Wood Use in British Columbia Schools

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Executive Summary

Executive Summary

Designing today's school facilities demand economically and environmentally sustainable solutions that can simultaneously create safe and inspiring learning environments for educating our youth. This has made wood a very important part of the conversation when selecting materials for structural and finish applications in schools.

This report addresses the opportunities and challenges for the use of wood and wood products in the construction, renovation and repair of schools in British Columbia. The main objectives will be to:

- Provide an overview of wood use in schools
- Address the main concerns impeding the use of wood
- Describe common best practices for wood use in schools
- Identify the opportunities and challenges with wood use in schools

The province's Seismic Mitigation Program, and School Expansion Program and School Replacement Program present an opportunity to increase the use of wood to support British Columbia's initiatives on climate and economic development. The province's forest sector is an important part of the local economy. It supports healthy, stable communities and provides jobs for tens of thousands of residents. Less energy is required to create and transport wood building products that are locally sourced and our carbon footprint can be further reduced through carbon storage in the wood itself.

Building schools with wood can have construction and operational cost benefits. Building designers have a variety of options for using wood in schools, from traditional dimensional lumber framing to innovative wood products like exposed mass timber systems using cross-laminated timber (CLT), nail-laminated timber (NLT), dowel-laminated timber (DLT) or glue-laminated timber (GLT). These systems can be used economically and effectively to meet the objectives of almost any school project. Various wood applications for schools are permitted under the BC Building Code (BCBC).

Wood's strength, ease of use, and versatility make it an ideal building material for schools.

- Wood is durable, lightweight, and can perform well in seismic events.
- Wood buildings are easy to renovate, expand and adapt to changing uses while meeting code and safety requirements.
- Lower building cost and faster construction speeds are two key factors that can sometimes favour wood construction in schools.
- Wood frame assemblies can meet a variety of acoustic performance needs, and engineered products such as acoustic wood panels can further enhance performance.
- The inherent thermal qualities of wood structural elements and potential assemblies can result in significant energy savings in schools.

In addition to its material benefits, there is a growing body of research supporting the positive impact that exposed wood can have on a building's occupants, including health and learning benefits—making wood an optimal choice for educational environments. Furthermore, integrating wood into schools can create ties between cultures and reinforce traditional and regional values, including the significance of wood in local First Nations cultures. For small communities where schools also serve as gathering areas and community centres, this is an important symbolic element.

Definitions

Air-transported Moisture: Air-transported moisture is the vapor content of air as it leaks out of or into a building. Air leakage is driven by a combination of holes through the building envelope and one of three driving forces: wind, stack effect, or mechanically induced pressure differences (fans) between the inside and outside of the building. Left untreated, this can cause condensation that can eventually lead to rot. Air-transported moisture is managed with a continuous air barrier in the building envelope, built with interconnected air-impermeable sheet goods, caulks, sealants, and spray foams.

Authority Having Jurisdiction: Governmental agency or sub-agency that is responsible for adopting and enforcing laws and regulations for construction. To enact building and fire regulations, the provinces, territories, and municipalities pass legislation that references the relevant Codes Canada publications or provincial code.

"BCBC" refers to the British Columbia Building Code

Braced Frame: Steel or wood braces used in an X or chevron configuration.

Brisco Panels (secondary laminated LVL): Glued LVL beams which are cut into wide panels.

Bulk Water: Rain, runoff and other significant water flows infiltrate buildings through gravity but also through wind and pressure differences. This is managed by moving water off and away from the building. On the exterior of a building this is controlled through the use of overhangs, pitched roofs, interconnected flashings and adequate drainage. Inside the building bulk water will be controlled by preventing or containing plumbing leaks and condensation.

Capillary Water: Capillary water moves under tension in porous building materials or through narrow channels. Capillary water damage is often harder to detect and can result in significant damage if not addressed. Capillary action can best be controlled by providing a capillary "break" such as plastic, metal, damp-proofing compound or another impermeable material, or by leaving air spaces that are too large for capillarity to occur.

Composite/Hybrid Panels: Uses mass timber panels with concrete topping for composite action to provide additional strength and stiffness.

Cross Laminated Timber (CLT): Glue pressed dimensional lumber arranged in layers 90 degrees to each other for stability. CLT may also provide 2-way span ability due to the alternate layers. Panels are fabricated up to 2-3m wide and 12-15m long to allow for transport. Dimension/length restricted by transportation, not manufacturing or use.

Dimensional Lumber: Also referred to as Solid Sawn Wood, dimensional lumber is milled from logs and kiln dried to reduce the moisture content. Member sizes vary with nominal dimensions used for imperial unit designations (i.e. 2" x 4" nominal refers to 1 ½" x 3 ½" actual dimension).

Dowel Laminated Timber (DLT): Similar to NLT, wood dowels are used in lieu of nail for this refined panelized mass timber product.

Ductility: A material's ability to deform permanently under stress without failing

Engineered Lumber: Uses parts of milled wood to achieve greater capacity, more stability, and less vulnerability to moisture by gluing and arranging the wood into structural elements.

Glulam: A structural engineered wood product (columns or beams) comprised of layers of dimensioned lumber bonded together with durable waterproof adhesives

Glue Laminated Timber (GLT): Similar to glulam beams, GLT panels use regular stock dimensional lumber which are glue pressed and placed flat. This system is one-way due to the member arrangement all running parallel to the span. Plywood is typically placed over to create a horizontal diaphragm for lateral resistance. Panel sizes are dependent on panel thickness, but are typically 0.6m wide and 12–15 m long to allow for transport. Dimension/length restricted by transportation, not manufacturing or use.

Heavy Timber: A term used by building codes to denote minimum wood member dimensions that meet the relevant fire rating. Columns, beams, joists, and decking dimensions are provided and relate to code building types, sizes, and occupancy allowances.

I-Joist: Arranged dimensional or engineered wood elements in an I-shape to achieve greater efficiency and stiffness when compared to dimensional lumber. Typically used for floor and/or roof joists.

Innovative Products: New products and fasteners are being introduced in the marketplace regularly. Check with your building official for accepted use in your jurisdiction.

Laminated Strand Lumber (LSL): Smaller wood chips arranged to create pressed panels which are typically cut into beams, headers, and tall wall purlins. Occasionally used as mass timber panels where available.

Laminated Veneer Lumber (LVL): Laminated plywood veneers typically used for beams, headers, and tall wall purlins.

Lateral Force Resisting System (LFRS): The system used by the building to provide lateral support such as wood shearwalls, braced frames, or moment frames. Reinforcing existing LFRS or adding LFRS elements is common when seismically upgrading a building.

Light Wood Framing: Also referred to as traditional wood frame. Uses dimensional lumber (typically 2x) to construct walls, trusses, ledgers, and built-up beams, posts, and headers. Engineered lumber may also be used in light timber framing as engineered lumber when dimensional lumber is not adequate for the use. Gang-nailed trusses can use dimensional lumber to achieve longer spans. It is commonly used for single family and multi-family dwellings, 1 or 2 storey schools and community centres, as well as 5-6 storey commercial/office spaces.

Load Bearing: When framing is supporting the primary structure.

Mass Plywood Panels: As the name suggests, plywood veneer pressed into panels up to 24" (600 mm) thick.

Mass Timber: Typically consists of wood components (i.e. dimensional lumber, plywood, etc.) that are glued, nailed, or fastened together into larger panelized elements that are used for walls and decking, and on occasion wood beams.

Moment Frame: Rectilinear assemblage of beams and columns that resist lateral loads primarily by bending movement and shear force in the frame members and joints. Steel frames are most common and can be used when open areas are needed. They consist of column with fixed connections to stiff beams. Wood moment frames are also possible but require special detailing and additional analysis.

Nail Laminated Timber (NLT): Uses dimensional lumber (typically 2x or 38x) which are nailed together on edge to create larger panels. Given the simple nature of NLT, the panels may be prefabricated on or off site, or nailed in place. Plywood is typically placed over to create a horizontal diaphragm for lateral resistance. Finger-jointed wood is typically used for members spanning more than 3-4m.

"NBC" refers to the National Building Code of Canada

Non-Load Bearing: When framing does not support the primary structure (i.e. partition walls).

Oriented Strand Board (OSB): Pressed wood chips for a large sheathing panel. Typically used for a lateral diaphragm and exterior sheathing.

Parallel Strand Lumber (PSL): Arranged wood strands that are glued and pressed together to form larger beam and column members.

Plywood: Wood veneer pressed together to make larger panels. Typically used for structural sheathing, exterior sheathing, or millwork.

Post and Beam: Traditional form of wood construction using beams and columns/posts to support interior spans. Walls are typically limited to the perimeter of the building (which may consist of brick, concrete, or wood frame).

Racking: Deformation that can occur at the corners of wall structures when forces act on it transversely, this can result in a lateral displacement relative to the bottom structure.

