the second level (using a ball-drop technique) and a static deflection test (where a person on the floor acts as the load and the deflection gauge is fixed to a rod that is attached to the center of the floor). The final results showed that the ESB project design performed favourably. Despite a lack of provisions and design guidelines in the Code for controlling vibration in an innovative wood floor building, the engineers, architect and contractors surpassed the prescriptive construction requirements and were able to achieve the client's performance needs in a structurally sound building design.



To support the solid timber panels, a variety of different connection systems were incorporated within the ESB construction: steel to wood, wood to wood, wood to steel, and finally, wood to concrete. Some of the more novel components are discussed below.

Steel Beams to Wood Columns: Wood performs favourably in compression circumstances when forces are acting parallel to the grain, in comparison to when the grain is perpendicular to the load path. On the second level of the ESB there are long metal spans connected to wood that required a butt connection - whereby the top flange of a steel beam is notched into a glulam column and pinned for structural support.

Wood Beams to Wood Columns: Throughout the UBC ESB project, the structurally engineered timber systems used quick, safe and efficient Sherpa™ connectors. Approved for load bearing timber construction, Sherpa connectors are designed so that even the most complicated nodes can be assembled with ease. Similar to the traditional dovetail connection, these connectors are made of two parts that lock into place to create a form-fitting connection. With each connecting system designed, forces are transferred perpendicular to the installation direction for tension and compression purposes. An additional benefit of using this connection system is that the hardware can be pre-installed in the beams and columns at the point of manufacture, ultimately reducing the assembly time at the construction site. As well, since they are completely concealed, Sherpa connectors would be protected during a fire by the insulating char layer that would form on the encapsulating wood members.



Heavy Timber Shear Bracing: At the end walls of each storey, as part of the Seismic Force Resisting System (SFRS), diagonal glulam heavy timber braces were integrated to provide controlled resistance to the shear loads across the structure. Since the glulam members themselves do not have the ability to dissipate energy, the system relies on the predictable ductility of the connections. This was achieved using multiple steel knife plates with a large number of tight-fitting, small diameter pins. The slots in the glulam where the knife-plates are inserted were designed with longitudinal slack. This leaves room for controlled movement under shear loading that allows the tight-fit pin connection to yield in tension and compression. The precision required for these sophisticated connections was only made possible by pre-fabricating both the wood and the steel components with computer numerically controlled (CNC) machinery.

Full-Storey Transfer Truss Connections: Throughout the second storey of the academic wing, steel diagonal braces and steel beams, together with the glulam columns and glulam beams with an integrated concrete top plate, create a type of truss structure. The first storey (above grade) of the ESB project consists of a building-wide assembly space. As a result, the ceiling structure of the second floor supports the entire building above it. To carry this load, full-storey steel-glulam hybrid transfer trusses were designed, essentially converting the entire second floor structure into a 'roof truss' capable of carrying the load of the remaining floors across the entire span of the structure below.





‘Free-Floating’ Staircase: Located to the right of the impressive open concept atrium that links the academic and laboratory wings is a 5-storey free-floating cantilevered solid timber staircase. The clean and elegant lines of the massive timber seem poised with engineered perfection, offering a glimpse into the innovative aesthetic and structural capabilities of wood in construction. Based on the Holz-Stahl-Komposit-Systeme (HSK-System)[™], German for ‘wood-steel composite’, the rigid composite of the wood with glued-in steel HSK-connectors pushes the envelope of load bearing capabilities of wood construction. Adopted from projects in Germany, this system uses steel plates similar to those in the HBV system except the slots are cut into the ends of the glulam slabs and the plates are then glued into place with special adhesives.

The staircase at the ESB quickly morphed from an atrium feature into an individual project. The initial designs of the staircase, although feasible in wood, did not offer the clean and crisp look that was desired for the entrance. The implementation of the HSK-System ensured that the load bearing requirements were met, while maintaining the desired free-floating design. Complementing the rest of the atrium, the staircase feature is a unique project in that the geometry of the design was not driven by the architectural or engineering firm but by the users of the building who were most concerned about access and security. The Code required that the stairway be sprinklered so in order to maintain the clean lines, the stair stringer was notched so all of the sprinkler piping and power lines could be recessed within the wood. This detail ensured that the pragmatic applications were implemented within this unique design and that the safety of the user was not jeopardized as a result of innovative design considerations.