Sheathing: Typically plywood or OSB structural sheets used for a floor and/or roof deck as well as the lateral diaphragm. Sheathing is also applied to joists, walls, and NLT/GLT panels to provide lateral resistance (i.e. shearwall or diaphragm).

Shearwall: Structural system composed of braced panels to counter the effects of lateral load acting on a structure. Wood shearwalls use plywood sheathing over light framed walls. Concrete shearwalls are also common.

Vapour Diffusion: The movement of water as a gas. While building assemblies get wet through all four forms of water movement, once water gets in the main way it gets out is diffusion. So building assemblies should be built to dry through diffusion.

Wood Hybrid: A structural system comprising of wood elements paired with other materials, such as steel.

Wood Wave: Assembled dimensional lumber in a V pattern to provide additional strength and stiffness. Can be integrated with acoustic and other components if desired.

Introduction

1.0 Introduction

The overall purpose of this report is to inform the development of a strategy to increase the use of wood in British Columbia schools while supporting the provincial government's priorities in education. The main objectives include:

- Provide an overview of wood use in schools
- Address the main concerns impeding the use of wood
- Describe common best practices for wood use in schools
- Identify the opportunities and challenges with wood use in schools

This report consists of four parts that will address different aspects of using wood in British Columbia with a special focus on the construction of public schools. This first section provides an overview of the main drivers, including the widespread support for wood use in the province and the context of school construction. Section 2.0 discusses the characteristics of wood use through a range of topics applicable to British Columbia, and Section 3.0 will present examples of innovative wood use in schools from outside of British Columbia to provide a comparative lens and opportunities to learn from others. In Section 4.0, more detailed examples are presented of how wood has been implemented locally.

1.1 Why Wood?

Wood has historically been used as a structural and finishing material for many types of construction projects. Recent innovations in wood construction, engineered wood products, mass timber and hybrid systems allow architects, engineers and builders to create an even wider range of structures. The business and design rationale for wood across building segments comes from its durability, flexibility, installation efficiency and ease of use. In addition to the sustainability benefits wood can provide, discussed in more detail later in this report, wood's unique ability to respond to seismic activity makes it a practical and advantageous material choice for construction in British Columbia.

British Columbia is home to one of the world's largest and most competitive forest sectors. Maintaining the province's leadership requires continued effort to both develop innovative products and to diversify markets. The Ministry of Forests, Lands, Natural Resource Operations & Rural Development has made a commitment to advance several initiatives that ensure the sustainable development of forests to support local communities to strengthen and diversify their economies. Some initiatives that support this objective include:

- Working with communities and industry to develop long-term strategies that will create more jobs by processing more logs in British Columbia
- Expanding the innovative wood-products sector by addressing regulatory and capital barriers hindering the growth of engineered wood production and working with other ministries to ensure public projects prioritize the use of wood
- British Columbia's climate strategy priorities align with the initiatives by the Ministry of Forests, Lands, Natural Resource Operations & Rural Development
- The province's climate strategy priorities include:
  - A commitment to reduce greenhouse gas emissions to 80% below 2007 levels by 2050
  - Actions to reduce carbon pollution and transform British Columbia's current economy to a lower carbon economy, while creating jobs and opportunities for clean growth

1.2 Wood in Schools

Planning for the remediation, expansion or replacement of public school buildings is a shared responsibility between the provincial government and Boards of Education. Boards of Education submit Capital Plans to the Ministry of Education annually to seek funding support for projects from a number of the Ministry's Capital Funding Programs, including:

- **Seismic Mitigation Program (SMP)**
- **School Expansion Program (EXP)**
- **School Replacement Program (REP)**

Each of these programs presents an opportunity to support the province's goal of building a resilient, sustainable low-carbon economy and increasing the use of wood in buildings.

The Ministry of Education launched the Seismic Mitigation Program (SMP) in 2004 to make schools safer in the event of an earthquake by minimizing the probability of structural collapse. In liaison with the Engineers and Geoscientists of British Columbia, all public schools in British Columbia have been assessed for seismic risk, identifying 346 eligible schools that require mitigation through strengthening, partial replacement, or full replacement.

Through the Seismic Mitigation Program alone, the Ministry of Education has spent $1.6B to date to complete 170 high risk projects throughout the province, with another $560M budgeted for high risk seismic projects in the Ministry's 3 year capital plan. As of February 2018, 170 high risk schools have been completed, with an additional 11 schools currently under construction, 20 projects proceeding to construction, schools in business case development, thereby leaving 116 schools as future priorities.

The Ministry of Education also has established budgets for their School Expansion Program and School Replacement Program to address the demand for school projects associated with significant population growth in certain school districts in the province, as well as to address the Supreme Court of Canada ruling in 2016 modifying class size and composition.

It is important to note that the Ministry of Education does not currently have prescriptive standards or policies on specific materials to be used for construction projects, as the Ministry acts mainly as a funding agent. School districts in the province have autonomy on design and material selections and are responsible for all procurement of projects.

In the process of selecting materials for school construction in British Columbia, there can be a variety of determining factors that can decide whether wood is selected as the material of choice for a certain application. Section 2.0 presents the main topics of consideration pertaining to construction materials with a focus on how wood can, or in some instances cannot, accommodate the needs of a project.

1.3 Methodology

The information for this report was compiled through a combination of research methods that were catered to each subject matter. A literature review was conducted in the form of published articles, books, and reference materials such as building codes and CSA (Canadian Standards Association). Case studies of built projects were examined to identify current trends and innovative solutions. Interviews with subject matter experts (acousticians, sustainability consultants, and engineers) were held to verify general assumptions and gather additional information and resources. GHL code consultants and Fast + Epp structural engineers were involved in the process to provide additional resources and substantiate information gathered throughout this report.

Furthermore, a survey was conducted involving eight school districts respondents to determine from an owner's perspective, some of the important factors considered in school construction and some of the main factors for why wood is or is not selected as a material. A summary of the survey results is included in Appendix B.

A variety of factors in the construction process may result in unpredictable outcomes, and therefore general statements related to construction, cost, or performance could reflect ideal scenarios, or assumptions that best practices are followed. Most of the factors related to the performance of wood can be quantified and tested. However, some of the more qualitative aspects have relied on anecdotal evidence where further research may be necessary.

Utilizing Wood

2.0 Utilizing Wood

Wood is a versatile construction material that can be used in the construction of schools of all sizes and in a variety of building systems including light wood frame, heavy timber, mass timber, as well as in numerous exterior and interior finishing uses, which are explained in more detail in Section 4.0 of this document.

Wood can offer numerous benefits for the construction and renovation of school buildings. These include: building performance; construction benefits, including speed of construction and availability of materials; cost benefits; material performance benefits, including durability and acoustics; sustainable benefits; and social and cultural benefits, including enhanced educational delivery.

Interior

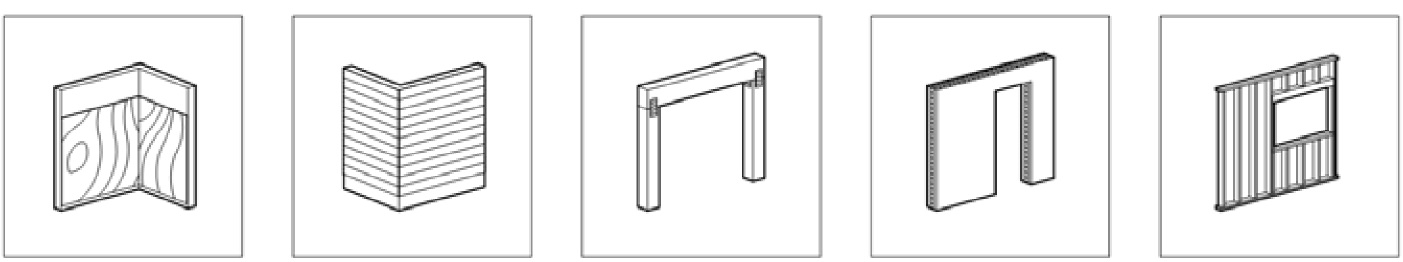


Figure 1. Diagrams of Wood Categories. From Left to Right: Interior Wood Use, Exterior Wood Use, Heavy Timber, Mass Timber, Light Wood Frame.

2.1 Building Codes

The BC Building Code (BCBC) governs the design and construction of all buildings in British Columbia. The BCBC provides minimum standards for health, safety, and general welfare including structural integrity, mechanical integrity (including sanitation, water supply, light, and ventilation), means of egress, fire prevention and control, and energy conservation. Building codes require all building systems to perform to the same level of safety, regardless of the material used.

BCBC and School Design

Under the BCBC, school buildings fall under the Major Occupancy Classification **Group A Division 2**. This classification is used to determine which BCBC requirements will apply to the design and construction of a school.

The building codes applied to schools are particularly stringent, not only to protect students and occupants from harm, but also because elementary, middle, or secondary schools are likely to be used as a post-disaster shelter in the event of a major emergency. Categorized as “High” in the importance category in the BCBC, all school buildings must be designed to meet the same design loads, regardless of construction type or material used. The BCBC governing factors for wood construction systems for school buildings include the building area, number of storeys, street access for firefighting, and whether there are sprinkler systems installed.