Best Practices

It takes work to be a leader. With the implementation of any new construction application, research into the design, engineering and manufacturing elements may not be readily available. The HBV-Composite floor system used in the construction of the ESB project was an application adopted from Germany, and as such, the majority of the research materials and resources were available strictly in German. With the successful completion and implementation of the HBV-Composite flooring system in the UBC’s ESB, it is anticipated that its use will be repeated and the HBV-Composite floor system will find broader uses as it is more widely accepted in North America.

The academic wing of the UBC ESB project had to complement the concrete laboratory wing, even though it was executed primarily in wood. The presence of wood has a warming effect on any room and the idea of having it featured more prominently throughout the project, without compromising the aesthetic coherence of the buildings, was a venture worth exploring.

The peer-review process played an important role in the Building Code approval process. Traditionally, building permits are issued by Municipal building officials / inspectors who have a good knowledge of the prescriptive Building Code requirements; however they may not have advanced training in fire engineering. A thorough peer-review process exists at UBC for any major new projects. In the case of the proposed Building Code Alternative Solution that would permit the use of wood as the principal construction material for the academic wing, peer review was conducted by another engineer with expertise in fire engineering. In this review, the engineer considered the overall level of safety of the final project upon completion and whether it would meet an acceptable level of risk of injury in the event of a fire compared to typical solutions prescribed by the Code.

Broader Implications/ Outcomes

Solid timber and composite floor systems present a great opportunity for the wood industry in the commercial market – especially in multi-storey residential and non-residential buildings. Since they are lighter than similar concrete assemblies which must support their own weight, there is increased opportunity for larger spans with the use of solid timber panels.



The ESB is a revolutionary structure, not just for its confident use of new products, but also for the way it reinvented products that have been available for years to use them in exciting new ways. The new solutions, applications, and innovations used throughout the building surpass anything done in the past, making this an excellent demonstration building. The design community is inspired by the possibilities shown in the ESB. Commercial developers are now very interested in the advantages of solid and composite wood floor diaphragms and are keen to use them in other buildings. The construction of the ESB was such a success that The University of British Columbia plans to implement the composite floor system at their Okanagan Campus Fitness & Wellness Centre in Kelowna.

Design Team

The below mentioned list of companies may not represent the entire design and construction team for this project.

Architect: Perkins+Will, www.perkinswill.com

Structural Engineer: Equilibrium Consulting Inc.,
www.eqcanada.com

Building Code consulting and Fire Protection Engineering Firm: GHL Consultants Ltd., www.ghl.ca

Construction Company: Bird Construction, www.bird.ca





University of British Columbia – BioEnergy Research and Demonstration Facility

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Background

The University of British Columbia (UBC) partnered with researchers and architects for the proposal, design, and construction of an innovative wood structure that would enclose the biomass-fueled combined heat and power (CHP) system constructed on its Point Grey Campus.

In an effort to expand the appreciation of mass timber panel technology in North America and its applications in non-residential construction, Cross-Laminated-Timber (CLT) was selected as the building material for the \$6.7 million BioEnergy Research and Demonstration Facility (BRDF). The 1,950 m² structure is classified as a 'medium hazard' industrial occupancy and houses the main process floor for the power plant in addition to an upper floor area for the building operations control office, multi-purpose lab and public viewing spaces.

What is truly unique about the BRDF project is the presence and use of wood. From the project's location on campus in a relatively dense area of mature trees, to the construction of the building using CLT, to the utilization of wood waste as fuel for the gasification unit – wood is omnipresent.

Design Considerations

The BRDF is a forestry and bio-mass combustion alternative energy demonstration project that consists of the bio-mass raw material receiving/handling area, the main gasification process area, and the control room/laboratory environments which are located on the upper level. The project is classified as a Group F, Division 2 (Industrial) major occupancy under the British Columbia Building Code (BCBC) 2006, so the consulting team developed concepts that would achieve the level of fire protection and life safety required by the Code for this building type. Where compliance with code requirements could not be practically achieved, alternative solutions were developed to meet the objectives/intent of the applicable functional requirements. The Building Code applications and implications of structural materials such as heavy timber glue-laminated beams/columns and CLT panels, which were used throughout the project, were reviewed as part of the building code analysis and documented for the project design.





Summary of Applicable Building Construction Requirements for Structural Fire Protection

Based on the project characteristics and major occupancy classification for BRDF, the following table summarizes the construction/structural fire protection requirements for the project:

Occupancy Classification	Applicable Article	Maximum Building Height	Construction Type	Floor Assembly	Structural Supports
Group F, Division 2 (Industrial) major occupancy	3.2.2.70.	4-storey	Combustible or non-combustible	¾ hour	¾ hour

The construction/structural fire protection requirements were as follows:

- permitted to be of combustible or non-combustible construction;
- sprinkler protection required and installed in accordance with National Fire Protection Association Standard No. 13;
- load-bearing walls, columns and arches supporting a fire separation having a ¾-hour fire-resistance rating; and
- load-bearing walls, columns and arches supporting an assembly required to have a ¾-hour fire-resistance rating (if of combustible construction).

Use of Heavy Timber Construction - In accordance with the 'defined terms' of the BCBC 2006, heavy timber construction is defined as a "type of combustible construction in which a degree of fire safety is attained by placing limitations on the sizes of wood structural members and on thickness and

composition of wood floors and roofs, and by the avoidance of concealed spaces under floors and roofs." In accordance with Articles 3.1.4.5. and 3.1.4.6. of the BCBC, heavy timber construction is required to have a fire-resistance rating of no more than ¾-hour, provided it met with the dimensional criteria of Article 3.1.4.6.

In conclusion, the heavy timber and massive timber panel construction of the BRDF project was deemed to have met or exceeded the structural fire protection requirements of the BCBC 2006, based on the permitted use of 'combustible construction' for the specific occupancy classification of Group F, Division 2 (Industrial), and the relative thickness of the solid wood elements (i.e., glue-laminated beams/columns and CLT wood panels) which provided the necessary degree of fire-resistance rating for the floor assemblies and their supporting structures. The building also has a comprehensive fire alarm/detection and automatic sprinkler system to protect the building's structure and its occupants in the event of a fire.

The BRDF was the first CHP facility of such a large scale in North America. As a demonstration facility, public access was part of the university's initial request and influenced the design considerations for the structure. The BRDF was designed with glass walls along the sides so that members of the public could openly view the operations of the CHP process, as well as pay homage to the impressive display of engineered wood products throughout the building. The building tells an evolving story of innovation in the context of functionality and construction design - one that the design team was eager to share with members of the public, as well as adapt to future project applications.

Cross Laminated Timber

At the time of construction of the BRDF, CLT, also commonly referred to as a solid or mass timber panels, was one of the newest and most widely discussed structural wood systems on the market. Used throughout Europe in a diversity of structures ranging from a 9-storey apartment building, large institutional buildings, and warehouses, the use of CLT in varying climate and seismic regions, the review of best practices and lessons learnt was valuable information referenced for the construction of the BRDF.

The introduction of CLT panels to North America provides architects and engineers with more design options and a more sustainable building system for heavy structures; one that displaced applications normally relegated to concrete or masonry. This highly promising wood system has been identified by the forest products industry, as well as the research and design communities, as a new and innovative opportunity for advancing wood in non-traditional applications.

CLT consists of three or more layers of dimensional lumber boards stacked crosswise at 90° that are then connected together with adhesives or mechanical fasteners to form a composite system. The resulting panels vary depending on manufacturing equipment and transportation. These CLT panels have very high axial capacity and high shear strength to resist horizontal loads. They also have significantly lower mass than the common solid diaphragm and solid wall systems. The panels can be delivered to sites and installed just-in-time, with a single crane and minimal crew. This significantly reduces the erection time, offers new opportunities for efficiencies to sub-trades and lessens the burden on working capital.

CLT Process

Compared to traditional light wood-frame construction methods, which rely on plywood sheathing over wood studs (walls) or rafters and beams (roof), the use of CLT panels offers an alternative in the form of a single component that is load bearing and provides an aesthetically pleasing finished surface. The solid timber panels also offer the option of very shallow floors and exposed timber ceilings.

FPInnovations, a Canadian not-for-profit research institution, developed a codes and standards roadmap for CLT that provides strategies for acceptance of CLT under 'alternative solutions' for early adopters, as well as strategies for future inclusion in the building codes as an 'acceptable solution' for general practitioners. (To learn more visit www.fpinnovations.ca.) An ANSI manufacturing standard ("PRG 320 – Standard for Performance Rated CLT") was



published in January 2012, and at the time of this publication, the possibility of this process being adopted by Canadian Standards Association (CSA) was being explored. was in the process of being adopted by the CSA. To learn more visit www.apawood.org.

The architectural firm for the BRDF conducted a study on the feasibility of a CLT panel application as a key building component for the project. The study found that CLT was a logical extension for the project in order to best demonstrate sustainable solutions in community infrastructure and within the wood industry. The use of CLT panels also provided a means to meet some of the prescriptive requirements for the building envelope design. With limited CLT manufacturing in Canada at the time of the project's initial inception this approach was seen as a notable industry endeavor.