Requirements on the specification of structural wood products and wood building systems are set forth in the BCBC which is concerned with health, safety, accessibility and the protection of buildings from fire or structural damage. The building code applies mainly to new construction, but also aspects of demolition, relocation, renovation and change of building use. In addition to outlining the minimum requirements for structural, fire safety and seismic details, the BCBC also outlines product specific standards for individual elements, wood or otherwise. The CAN/CSA-O86 Engineering Design in Wood outlines the wood design requirements for Canadian conditions. Referenced throughout the BCBC, the CSA 086 is a comprehensive set of requirements for the structural design and appraisal of structures or structural elements made from wood or wood products.

The building code is continually revised in response to new research, emerging technologies and increased understanding about the complex factors that impact the performance of buildings. Wood-frame, wood-hybrid and mass timber construction are resilient with a proven safety and performance record for a full range of conditions including fire, seismic and wind. Section 4.0 of this report outlines the building code implications in more detail for each of the major categories of wood application.

Appendix B–Matrix for Wood Use provides more detailed information and categorization for how wood can be used in school buildings in compliance with the building code.

Fire Safety

Fire safety requirements for schools are outlined in the BCBC and the ***BC Fire Code***. The ***BC Fire Code*** contains technical requirements designed to provide an acceptable level of fire safety. It applies the core concepts of the National Fire Code, combined with elements specific to British Columbia.

Under the BCBC and BC Fire Code there are two main categories of construction: combustible and non-combustible. Combustible construction generally refers to wood and non-combustible refers to concrete and steel. Wood is a combustible material, however there are several ways that combustible materials can be used in a non-combustible building. When a building is categorized as non-combustible construction the BCBC does not entirely prevent the use of wood, rather it limits how wood can be used. For example, wood-based finishes, exterior cladding, non-structural partition walls, blocking materials, finished flooring, and millwork, can still be used as long as the relevant requirements are met, such as specific flame spread ratings[1]. Heavy Timber is a term used in the building code to refer to wood elements with a minimum dimension, determined to provide a specified level of fire safety (Figure 2).

1 **cwc.ca/wp-content/uploads/2013/11/FlameSpread.pdf**

Table 3.1.4.7. Heavy Timber Dimensions Forming part of Sentence 3.1.4.7.(2)				
Supported Assembly	Structural Element	Solid Sawn (width x depth), mm x mm	Glued-Laminated (width x depth), mm x mm	Round (diam), mm
Roofs only	Columns	140 x 191	130 x 190	180
	Arches supported on the tops of walls or abutments	89 x 140	80 x 152	–
	Beams, girders and trusses	89 x 140	80 x 152	–
	Arches supported at or near the floor line	140 x 140	130 x 152	–
Floors, floors plus roofs	Columns	191 x 191	175 x 190	200
	Beams, girders, trusses and arches	140 x 241 or	130 x 228 or	–
		191 x 191	175 x 190	

Figure 2. Heavy Timber Table

SOURCE: BCcodes.ca

The most common guiding principles for determining combustible and non-combustible construction in schools is typically based on area and can be broken down into the three categories listed below. Area allowances for school construction is provided by the Ministry of Education's Area Standards based on capacity requirements for specific schools.

1. **Buildings under 2,400 m²**: All buildings under 2,400 m² are allowed to be of combustible construction. This category typically includes many elementary schools in smaller jurisdictions throughout the province where student capacity requirements are less than 250 students.
2. **Buildings up to 2 storeys but over 2,400 m²:** For structural applications in this category, Heavy Timber is permitted for the roof and its supports, provided the building is sprinklered. Most middle and secondary school buildings in the province fall into this category. Buildings with a larger area can be divided into separate compartments using firewalls, which treat resultant compartments as separate buildings. This method is not often used as it can be complicated to achieve and may result in undesirable architectural outcomes.
3. **Buildings over 2,400 m² and up to 6 storeys:** Although schools above two stories are not common in British Columbia, as land values increase in urban areas and designs solutions are continuing to be proven safe in other building types, taller wood schools can be expected in the near future.

Flame Spread Ratings

Flame spread is primarily a surface burning characteristic of materials, and a flame-spread rating (FSR) is a way to compare how rapidly flame spreads, on the surface of one material compared to another. Any material that forms part of the building interior and is directly exposed is considered an interior finish and requires a FSR. This includes interior claddings, flooring, carpeting, doors, trim, windows, lighting elements, as well as exposed structural assemblies.

In general, maximum flame-spread for interior finishes of walls and ceilings for all building types can be met with nearly all wood products used as finish materials without the need for fire-retardant treatments or coatings. In the event of a fire, the flooring is usually the building element least likely to be ignited and therefore has the least amount of regulations for flame spread ratings.

Alternative Solutions

If the desired wood use does not fall under an acceptable solution outlined within the BCBC, proposing an alternative solution is an acceptable way to reach compliance by increasing the fire separation and fire safety measures.

Alternative solutions are considered on a project-by-project basis, however they will typically address:

- Occupant safety – evacuation
- Fire Resistance rating
- Char analysis if wood is exposed

British Columbia is generally receptive to alternative solutions particularly as solutions for wood use have become more frequent and desirable. If design direction is known early on, a meeting can be set up with authorities having jurisdiction to establish goals and ensure a smooth process to meet relevant requirements. As research results for fire and structural performance of wood construction become widely available, future building codes will likely see changes for what is acceptable. Smaller jurisdictions in British Columbia that less frequently see proposals for alternative solutions may not be as willing to accept alternative solutions, however the smaller building areas typically required would allow for combustible construction and therefore there would be fewer obstacles to using wood.

Seismic Safety

A majority of British Columbia's population lives within a zone with considerable or high seismic hazard, and there are growing concerns that many of the public buildings, including schools, would fail in the event of a major earthquake.

In response, the Ministry of Education has undertaken the Seismic Mitigation Program to improve the safety of schools within the province. Through this program schools have gone through an assessment process and if deemed necessary go through a seismic retrofit, and in some cases schools are being entirely replaced.

Wood is a suitable construction material in seismic zones because it has inherent characteristics that make it a suitable material in areas prone to seismic activity:

- **Light weight**: Earthquake damage is most commonly caused by seismic waves that cause the ground to move. Earthquake forces are proportionate to a structure's mass and with wood being lighter than steel and concrete structures, properly designed and built wood frame structures perform well during seismic activity.
- **Ductility**: Wood frame structures are constructed with multiple nailed connections and joints. This creates a ductile system that can flex during an earthquake, thus absorbing and dissipating wave energy.
- **Redundancy:** Sheathing and finishes that are attached to wood structural members such as studs and joists provide redundant load paths for earthquake forces. In other words, if some connections fail, there are adjacent connections that can help to take the load and avoid collapse.
- **Strength and stiffness**: Walls tend to rack during earthquakes, but wood shear walls can provide the necessary stiffness to resist racking.
- **Connectivity**: A structure acting as a single, solid unit is critical to withstanding earthquake forces. In wood buildings the structure's walls, floors and roof framing are anchored to the building foundation with standard connections and tie-downs to resist racking and overturning.