The design team's overall goals for the building envelope were to:

- Provide an integrated and sustainable design that was central to the overall use of the building;
- demonstrate the opportunities that exist in renewable energy operations; and
- showcase the design opportunities and properties for mass timber construction in combustible and non-combustible buildings.

Another design consideration for the BRDF was to promote natural ventilation using the natural buoyancy of internal spaces created by the building's geometry to draw exterior unconditioned air through the building via convection. Given the scope of environmentally friendly efforts made in the design and construction of the project, minimizing mechanical ventilation for the facility made sense. Ventilation fans were included, but were only intended to operate when internal temperatures exceeded those that could be controlled by natural ventilation. A computational fluid dynamics model was developed to determine how air would move naturally throughout the building volume. This was included in the final



design, and showed air intake on the low windward side, and air exhaust on the high leeward side. As well, horizontal, outwardly angled CLT panels helped direct heat upwards and away from the power plant towards the glazed areas where heat could be conducted to the exterior. These panels also encouraged a convective flow to mitigate the formation of condensation on the glazing.

The CLT panels for the BRDF project were locally manufactured by Canadian Sustainable Timber Innovations, one of the first producers in North America. The CLT was fabricated from multiple plies of 38 mm thick, grade 2 and 3 dimension lumber. The panels met the performance requirements outlined in the BCBC for 'non-combustible' construction and also provided excellent structural capacity in bending, ease of joinery and acoustic insulation. CLT properties implemented in the construction of the BRDF included:

- Clear span for roof deck use;
- shear strength with excellent seismic diaphragm capacity;
- durable interior surface with visible natural wood surface;
- suspended floor systems;
- sufficient thickness to assist with the sound offsetting of the plant's processing equipment;
- expedited construction due to standard sized panels delivered 'just-in-time' from a local manufacturer;
- simple connection details and fewer component parts resulting in increased erection efficiency.



Construction Methodology

The BRDF contains approximately 700 cubic meters of engineered wood products, mainly CLT and glulam. While CLT tends to be used in wall and floor construction and glulam for columns and beams - the use of both building materials for the columns along the side walls of the project created an opportunity for innovative construction. The building crew needed to deal with the fact that glulam has a natural curve to it whereas the CLT is more rigid in nature. The end result featured glulam columns combined with CLT walls along the sides of the BRDF. Glulam beams supporting the roof were pre-cambered, which provides compression as they support the solid CLT roof panels. This enabled the entire plane of the roof to function as a single structural element.

Several important connection features were included in the construction of this project, including moment frame box connectors, various knife-plate connectors and plywood strips to join CLT roof panels.

Box Moment Frame Connectors: Tall glulam columns form together with glulam beams to create a moment frame across the 24.5 m span of the building for resistance to lateral shear forces. The corner connection detail included steel box connectors that were integrated into the wood members by steel rods embedded in the end grain and bolted through the box. Tight fitting steel pins along the course of the embedded rods secured them and provided additional shear resistance.

Column to Foundation Box Connectors: Similar box connectors were used to mount the glulam columns to the concrete foundation. The same threaded rods and tight-fitting pin configurations were used. This type of sophisticated connection is possible only by using Computer Numerically Controlled (CNC) equipment to prepare the mating members to exacting detail.

Knife-Plate Connectors: For less-stressed joints, concealed knife-plate connectors were used to attach glulam beams to glulam columns, glulam braces to glulam beams and glulam beams to CLT walls. This connection consists of a steel

plate inserted in a slot cut into the wood beam that is then bolted through. The bolted knife plate connection with the timber side plates was in double shear – a balanced shear relationship whereby bending is eliminated and tension loads on shear attachments are distributed evenly.

Best Practices

The construction site of the BRDF had space restrictions, therefore adding machinery and a crew to the mix meant more congestion. With classes running year round at the university and limited construction space, care was taken not to disrupt the day-to-day functions of the campus while preserving the integrity of the construction site requirements such as health and safety, ease of operation and access, and transportation of materials. Due to the site's space restrictions, an arrangement was made with the CLT panel manufacturer for a series of carefully coordinated deliveries rather than a few bulk shipments. This allowed more space for the construction crew and ensured that the material delivered was incorporated into the construction in a timely manner, as opposed to being stored on-site until needed. This is a major advantage of off-site prefabrication, which is standard for CLT and other mass timber panel systems.

Due to the size of the gasification equipment components and the restricted space of the location, the BRDF building was constructed around and over the completed gasification system – another benefit of using pre-fabricated large timber panel systems.