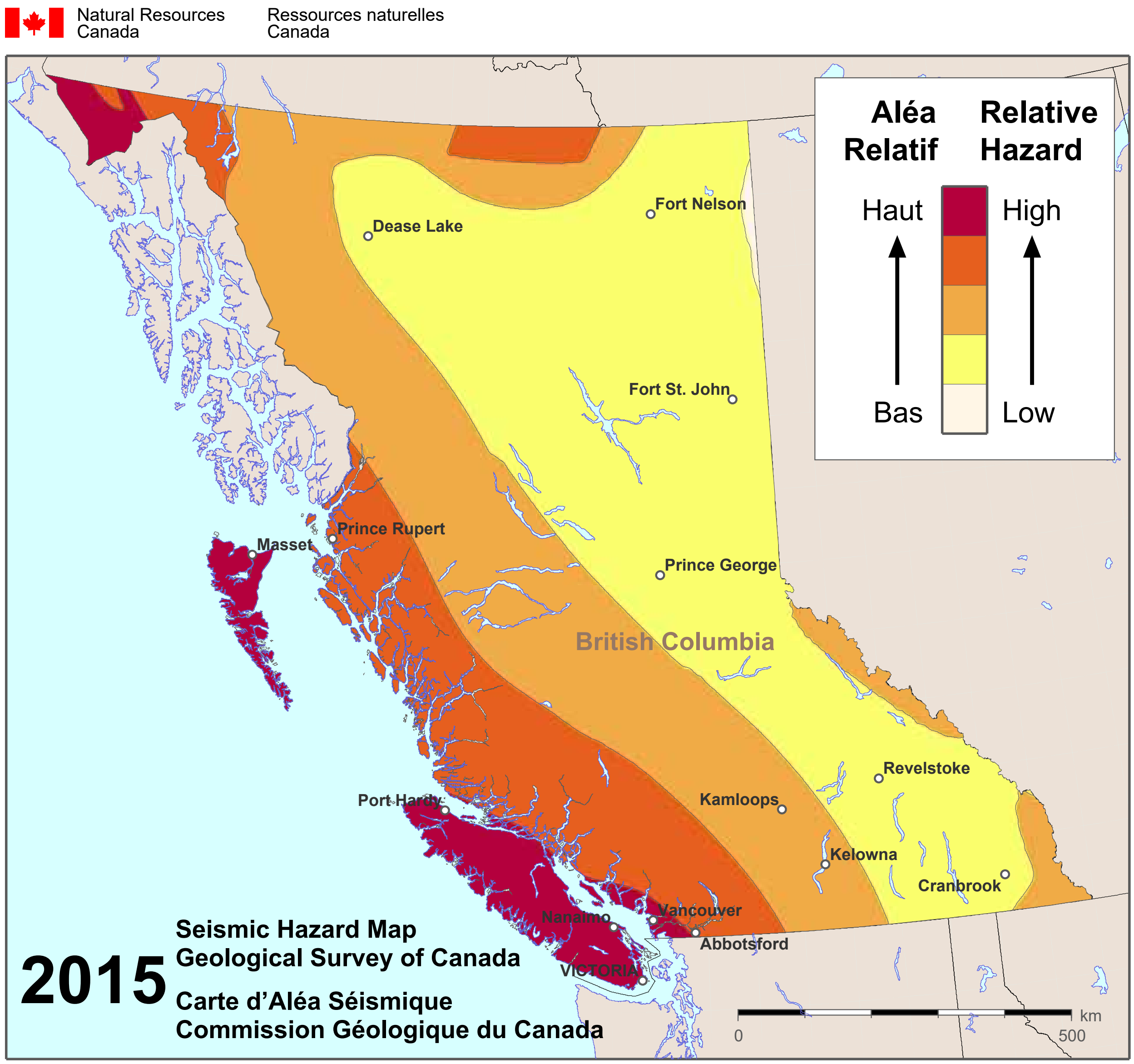


Figure 3. Simplified British Columbia Seismic Map

SOURCE: seismescanada.rncan.gc.ca/hazard-alea/simphaz-en.php

Wood-frame schools are common on the West Coast, where seismic design is a particular concern. For example, in California, one of the most highly regulated states for seismic requirements, approximately 40% of schools use wood-frame construction. Wood construction systems are not typically limited by seismic considerations in 2-storey buildings and often demonstrate superior performance, even in higher structures, when subjected to such forces.[2]

There are already schools in British Columbia that have opted for wood systems to meet the demands their seismic upgrades, which yielded economical and aesthetically pleasing results. For example, Cordova Bay Elementary in Victoria employs a combination of cross-laminated timber (CLT) and nail-laminated timber (NLT) panels, while Surrey Christian School combines a glulam post-and-beam system and light-wood frame shear walls with NLT roof panels.

2 ATC/SEAOOC. Seismic Response of Wood-Frame Construction Part A: How Earthquakes Affect Wood Buildings. https://www.atcouncil.org/pdfs/bp3a.pdf

BC Energy Step Code

British Columbia is taking steps to increase energy-efficiency requirements in the BC Building Code to make buildings net-zero energy ready by 2032. The BC Energy Step Code—a part of the BC Building Code—supports that effort. The BC Energy Step Code is a voluntary provincial standard that provides an incremental and consistent approach to achieving more energy-efficient buildings that go beyond the requirements of the base BC Building Code. It does so by establishing a series of measurable, performance-based energy-efficiency requirements for construction that builders can choose to build to, and communities may voluntarily choose to adopt in bylaws and policies.

In addition to supporting long-term improvements in energy efficiency in the BC Building Code, the BC Energy Step Code will improve the consistency of building energy regulations in the Province. The Energy Step Code is a single provincial standard that replaces the patchwork of different green building standards that have been required or encouraged by local governments in the past. This will allow local governments to continue to play a leadership role in improving energy efficiency, while providing a single standard for industry and build capacity over time.

The BC Energy Step Code takes a performance-based approach that identifies an energy-efficiency target that must be met and lets the designer/builder decide how to meet it. To comply with the BC Energy Step Code, builders must use energy modelling software and on-site testing to demonstrate that both their design and the constructed building meet the requirements of the BC Energy Step Code. The new standard empowers builders to pursue innovative, creative, cost-effective solutions, and allows them to incorporate leading-edge technologies as they come available.

When buildings target higher energy performance and improved building envelope assemblies, wood is often chosen because it is less conductive and therefore better at meeting stringent targets. Examples of highly energy efficient schools are explored in Section 3.0. Increased energy efficiency in school buildings leads to increased thermal comfort for occupants, operational cost reduction, and sustainability benefits.

2.2 Construction

Wood construction generally falls into three categories: light wood framing, post and beam, and mass timber. While all types of wood construction are relatively fast and can be cost-effective, they have different merits and it is not uncommon to utilize a combination of the following categories.

1. **Light wood framing:** Involves load-bearing wood stud walls, sheathed with plywood when needed as shear walls, supporting floors formed of dimensional lumber joists or engineered wood products such as wood I-joists, laminated veneer lumber (LVL), laminated strand lumber (LSL) or parallel strand lumber (PSL).
2. **Post and Beam**: Traditionally uses large solid pieces of roughhewn lumber which can be connected with many variations of mechanical and joinery connections. In modern construction, this more often includes members that are glue-laminated (glulam), however, the structural approach typically remains the same. Post and beam construction provides greater strength than light wood framing by using columns (posts) and beams to support the floors, rather than load-bearing walls.
3. **Mass timber construction:** Includes flooring systems commonly involving glue-laminated (glulam) beams supporting slabs of cross-laminated timber (CLT), glue-laminated timber (GLT) or nail-laminated timber (NLT). Products more recently introduced to British Columbia include dowel-laminated timber (DLT)—a product without any steel fasteners or glue—and mass plywood panels. Mass timber floors may be used in buildings with either wood or non-wood walls and columns. Mass timber panels may also be used for bearing walls and shear walls.

Speed and Ease of Construction

In the construction of schools, the schedule is always a concern. Decreased construction time reduces disruptions to site and provides advantages in northern climates where weather makes construction difficult. Light wood frame construction is fast, compared with concrete or steel construction. While the erection of steel framing itself is similar in speed to light wood frame construction, floors in a steel-framed building are usually finished with a structural topping concrete poured onto steel deck, which reduces the overall speed of construction. Light wood frame construction may be slowed by poor weather conditions due to concerns with moisture during construction, however this is also an issue with concrete construction.

Heavy timber and mass timber construction is also fast when compared with concrete construction as it does not require the additional step of constructing falsework and formwork that concrete construction does. Furthermore, concrete and propped steel construction uses poured concrete over a steel deck for the floors and this requires time to cure before it can support the weight of subsequent structural elements. In a mass timber system, many wood elements can be prefabricated which allows building elements to be built off-site in a controlled environment— resulting in higher levels of quality control, faster assembly on site, and a reduction in construction waste. Prefabricated wood elements are delivered to the site and fastened to connection pieces that have been fixed. Although this process involving prefabrication can dramatically speed up the construction schedule, it is dependent on a reliable supplier that can meet the demands of the project. This reliability is increasing in British Columbia, however it varies by region and product.

Figure 4. Glulam Columns Protected During Construction of the Wood Innovation and Design Centre in Prince George

SOURCE: naturally:wood

Figure 5. Installation Of Pre-Fabricated Mass Timber Floor Components for Brock Commons Tallwood House at the University of British Columbia

SOURCE: naturally:wood

In terms of construction, techniques for mass timber construction can be quickly learned, with more and more contractors self-performing the installation. Furthermore, the numbers of trades and workers on site can be reduced if an all wood construction is designed (i.e. wood walls, columns, and panels), further increasing construction efficiency.

This can also be an important factor in small communities or remote locations where labour may be more difficult to secure. Skills for light wood frame construction, available from residential construction in small communities can be easily adapted to construct light wood frame schools as well.

Light wood frame buildings are constructed from dimensional lumber and other light-weight wood products which require little staging area on site and can be delivered in a small number of delivery trucks.

Mass timber may require a larger staging area for larger beams, columns or panels (GLT, NLT, DLT or CLT decks or walls) on site or off site if space is restricted. This can also be managed by maximizing pre-assembly in the shop as well as adequate pre-planning for truck delivery to be coordinated with direct placement of the panels.

Availability of Materials/Trades

Wood construction offers benefits over steel and concrete due to the availability and accessibility of wood materials and trades in British Columbia. The dimensional and engineered lumber used in light wood framing is readily available in British Columbia. All types of construction require qualified trades persons with the required skills, however for wood frame construction carpenters and supporting trades are widely available. It can be more challenging to find a qualified crew for concrete or steel construction, especially in remote areas or small communities. There are additional costs to bringing in out of town trades and these costs directly impact the project budget.