As with any construction project, weather conditions and site access were factored into the overall equation for the building assembly. Having a climate heavily influenced by latitude, a mountainous landscape and the Pacific Ocean –British Columbia is no stranger to variations of rain, snow or sunshine. Given the time of year of the construction, Blueskin™, a peel-and-stick protective membrane, was applied to the roof CLT panels at the manufacturing stage, to protect the wood from moisture exposure.





The project was located in a densely treed part of campus that was well shaded and received little-to-no sunlight. At the time of construction an unexpected snowfall covered the roof and remained for several days. This impeded crews from working on the roof (due to the slipping hazard) and forced construction to halt temporarily until the snow melted and the surface dried. If a skid-resistant polyethylene surface film had been used, the construction could have resumed regardless of the weather conditions.

On hand to help forecast any issues in the construction and to potentially mitigate delays in production was a well-coordinated general contractor. UBC Infrastructure Development opted to go this route for the BRDF project because it permitted more competitive pricing, allowed the university's Properties Services to be more intimately involved in the project details, and also because it promoted a team building approach to the construction.

Broader Implications/ Outcomes

Given the scope of the project and the fact that it was the first of its kind constructed in North America, it is anticipated that the BRDF will help to establish a precedent for municipalities to set new and improved standards for future bioenergy operations.

Innovative design encompasses much more than a simple willingness to use new products. It is a marriage of new ideas with functionality and an understanding of environmental and site considerations. This building inspires other design teams to use mass timber systems by demonstrating how it is able to achieve innovative, functional, and sustainable designs.

The BRDF is an example of the broader applications of mass timber panel systems in industrial buildings. It demonstrates a simple and economical construction system that can be applied to other non-combustible structures. The use of engineered wood throughout the BRDF solidified CLT's growing presence in North American construction as a cost-competitive, wood-based solution that compliments the existing light-frame and heavy timber wood options. It has proved to be a suitable substitute for many applications that otherwise would require alternative, less environmentally friendly building materials. The BRDF building paved the way for the wider use of mass timber in low-rise industrial occupancies.

Market Size (adapted from McGraw-Hill, US 2008)
<http://www.er.gov.sk.ca/Cross-Laminated-Timber>



STOREY CLASS	TOTAL			COMPETITIVE CLT
	FLOOR AREA (Million ft ²)	FLOOR AREA (Million m ²)	FLOOR AREA (Million ft ²)	FLOOR AREA (Million m ²)
Low-rise (1–4)	1,633	152	1,040	97
Mid-rise (5–10)	432	40	317	29
Total	2,065	192	1,357	126

Gasification Technology

Wood fuels an electric idea! The gasification of biomass in the form of wood shavings, wood chips, wood pellets, construction wood debris and municipal tree trimmings - examples of primary fuel sources - runs a combustible engine that produces both heat and power.

Gasification, although not a new technology, offers an excellent alternative to conventional systems of generating electricity with the added bonus of lowered Green House Gas (GHG) emissions. It is estimated that when the BRDF is in full operation, the gasification system will be able to produce:

- steam at 6,500 lbs/hr
- hot water at 3.6 GJs/hr
- electricity at 3MW/hr



UBC BRDF Project – System Components

The biomass-fuelled heat and power system of the BRDF, when complete, will use gasification technology to convert wood waste into a clean, synthetic gas that will replace the natural gas used in the current campus heating system. It will also convert synthetic gas (gas mixture containing carbon monoxide and hydrogen) into electrical power.

The UBC campus will reduce GHG emissions by 4,500 metric tonnes each year by heating with steam from the gasification plant instead of natural gas. As well, using electricity produced by the plant will reduce GHG emissions by an additional 1,500 metric tonnes (compared to electricity produced using fossil fuels). Together the combined GHG reductions are roughly equivalent to taking more than 2,200 cars off the road for one year.

Positioning itself as a hub of excellence for sustainability, UBC has combined the talent of its researchers and operators with the expertise of innovative companies to create what they refer to as the ‘Campus as a Living Lab’ concept. In addition to generating clean energy for the campus and learning opportunities in the clean energy sector for students, the design and function of the project itself is an excellent teaching tool. It demonstrates how wood is an environmentally responsible option not only for creating clean energy, but also for constructing sustainable buildings.

Design Team

The below mentioned list of companies may not represent the entire design and construction team for this project.