The availability of mass timber products varies with the type of product and quantity required. Nail-laminated timber (NLT) is widely available as it requires a lower, manual, skill-set to produce. Glue-laminated timber (GLT) floor and roof panels are engineered products which are produced in controlled processes but are also widely available. In North America, cross-laminated timber (CLT) is produced in facilities in British Columbia, across Canada and the United States, but large quantities are only available from a small number of suppliers, including Structurlam (British Columbia), Nordic (Quebec) in Canada. Several manufacturers have announced new CLT production in the U.S., including in Washington State.

The largest part of world-wide production of CLT – more than four-fifths – is in Europe. Manufacturing efficiencies mean that European CLT is able to compete with local suppliers in the North American market. European suppliers are often able to provide competitive rates to the North American manufacturers (including shipping costs). In addition, the European suppliers may be able to meet supply needs on a more reliable schedule given their capacity. Mass timber is picking up in popularity so early discussions with manufacturers is important to ensure the dedicated supply for the project.

2.3 Cost

Wood can be a cost-effective solution for a school building and can provide cost savings for both materials and installation. Upfront construction cost savings can stem from offsite fabrication efficiencies, and availability of materials and labour. In addition, wood can provide long term savings by reducing operating costs if applied in high performance building assemblies. Further cost savings can be expected as the wood industry continues to expand in British Columbia. Areas such as Austria and Germany, where CLT and glulams are more common, see significant cost savings when using wood construction. This is further discussed in Section 3.0.

Operational Costs

As schools seek to reduce their energy costs—a high expenditure for every school district—there will be increasing demands for more energy efficient buildings to ensure a sustainable future. Wood-frame schools can be easily designed to meet or exceed the demanding energy-efficiency requirements of school districts and they can do so in a cost-effective manner. Wood is less thermally conductive than concrete or steel, which means that wood construction is affected to a much smaller extent by thermal bridging (the unwanted transfer of heat in or out of a building through structural members penetrating the building envelope) than steel or concrete structures.[3] Nevertheless, many of the measures that can be taken to significantly reduce energy costs have less to do with building materials and more to do with construction strategies for building envelope—regardless of material—as well as the selection and efficient use of equipment and HVAC systems.

Wood buildings can offer long-term durability however they do require maintenance, as do all types of buildings. A maintenance strategy would include periodic inspections for rot or termite damage, recoating (depending on the surface finish) and repairs from vandalism. In the survey conducted with school districts in British Columbia for this report, it was noted that the use of wood reduces vandalism compared to other materials, likely due to its perception as a finish material. Furthermore, because wood construction involves few exposed steel elements, it does not suffer from corrosion, cracking and spalling problems associated with steel and concrete construction. Maintenance for wood buildings can be greatly reduced if the wood is properly designed and detailed to reduce its exposure to water and direct UV.

3 **woodworks.org/wp-content/uploads/Wood_Schools.pdf**

Figure 6. Dimensional Lumber at West Fraser Sawmill, Quesnel, British Columbia

SOURCE: naturally:wood

Construction Costs

Light wood frame construction uses cheaper material and labour than any other construction and therefore is often the least costly option for 1 and 2 storey schools. Due to a widely available stock of material and trades, that there may be only a small economy of scale—i.e., even at a small scale, it remains a fast and cheap type of construction. Light wood frame can be permitted for school structures up to 6 storeys—however the costs increase disproportionately due to seismic and high wind demands.

Mass timber construction is cost-competitive with steel and concrete construction. In some conditions, its material costs are higher than an equivalent steel or concrete building, however its efficiency gains from pre-fabrication and reduced time on site can reduce overall costs. Mass timber products can also offer an economy of scale for simpler products such as NLT, as well as for those with more controlled manufacturing processes and requirements such as CLT. While there is still some contention over cost within the industry, as mass timber becomes more widely produced, designed and built within Canada, its competitiveness will continue to increase.

Figure 7. Full-Scale Wood Frame Building Subjected to Three Earthquakes on the World's Largest Shake Table in Miki, Japan

SOURCE: awc.org/pdf/education/des/ReThinkMag-DES700A-BuildingResilience-160623.pdf

2.4 Material Performance and Maintenance

Resiliency

In addition to serving as an important public asset holding our community's children, schools are also likely to be used as a post-disaster space in the event of an emergency and expected to return to operation quickly. This demands a high level of resilience– the ability to withstand and recover from adverse events. Properly constructed wood frame buildings that comply with building code requirements have been shown to suffer minimal damage from seismic events and high winds. In a full-scale earthquake test of a 6-storey wood frame building on the world's largest shake table in Miki, Japan, the building performed exceptionally well even when tested for the most extreme seismic events.[4] A school building constructed to withstand natural disasters minimizes human risks and also contribute to maintaining a sustainable community by reducing material waste and lowering restoration costs.

4 **awc.org/pdf/education/des/ReThinkMag-DES700A-BuildingResilience-160623.pdf**

Durability

There is a common misperception that concrete or steel should be the obvious material choice for constructing long lasting buildings, however, buildings are rarely demolished because of a failing structural system. Rather, studies have shown that most buildings are demolished due to changing land values, changing tastes and needs, or lack of maintenance on non-structural components.[5]

It is also a common misconception that wood buildings require greater levels of maintenance than those made from other materials and have shorter lifespans. This can be perceived as a limitation for schools where a long lifespan paired with easy maintenance is crucial. However, with proper design and detailing, wood schools can match the durability performance of schools made from any other material.

There are two main concerns around the durability of wood: Its ability to withstand the wear and tear in areas of high traffic and its susceptibility to damage due to weather. Durability of finishing materials is a big concern for schools which has resulted in painted masonry being a very popular choice. While this may be a durable choice requiring very little maintenance it is often perceived as very cold and institutional. Using wood as a structural framing material allows a lot of versatility in finishes, which can be a cost-effective method of achieving a variety of architectural finishes for different purposes ranging from simple partitions to impact resistant assemblies providing protection in needed areas such as interior corridors.[6]

In high-traffic areas, the structural material doesn't tend to be at risk unless the structure is also the finish material, as it often is with CLT or other mass timber products. Common options for avoiding damage to structural wood include high-durability finishes, such as hard tile, medium-density fiberboard, impact-resistant gypsum, and vinyl wall coverings. To make these finishes cost-effective, they are often added just to the lower portion of the wall (e.g., the bottom 6 feet) where the most wear and tear can be expected.

Weather

The biggest concern with using wood for constructing schools is how it performs when exposed to the elements. With proper design and construction, wood-frame buildings and envelope assemblies can resist damage from moisture and provide decades of service equivalent to other building types.

Water moves in, on, and through buildings through the following four paths: bulk water, capillary water, air-transported moisture, and vapor diffusion. Wood is known to fade and weather over time, however the biggest threat to the durability of wood is decay from continued exposure to water. Wood is a natural, biodegradable material and there is a misconception that it may deteriorate faster than other materials, however, all building materials will have issues if moisture is not managed properly. Water by itself doesn't cause harm to wood, in fact wood handles high humidity without compromising its structural integrity, but water enables fungal organisms to grow which leads to decay. Moulds are notorious for their contribution to poor air quality and potential impact on human health. Mould spores can grow and thrive where there is moisture, including humid air—which means they can proliferate almost anywhere. They grow on many surfaces, wood included, and usually signal a deficiency in a building's moisture management program.

The key to controlling decay is controlling excessive moisture. There are a number of ways this can be achieved; through design, through species selection and through surface treatments.

Building Envelope Design

The strongest defense against water infiltration into a building is a well designed and constructed exterior wall assembly. The BCBC governs the design of the exterior envelope, to ensure wall assemblies have the ability to deflect, drain, and dry moisture. If a wood product is to be used in an application that will frequently be wet for extended periods, then measures need to be taken to protect the wood. Wood buildings also require detailing to include overhangs and canopies that provide the first line of defense against water. Scuppers can be detailed so as to direct and discharge water away far away from the building.

5 O'Connor, J., Horst J.S., Argeles, C, 2005. Survey on Actual Service Lives for North American Buildings, FPInnovations, Proceedings, 10th International Conference on Durability of Building Materials and Components

6 woodworks.org/wp-content/uploads/Wood_Schools.pdf

Figure 8. Crawford Bay Elementary–Secondary, School District No. 8—Roof Overhangs Designed To Protect Exposed Wood

SOURCE: Canadian Wood Council

Decay Resistant Wood

One way to preserve exposed wood from moisture is to select a wood that has natural characteristics that protect it from decay, such as western red cedar. Most of our construction lumber is not naturally decay resistant, however it can be treated with preservatives through pressure treatment. Properly treated wood can have 5 to 10 times the service life of untreated wood. Preservative-treated wood or naturally decay-resistant wood is typically used for applications such as cladding, shingles, sill plates, and exposed timbers or glulam beams, where moisture tolerance is necessary. In Canada, the use of pressure treated wood is regulated by the NBC and the CSA. As of 2016, Chromated Copper Aresentate (CCA) Pressure Treated Wood has been phased out of school building construction and other alternatives have been created. For example, thermally modified lumber utilizes heat and steam to produce a dimensionally stable, relatively decay resistant wood which is non-toxic.

Surface Treatments

There are a variety of paints, stains, varnishes and water repellents can be applied to wood products provide some protection against moisture uptake and extend the life of wood. However, coatings cannot be considered as substitutes for preservative treatment. Surface coatings are classified in a number of ways, including opacity, by carrier type or by coating thickness. Each method has its merits, however regardless of the coating used, regular maintenance is required to maintain the integrity of the finish. The durability of wood can easily be increased through simple maintenance strategies such as annual inspections and minor repairs to signs of water damage or ingress.

Figure 9. Linear Wood Slats Used on Ceiling for Acoustic Absorption and Aesthetic Finish at Salish Secondary School in Surrey, BC

SOURCE: School District 36

Insects

For wood, an additional consideration for durability is protection against insects. There are three categories of termites found in North America, however only one is found in British Columbia. Dampwood termites are prevalent in the Pacific Northwest, but they primarily attack decaying wood. Eliminating the moisture source leading to the decay normally controls them. These termites are rarely a problem in buildings and do not constitute a major risk to a building's integrity.

Figure 10. Wood Used in Concert Hall for Acoustic Finish, Sevenoaks School of Performing Arts - Kent, England

SOURCE: woodawards.com

Acoustics

Wood construction and specialty wood products can offer a variety of acoustic solutions for school buildings. The desired acoustic performance in schools can vastly range for spaces such as libraries, performance theatres, shops, classrooms, gymnasiums—and the design considerations are especially important when conflicting spaces are adjacent to each other.

Wood assemblies can be manipulated in various ways through geometry and construction details to meet the appropriate acoustic performance in a room. A range of sound transmission class (STC) ratings can be achieved with variations of simple wood frame wall assemblies with batt insulation and drywall. Common strategies to increase STC rating could include the doubling of studs or gypsum in a wall assembly, as well as the addition of a resilient channel to support the gypsum. Similarly, a range of STC ratings for wood frame floor or mass timber floor assemblies can be achieved depending on the needs of a space. The addition of a resilient channel along with a lightweight gypsum to the underside of the structural framing, or a concrete topping to create a composite assembly can help improve the sound transmission of floor assemblies. In addition, acoustical membranes and different floor finishes can be utilized to increase sound attenuation from impact noise.[7]

Absorption principles can be applied for floors, walls, and ceilings in areas such as libraries and study spaces, but can also be used in any space throughout the school to control sound transmission. Although wood alone is not sound absorptive, there are many engineered wood products available for acoustic absorption which utilize wood. Typically, these products use wood as a surface material or as a component (such as linear slats), with perforations and an additional membrane layered behind to absorb sound (Figure 9). In a performance theatre, acoustic design often considers wood because it conducts very well and can create the desired reflective properties but also can be manipulated and designed to ensure sound is diffused or evenly spread within a space (Figure 10). While other materials can achieve a similar acoustic performance as wood, the benefits of wood acoustic panels go beyond the pragmatics of sound attenuation and absorption because they are proven to promote feelings of comfort and wellness[8].

7 research.thinkwood.com/en/permalink/catalogue750

8 continuingeducation.bnpmedia.com/courses/think-wood/designing-modern-wood-schools/4/

2.5 Sustainability Performance

Operational Energy Efficiency

Wood-frame schools can be easily designed to meet or exceed the demanding energy-efficiency requirements, including the new BC Energy Step Code—and they can do so in a cost effective manner for school districts. Wood frame buildings are inherently more efficient than steel-frame, concrete or masonry construction because of the low conductivity of wood structural elements, including studs, columns, beams and floors. But while wood is not as conductive, other factors such as the use of high-efficiency doors, windows, and proper detailling have a greater impact on a building envelope's energy efficiency. Constructing a thermally insulated and airtight building envelope contributes to the reduction of total required energy consumption in a building and wood framing offers a thermal benefit because wood does not require separation between the structure and exterior envelope that concrete and steel structures do. In these building systems, continuous insulation is required to prevent the transfer of heat. This can often be avoided in wood frame envelopes. Increasing the thickness of the walls in a wood-framed building envelope is one way to add insulation value in an economic way. With wider wall cavities, more batt insulation can be installed and thus increase the R-value of the exterior envelope.

For heavy timber construction, prefabricated systems such as cross-laminated timber panels can be insulated and can also achieve some of the thermal mass characteristics which are normally associated with concrete or masonry buildings. This thermal mass of the building enclosure elements, and interior floors and walls store solar energy during the day and release it at night which reduces the peak utility loads. Wood sheathing products such as plywood and oriented strand board (OSB) can also be an asset to designers looking to implement continuous, solid exterior barriers to prevent air leakage.

Embodied Carbon

Trees and forest products are crucial in addressing climate change and reducing greenhouse gases. Trees absorb carbon dioxide as they grow, filtering the air, releasing oxygen, and storing carbon in their wood, leaves and needles.[9] Because our forests can store and sequester carbon, the responsible use of wood can play an important role in managing climate change. When wood is used to create building products, carbon which was stored by the trees during their lifetime, continues to be stored in those products. In British Columbia, wood products can sometimes be manufactured and used within the same region, greatly reducing the need for shipping of materials and hence reducing embodied energy.

Analysis of wood structures when compared to steel or concrete have demonstrated 50–90% reduction in embodied energy and GHG emissions.[10] As an example, Westview Elementary School in Powell River has the following carbon benefits because its primary structure is wood rather than concrete or steel (Figure 11).

In order to assess carbon impacts in a holistic manner, a Life Cycle Assessment (LCA) can be used as a tool which is internationally recognized. Life Cycle Assessment (LCA) is a performance-based evaluation on the environmental impact of building materials at all stages of the product's life. It includes the extraction of the material, manufacturing, distribution, construction, maintenance, and disposal. Wood performs better than concrete and steel in all measures including embodied energy, air and water pollution, carbon footprint and global warming potential.

Sustainable Wood Supply

Sustainable forest management is ultimately the biggest factor when considering wood as a sustainable building material. At the end of 2016, British Columbia had 52 million hectares (128.5 million acres) of certified lands.[11] Third-party forest certification is a voluntary process that began in the 1990s in response to concerns about logging practices and forest conversion. Two independent non-profit global programs endorse forest certification programs developed nationally and regionally in countries around the world: Programme for the Endorsement of Forest Certification (PEFC) and Forest Stewardship Council (FSC). In Canada and British Columbia, there are three third-party certification systems for sustainable forest management: Canadian Standards Association's Sustainable Forest Management Standards (CSA), FSC and Sustainable Forestry Initiative (SFI). The CSA and SFI standards are recognized by PEFC.

Volume of wood products used	217 cubic meteres of wood products
US and Canadian forests grow this much wood in	1 minute
Carbon stored in the wood	194 metric tons of CO2
Avoided greenhouse gas emissions	412 metric tons of CO2
Total potential carbon benefits	605 metric tons of CO2
Number of cars taken off the road for a year	128 cars
Number of homes that can be operated	64 homes

Figure 11. Estimated Carbon Impact for Westview Elementary School in Powell River, School District 47

SOURCE: Canadian Wood Council (2017). Carbon Summary for Westview Elementary

9 naturallywood.com/sustainable-forests/carbon-climate

10 Tall Wood Buildings (Michael Green, Jim Taggart 2017).

11 naturallywood.com/sustainable-forests/certified-forests

2.6 Social and Cultural Performance

Health and Wellness

The physiological and psychological benefits related to the use of wood in indoor environments have been identified through various studies. Exposure to wood in buildings can improve an occupant's emotional state, and reduce blood pressure, heart rate, and stress levels. Studies have also shown that wood use in interior spaces can increase levels of well-being, productivity, and creativity.

A 2014 study conducted at the University of British Columbia refitted similar offices with different materials and measured health aspects of occupants. As visual wood surfaces in a room increased, it lowered sympathetic nervous system activation, which is responsible for physiological stress response.[12] A Japanese study of 700 schools over a three-year period found various benefits to wood use, including reduced flu outbreaks (compared to concrete facilities). Another Japanese study found that teachers and students in wood schools experienced less fatigue in environments with wood.[13] An Austrian study found significant benefits in classrooms with solid wood furnishings. Students of these classes had a lower heart rate during the day and showed significantly higher vagal tone which plays an important role in protecting the heart[14].