Architect: McFarland Marceau Architects Limited, www.mmal.ca

Consulting Firm: Equilibrium Consulting Inc., www.eqcanada.com

Real Estate Investment: Ledcor Group, www.ledcor.com

Building Code Consultants: LMDG, www.lmdg.com

Confederation College – REACH Building

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Background

Located in Thunder Bay, Confederation College's Regional Education Alliance for Community Health (REACH) project is a 3-storey addition to an existing building on campus. The new addition demonstrates an understanding of wood use in a large institutional building and showcases the strength, beauty and versatility of wood systems.

The new REACH building was created to provide Confederation College with the space necessary to train the new health and community service professionals needed to meet the growing demands of Northwestern Ontario's aging population. A total of 485 student spaces will help address the shortage of skilled health and community service professionals. Students are offered a diverse course selection that includes: Concurrent Disorders, Pre-Service Firefighter Education & Training, Community Base Collaborative Nursing, Cross Cultural Medical Interpreter and Communicative Disorders Assistant.

Design Considerations

The REACH project is an addition to an existing Group A, Division 2 building (Assembly – Major Occupancy which consists of building types such as, but not limited to, churches, court rooms, and dance halls, etc.). The project design included a 3-storey atrium, which, unless using an alternative solution as permitted by the 2006 Ontario Building Code, did not permit the use of combustible materials or unprotected heavy timber, which presented code challenges for the designers.

Incorporating wood elements into a non-combustible building, such as the use of wood columns to support a non-rated roof assembly in the REACH project, is not common practice. By taking the necessary steps to obtain approval for the wood column supports for the atrium roof, Confederation College and the project team proved that wood is a viable option and set a precedent for future wood use in buildings of this type.



A third party consulting company with expertise in building code and fire protection was hired to develop a proposal for an alternative solution to demonstrate, through the use of empirical data, that heavy timber (glulam) could be used throughout the atrium. In the end the atrium consisted of heavy timber and acted as a separation between the existing building and the new development at the third-storey. The glulam was supplied by Western Arch Rib (Manitoba).

In order to meet the requirements of the 2006 Ontario Building Code for the installation of glulam columns and roof beams as supporting structures for the atrium roof, an alternative solution was developed using the Fire Dynamics Simulator (FDS). A system supported through research by the National Institute of Standards and Technology, FDS was first released in 2000 and is now widely used by fire protection engineers to predict fire growth and smoke transportation throughout buildings. The alternative solution concluded that the glulam columns and beams needed to be protected by Early Suppression Fast Response sprinklers positioned at the top of the atrium and installed with the sole purpose of providing additional protection in the event of a fire. At the time of construction, the existing Confederation College building was a 3-storey, non-sprinklered building. The desired addition entailed a 3-storey sprinklered building. The proposed solution satisfied the intent of the 2006 Ontario Building Code, relating to combustible construction in a building required to be non-combustible:

OS1.2 – An objective of this Code is to limit the probability that, as a result of the design or construction of a building, a building will be exposed to an unacceptable amount of damage due to fire caused by fire or explosions impacting areas beyond its origin.

OP1.2 – An objective of this Code is to limit the probability that, as a result of the design or construction of a building, a person in or adjacent to the building will not be exposed to an unacceptable risk of injury due to fire caused by fire or explosions impacting areas beyond its origin.

How does FDS work?

FDS is a program that models fire starting patterns using a database of standard materials. After the materials are chosen, the dynamics of the fire are simulated based on the chemical and physical properties of the materials selected and the equations are solved based on the described evolution of the fire.

The FDS research showed that by protecting the glulam beams and columns in the atrium with an Early Suppression Fast Response (ESFR) sprinkler system, the wood structure would not expose an individual in or adjacent to the building to the possibility of injury resulting from a fire. This was demonstrated to provide the same level of performance as the prescriptive requirements in the Ontario Building Code without compromising the safety of the public at large. The research and alternative solution were presented to the local officials in Thunder Bay and accepted.

Construction Methodology

The atrium of the REACH project features 8 impressive glulam columns made from 90% spruce and 10% lodge pole pine sourced from sustainably managed forests and manufactured at Western Archrib in Manitoba. The structure of the columns mimics the trees from which they originated. The REACH project is one of the most recent projects in the region to embrace the use of wood throughout construction

and incorporate sustainable building practices. To meet one of the certification requirements of the project, the adhesive system used to laminate the wood beams was checked for low emitting volatile organic compounds (organic chemicals that can be dangerous to human health and may cause harm to the environment). The project achieved LEED Silver certification.

The exposed wood columns in the REACH project were left in their natural state, allowing the changes in weather and natural light to complement the warm undertones of the wood and highlight the different textures of the grains. The most striking feature of the REACH building design is the glulam beams, which bring the beauty of natural wood inside the facility. The exposed beams and the way they fit with the design of the project prove that wood is a viable option for various types of construction for its structural merit as well as its aesthetic appeal.



Apart from the columns and roof beams of the 2-storey interconnected floor space, the REACH building expansion used non-combustible construction. Demonstrating the natural features and capabilities of wood, the heavy timber 'tree' structures consist of the following dimensions:

- main trunk: 836 mm x 315 mm
- two side branches: 380 mm x 315 mm
- single branch: 228 mm x 315 mm
- roof beams: 570 mm x 315 mm

Two exit stairs were incorporated into the design of the REACH project. One is located in the addition and the other, in the existing building, is accessible through the atrium by way of bridges. The bridges are located on the 2nd and 3rd storeys of the REACH building and are of non-combustible construction. The floor assemblies of these bridges consist of concrete on steel decks supported by steel columns. In addition, the bridges on the 3rd storey are separated from the atrium by construction that provides a 1 hour fire-resistance rating, in part, by sprinkler protected glazed wall assemblies.

Best Practices

No building product is exempt from the negative effects of fire. However, testing has shown that large dimension wood sections have an inherent resistance to fire because they develop a layer of char which acts as an insulating layer that protects the wood beneath the surface.

The team at Confederation College, along with the architectural firm, needed to overcome many challenges in order to demonstrate code compliance and enable wood to be permitted in the 3-storey REACH project. The combination of appropriate expertise, co-operation from the City of Thunder Bay, and the College's commitment to the entire construction process resulted in a magnificent building that showcases an underutilized application of wood.

Broader Implications/ Outcomes

The valuable knowledge and experience gained during the construction and design phases of the REACH project will be transferred to other construction and design professionals, through the dissemination of resources such as this case study, so that future applications of wood in non-combustible buildings can be more easily achieved. This project is one example of the endless opportunities for design innovation that exist for wood products in all types of construction. The creative design solution achieved by the REACH project team will inspire future buildings and design adaptations.

Educational facilities usually house teaching, research, library, and student spaces, academic and non-academic offices, as well as residences, specialized laboratories and retail or restaurant spaces. It is essential that these spaces are constructed with the safety and security of staff, students, faculty and visitors in mind. Often the challenge in terms of fire protection and building code compliance is due to the relatively high occupant load in the assembly areas of the building, and the high importance that must be paid to property protection for unique and irreplaceable documents and research material.

In this project, the re-design of the sprinkler system met the intent of the 2006 Ontario Building Code and enabled the use of combustible construction in a non-combustible building. This innovative solution clearly demonstrates how wood can be used within buildings of this type without compromising the safety of the occupants or the design expectations of the client.

Design Team

The below mentioned list of companies may not represent the entire design or construction team for this project.

Architecture Engineering: FORM, www.formarchitecture.ca

Building Code and Fire Protection Consultants:
Larden Muniak Consulting Inc., www.lardenmuniak.com



Port Alberni – Secondary School

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Background

The new 138,000 square foot Alberni District Secondary School (ADSS) in Port Alberni, British Columbia serves 1,000 students and features two gymnasiums, a 500-seat state-of-the-art community theater, a First Nations gathering place, a youth health clinic and a Neighborhood Learning Centre. Students attending this modern, cutting-edge school also benefit from exposure to a wide variety of community groups, activities and services. The school incorporates a range of environmentally friendly features including ground-source geothermal heating. It is estimated that the environmental design features will save the school board up to 60 per cent in yearly operating costs.

The initial building design specified conventional steel decking on open-web steel joists in all areas where special ceiling finishes were not required. However, the project team's desire to showcase British Columbia wood construction prompted them to explore alternatives. The roof of the smaller gymnasium was chosen for its potential to incorporate and showcase innovative wood technology. Since this gymnasium is adjacent to two classrooms on the 2nd level, it also permits occupants to see the system through the glazing.

The design team engaged StructureCraft Builders Inc. to devise a wood solution for the gymnasium roof. The open web steel joists and steel roof deck initially specified were replaced with a scaled down adaptation of the 93-metre WoodWave Structural Panel© system that was first developed for the award winning Richmond Olympic Oval. The end result is a truly innovative and replicable system of WoodWave panels on timber trusses; an assembly with promising commercial potential.



Design Considerations

Built on a greenfield site and designed to LEED Gold standards, the ADSS project is a multi-faceted complex designed to meet the day-to-day demands of students and faculty. Replacing the proposed steel decking and open-web steel joists in the gymnasium roof with a wood panel deck and truss structure enhanced the sustainability of the design.