In addition to measurable physical benefits, anecdotal evidence of positive responses to wood had been brought to the attention of researchers. Using wood creates indirect associations to nature, providing positive physiological and psychological benefits. Human beings have a genetic connection to nature and the concept of biophilia is widely used to refer to this emotional connection.[15] As a result, an increasing number of health-care facilities are making use of natural daylight, views of nature, and exposed wood to create warm, natural environments that support their healing objectives. These same techniques are also being used in schools and offices to improve performance, productivity, and occupant well-being.[16]

12 wood100.ca/articles/wood-and-human-health.pdf

13 csengineermag.com/article/wood-framed-schools/

14 humanresearch.at/newwebcontent/?page_id=75&lang=en

15 schoolconstructionnews.com/2017/05/23/wood-schools-can-nourish-learning/

16 continuingeducation.bnpmedia.com/courses/think-wood/designing-modern-wood-schools/7/

Air Quality

Indoor air quality is an important consideration to address the health and wellbeing of students in schools. Good indoor air quality includes control of airborne pollutants, introduction and distribution of adequate outdoor air, and maintenance of acceptable temperature and relative humidity. Children suffer from higher rates of asthma, allergies, and are more susceptible to environmental toxins than adults.[17] Good indoor air quality creates an ideal environment for student learning, and staff and teacher performance.

Wood is a hypoallergenic material and is easy to clean to prevent buildup of dust, particulates, and other allergens. Wood products used in building interiors have greatly improved in recent years by reducing or eliminating the use of urea-formaldehyde glues. Urea-formaldehyde glues are used primarily in wood panel products, such as particle board, medium density fibreboard (MDF), and hardboard. There was a concern that these products can produce off-gases and release volatile organic compounds when left unsealed, negatively affecting indoor air quality. Wood-based panel products are now required to have reduced volatile organic compounds and are third-party certified. A study on the effects of wood on indoor air quality in hospitals, where indoor air quality is critical, concluded that adding wood-based panels did not have a measurable effect on the volatile organic compounds in the air.[18]

17 epa.gov/iaq-schools/why-indoor-air-quality-important-schools

18 Nyrud, Anders & Bringslimark, Tina & Englund, F. (2011). Wood use in a hospital environment: VOC emissions and air quality. European Journal of Wood and Wood Products. 70.10.1007/s00107-011-0578-3

Figure 12. Custom Wood Millwork in a Library Space—Whistler, British Columbia

SOURCE: naturally:wood

Impact on Learning

British Columbia's new curriculum for K-12 includes new key competencies and principles: Communication, Creative Thinking, Critical Thinking, Positive Personal & Cultural Identity, Personal Awareness & Responsibility, and Social Responsibility.[19] This shift includes a greater emphasis on diverse learners and inquiry-based learning and moves schools further away from traditional teaching paradigms. This is reflected in the fact that learning is recognized to take place everywhere, demanding more active and diverse teaching spaces.

Wood provides many benefits that can help support the new curriculum and meet student, teacher, and parent expectations for learning environments. The acoustic properties of wood help to mitigate the sound levels in these learning spaces, which have open floor plans and are much more active environments than the classrooms of the past. Wood positively impacts learning by providing many health and wellness benefits as discussed above. The emphasis on individual learning, such as the inclusion of students with special needs, requires an environment that is both calming and welcoming, and caters to the health and wellbeing of all occupants. The warmth of wood can enhance learning environments by creating an inviting space that is more encouraging of collaboration and creativity compared to steel or concrete spaces, which may create a more cold and institutional atmosphere. In addition, the use of wood encourages sustainable thinking and creates a tangible connection to the natural world.

19 curriculum.gov.British Columbia.ca/sites/curriculum.gov.British Columbia.ca/files/pdf/curriculum_intro.pdf

Figure 14. Kwakiutl Wagalus K-7 School, Port Hardy, British Columbia - Design Utilizing Heavy Timber Construction (Completed 2016)

SOURCE: Lubor Trubka Associates

Culture and Tradition

Another key change in the British Columbia curriculum includes a greater emphasis on Aboriginal perspectives and knowledge which also aligns with the national goals of truth and reconciliation. Increasing the success of students, especially Aboriginal students, requires the inclusion of Aboriginal languages, cultures, and histories in the curriculum. This can be further supported through the use of wood in schools, because the identity of British Columbia is rooted in its connection to Indigenous cultures in the region.

The use of wood provides direct links to the past building and cultural traditions of First Nations. For coastal First Nations, cedar in particular has been a key natural resource in the production of material goods. The tree also plays an integral role in the spiritual beliefs and ceremonial life of coastal First Nations.[20] Advancements in wood and wood products still retain a strong connection to architectural traditions for communities across British Columbia.

← **Figure 13. Carving of Welcome Figure - Kayachtn (Bottom) and Celebration at Unveiling at Ridgeway Elementary School in North Vancouver (Top)**

SOURCE: sd44.ca

20 sd72.bc.ca/school/robron/aboriginaleducation/abededucationalresources/Pages/default.aspx

Learning from Others

3.0 Learning from Others

Schools in Europe have been constructed using heavy timber, including CLT and glulam for many years. This has included the development of prefabricated and modular systems which have seen good results in terms of cost effectiveness, speed, and ease of construction. Prefabricated and modular wood schools, mainly utilizing CLT, have started to appear in North America as well. Other considerations that also are prevalent in examples in Europe are high performance and Passive House wood buildings. There is also strong precedence in California, Japan and New Zealand for wood frame schools in high seismic risk areas.

3.1 Construction: Prefabricated and Modular Schools

Prefabrication and modular construction can provide solutions that align with British Columbia's Ministry of Education objectives to initiate school construction projects that are cost-effective, efficiently built, quality assured, and with a measure of equity across school districts. Modular systems lend themselves well to phased construction and can be reconfigured for changing requirements. Modular construction can also be designed to allow for schools to expand in capacity when needed and can be relocated when those needs change. In addition, modular and prefabricated structures can provide both cost and schedule savings; the construction of modular systems requires little time on site and can be an additional benefit to projects in remote communities where there may be a shortage in labor and materials. The following examples from Washington State, Quebec, the UK, Frankfurt and Vienna highlight the benefits of modular and prefabricated wood schools in both urban and rural contexts.

Washington State is currently piloting a project to construct schools using prefabricated CLT. This state-funded project utilized opportunities at schools which required additional classroom space, and would have otherwise required another modular solution, to test the erection of prefabricated CLT modules. The intention is that the modules can be applied to different districts and schools easily and help create local jobs especially in rural communities while also improving the learning environments for students. By using exposed CLT interiors, students are surrounded by natural wood eliciting biophilic responses and some of the health, wellness, and learning benefits previously mentioned (Figure 15).

This project utilizes Pacific Northwest capabilities for innovative wood construction and prefabrication. Loadbearing exposed CLT walls are combined with removable interior partition walls to allow for flexibility and to promote co-teaching. The modular designs were found to reduce construction waste and provide significant time savings. In total, four modular classrooms are being built on five different sites[21] (Figure 16).

Figure 15. K-3 CLT Classrooms—Adams Elementary in Wapato Washington, US

SOURCE: grahambuilds.com/projects/k-3-clt-classrooms/

Figure 16. Installation of CLT Wall Panels at Grey Wolf Elementary in Sequim Washington, US

SOURCE: medium.com/wagovernor/new-timber-product-helps-schools-manage-crowding-class-size-c0464003fdd0

21 oregonclt.com/washington-states-raises-cross-laminated-timber-panels-fourth-k-12-school-site-part-innovative-pilot-project/

In Northern Quebec, the Long Point First Nation School chose to utilize a complete prefabricated CLT structure for ease of construction, speed, high quality of construction, and on budget delivery. In addition, CLT was a material of choice because it represented the community's interest in natural and native materials. The shortened assembly time was suitable to building in a northern climate.[22]

The UK currently has the most schools built in mass timber and educational buildings remain one of the most popular building types for CLT structural solutions. In addition to addressing goals for sustainability and optimizing learning environments, the use of CLT provides the added benefits for construction projects where schools need to remain safe and operational during construction with minimal disruptions. The use of prefabricated elements has successfully demonstrated a reduction in the overall time required on site, with less noise and dust created during construction. CLT continues to be used with support from councils and the Education Funding Agency.[23]

Frankfurt, Germany, has also chosen a modular architectural solution for a large urban school with a tight construction and design schedule. The school was constructed using three different types of modules (3m x 8m) which utilized glulam beams and plywood walls (Figure 17 and Figure 18). Modules can serve as individual spaces or be combined into larger ones. The modules were prefabricated to include insulation, electrical cables, plumbing and sanitary fixtures, acoustic panels, glazing, and heating units and were transported to site on a flatbed truck and assembled. The project met the tight schedule, cost 25% less than a traditional school, has the capacity to be disassembled and rebuilt elsewhere, and meets educational and aesthetic expectations.