The desire for increased structural efficiency and superior acoustical absorption also influenced the design resulting in a deep, hollow, perforated panel system that simultaneously meets structural, architectural and acoustic design objectives.

To start the process, the wood product supplier conducted a full-scale structural test on the modified WoodWave panel prototype in its Delta, British Columbia fabrication/testing facility specifically for the ADSS project. In addition, they commissioned an Equivalency (Alternate Solution) Report on the proposed panel system by LMDG Building Code Consultants, which was later reviewed by the Building Officials of the City of Port Alberni. Based on the test results and report findings, the Alberni School District and the governing jurisdiction (City of Port Alberni) approved the design builder's request to proceed with the installation of the WoodWave solution for the gymnasium roof assembly.



Construction Methodology

Instead of using a conventional steel roof structure system, 10 WoodWave panels were installed. The sections are 11' wide and 44' long and are supported by 5 king post timber trusses. The panel system features hollow, triangular-shaped composite wood 'Veels', spanning from truss to truss, which in turn span the width of the gymnasium. The name for the WoodWave design concept originated from the fact that it is built completely from lumber and plywood that is fastened together in a wave-like formation. The panels function in three ways: as a structural roof, a finished ceiling and a noise-reducing panel.

The staggered 2x4s of the structural panels are made from certified SPF lumber from mountain pine-beetle-affected forests. The lumber is arranged geometrically to optimize structural and acoustic efficiency. As in the Richmond Oval, the boards are attached to triangular Douglas fir bulkheads and are packed with absorbent material to provide a structurally sound, acoustically efficient, and aesthetically pleasing solution. The hollow spaces also conceal mechanical, electrical, and plumbing services as required.

The fabrication of the WoodWave panel system involved a completely unique process. Each 2x4 strand was custom cut with a computer numerically-controlled (CNC) machine, spliced and reinforced with screws. The result is a composite, multiple-span panel complex in which each component performs structurally at optimum efficiency. The 11” deep panels fabricated for the ADSS project, in addition to being significantly shallower than the 4.5’ deep panels used throughout the Olympic Oval, are flat rather than arched, adding to the complexity of this project.

The WoodWave roof deck was erected in a single day, an achievement that clearly demonstrates the commercial potential of this system and its ability to replace standard applications of steel decking on open web-steel joists in roof structures. The use of this innovative, hybrid wood panel system in the ADSS project is a successful outcome that is a direct result of embracing alternative solutions and pushing the known boundaries of wood applications.

Additional structural features of the WoodWave roof include its ability to carry the heavy Port Alberni snow loads while supplying an appearance-grade ceiling and achieving the significant acoustical dampening required in a busy gymnasium.

Best Practices

Unique structures such as the original WoodWave structural panel roof system used in the Richmond Oval sometimes have limited commercial applications. The adaptation of this system for use in this and other smaller scale projects was necessary to demonstrate its potential for use in a broader range of commercial and institutional buildings.

The pre-fabrication and rapid installation proved beneficial for the construction crew and client alike. The relative ease of installing light-weight panels has significant commercial benefits. Factory controlled environments improve fabrication quality. The WoodWave structural panel proved to be an efficient and cost-effective alternative structural system where a wood finish is desired for the ceiling.

Broader Implications/ Outcomes

The WoodWave structural panel system is just one component of the ADSS construction yet it fulfills the structural, acoustic, mechanical and aesthetic requirements of the building while improving the overall sustainability. The WoodWave advantages do not end there. Delving deeper into the design rationale for implementing this system reveals that the WoodWave panels also improve the building’s environmental performance. The system is a marriage of structural and sustainability considerations.

The decision to use the hybrid wood panel system marked the first real commercial application of the WoodWave panel for a typical institutional project. In British Columbia, and across Canada, numerous mid-span roof structure designs can now be specified and constructed in a similar fashion – allowing the hybrid panel method (with or without timber trusses) to be evaluated on an aesthetic, commercial and cost basis. The success of this demonstration project will encourage other project owners and specifiers to consider the WoodWave, as well as other wood panel roof systems for their future projects.

Design Team

The below mentioned list of companies may not represent the entire design or construction team for this project.

Architects: Meiklejohn Architects Inc., www.meiklejohn.ca

Architects: Atelier Pacific Architecture Inc., www.atelierpacific.com

Builders: StructureCraft Builders Inc., www.structurecraft.com

Construction Company: Yellowridge Construction Ltd., www.yellowridge.ca

Building Code Consultants: LMDG, www.lmdg.com





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- Werner Hofstatter, whofstatter@wood-works.ca



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