Vienna, Austria, has similarly utilized modular CLT construction in the face of the need for many new primary schools due to rapid population growth. These schools had the capacity to be constructed in just seven months from the time of order.[24]

Figure 17. 80 m^2 Classrooms Constructed of Prefabricated Wood Modules, Frankfurt, Germany

SOURCE: architecturalrecord.com/articles/11406-european-school-frankfurt

Figure 18. Prefabricated Classroom Module Being Installed On Site, Frankfurt, Germany

SOURCE: architecturalrecord.com/articles/11406-european-school-frankfurt

22 douglascardinal.wordpress.com/2012/02/08/lpfn/

23 Waugh Thistleton Architects, 100 Projects UK CLT.

24 ihb.de/wood/news/Stora_Enso_CLT_construction_38422.html

3.2 Cost and Sustainability: High Performance Energy Efficient Schools

As discussed in Section 2.1, the BC Energy Step Code encourages more energy-efficient buildings that go beyond the requirements of the BC Building Code. Another measure of high energy performance is the Passive House standard. Passive House is becoming more common in Canada as a certification that will assure its performance benefits the users and the environment. Although the number of Passive House buildings in Canada is increasing, a significant majority are residential buildings and to date, there are no K-12 school buildings that are certified Passive House.

Milestones have been made recently in British Columbia with the Okanagan College Daycare marking the first Passive House child care centre in 2017 and the Wood Innovation Research Laboratory in Prince George is the first post-secondary facility in Canada to be certified Passive House and built entirely with wood frame and heavy timber construction. Cost is the major reason why no K-12 school buildings have achieved Passive House certification in British Columbia. However, as the building industry adapts to the BC Energy Step Code requirements and moves towards more sustainable practices, Passive House will gain more traction and will be more attainable.

Wood is often the material of choice for high performance buildings due to its inherent properties that provide thermal mass, water resistance, structural integrity, and desired finish qualities. The advantages of a choosing Passive House for a school is the relatively predictable number of students and their use in the building, since body heat can be a major contributor to internal heat gains. Longer and more frequent hot periods in the future are predicted and, overheating is expected to increase in buildings. Passive House mitigates internal temperature while achieving low energy consumption, quality assurance, and high thermal comfort.[25]

Figure 19. Wilkinson Primary School, UK, Wood Frame Passive House School

SOURCE: architype.co.uk/project/wilkinson-primary-school/

There are many examples of wood schools which have achieved Passive House certification worldwide, including many in Austria, Germany, and the United Kingdom. A notable example includes the Wilkinson School in Wolverhampton, UK. (Figure 19). This school provides a glimpse of what can be achieved with municipal support and an experienced integrated design team. The climate in Wolverhampton is comparable to areas in British Columbia with an average yearly temperature of 8.9 degrees Celsius and a lot of rainfall throughout the year. Two previous schools delivered by the same team were the first Passive House schools in the UK and were built within the standard school construction budget. The standard budget was cut by 10% for Wilkinson School thanks to lessons learned from the previous two schools, and the project was delivered within a shorter timeline. With studies carried out through post occupancy evaluations, Wilkinson School performed better than its high-performing predecessors in air quality and internal comfort.[26] An airtight envelope on Passive House projects is critical to achieve certification, and close work with the wood frame subcontractors throughout the project allowed for the requirements to be met with the use of wood.[27]

25 passivehouseplus.ie/magazine/new-build/building-a-better-passive-school

architectsjournal.co.uk/buildings/post-occupancy-evaluation-of-five-schools-by-architype/10004526.article

naturallywood.com/sites/default/files/documents/resources/building-green-with-wood-toolkit-passive-design-framing.pdf

architype.co.uk/project/oakmeadow-primary-school/

26 architectsjournal.co.uk/buildings/post-occupancy-evaluation-of-five-schools-by-architype/10004526.article

27 architype.co.uk/project/wilkinson-primary-school/

Figure 20. Yamaga Elementary School, Japan, Utilizing Innovative Wood Structural Frame

SOURCE: graphisoft.com/users/bim-case-studies/yamaga-elementary-school.html

3.3 Seismic Safety: Schools in High Seismic Risk Zones

Other areas of the world which face similar seismic risk to British Columbia include Japan, New Zealand, and California. In California, more than 40% of schools are of wood construction, because of the ability of wood buildings to perform well in seismic events. After the 1994 Northridge earthquake in southern California, an assessment was done to the damage on schools. The conclusion was that the wood school structures performed well on the whole. For example, the Cayucos Elementary School in Cayucos, California is entirely framed in wood and utilizes custom glulam trusses and i-joists, and walls made with glulam studs.[28]

In Japan, wooden structures accounted for 20% of buildings or gymnasiums at public kindergartens, elementary schools, junior high and high schools, and special schools newly built or renovated in 2012. Additionally, half of concrete buildings utilize wooden walls and floors. With advances in wood construction, the use of wood has increased in schools as they are able to resist earthquakes. The ministry provides subsidies for wood schools and plans to amend the building code to allow for three-storey wooden schools to be constructed.[29] Yamaga Elementary School in Japan was originally proposed as a concrete structure, but through a design competition, wood was selected as having superior qualities, strengths, and large spans (Figure 20). The structure uses locally sourced solid wood throughout.[30]

Figure 21. Wood structural frame at Cathedral Grammar School, New Zealand

SOURCE: architecturenow.co.nz/articles/carefully-crafted-cathedral-grammar-junior-school/

New Zealand, a country also prone to earthquakes, has an exceptional example of a timber school—the Cathedral Grammar School in Auckland (Figure 21). The school provides a lot of flexibility with non-loadbearing interior walls and carefully crafted timber frame. The structure uses Laminated Veneer Lumber (LVL), which provided quicker construction, aesthetic qualities, precision prefabrication, fire resistance, sustainable resource use, and created a lightweight building that requires less engineering of foundations.[31]

28 csengineermag.com/article/wood-framed-schools/

29 japantimes.co.jp/news/2014/02/05/national/wood-the-material-of-choice-at-schools/#.XEjwvlxKiUm

30 graphisoft.com/users/bim-case-studies/yamaga-elementary-school.html

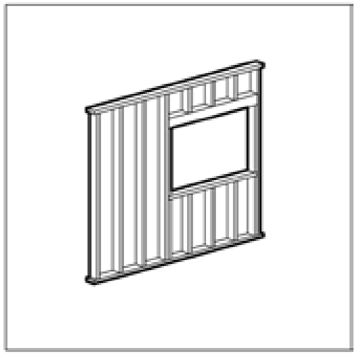
31 architecturenow.co.nz/articles/carefully-crafted-cathedral-grammar-junior-school/

Categories of Use

4.0 Categories of Use

There are several ways wood can be used in school buildings and often a combination of wood systems will be implemented to meet the needs of a project. The following applications describe the range of possibilities for wood use including both structural (light wood framing, heavy timber framing, and mass timber) and non-structural applications (exterior or interior finishings).

4.1 Structural Applications



Light Wood Framing

Also referred to as traditional wood frame, this method of construction uses dimensional lumber (typically 2x) to construct structural elements such as walls, trusses, built-up beams, posts, and headers. Repetitive structural members spaced not more than 600mm on centre are usually clad, sheathed, or braced on at least one side. Engineered lumber may also be used in light wood framing when dimensional lumber is not adequate in meeting the structural requirements.

Building code

Light wood framing is a combustible material and can be utilized in smaller schools which qualify to be combustible in the BCBC. However, it can still be utilized in larger buildings in combination with other structural systems such as concrete or steel. Light wood framing can be utilized in partitions of noncombustible buildings, provided they meet the requirements in Section 3.1.5.13 of the BCBC, which restrict fire compartment size, partition size, use, and total number of storeys.

Examples of use

Light wood framing can be the ideal choice for schools in more remote areas around British Columbia where many schools are small and the use of wood can also take advantage of readily available resources and labour. Because the construction methods for wood are less specialized, labour skills for light timber residential housing can be transferable to construction of schools.

One example of this construction method can be found in the remote community of Zeballos on the northwest coast of Vancouver Island (Figure 22). With a large portion of the region employed in the forestry industry, light timber framing was the structural system of choice for the replacement of the community's elementary/secondary school for a capacity of 70 students. Due to location and logistics of using heavy equipment on site, design decisions were based on the use of the most logical materials. Laminated veneer lumber (LVL) stud walls were used, continuous from sill to eaves, to support the engineered light gauge roof trusses. The lower portion of the walls are lined with plywood for a more durable finish whereas the upper portions are finished in drywall. The full height studs and prefabricated roof elements reduced the construction time required to complete the schools.

Some larger schools in the non-combustible categories (over 2,400 m^2) have also utilized light timber framing in combination with other structural systems. This was demonstrated in Samuel Brighouse Elementary in Richmond, British Columbia, where most of the building used light timber framing (Figure 23 and Figure 24). Because of the area limitations in the building code, the northern block of the building used a concrete main floor structure, in combination with a light wood frame second storey. Dimensional lumber from the interior of British Columbia affected by the mountain pine beetle was used in the prefabricated roof panels giving the school its signature expressive undulating roof.

Figure 22. Zeballos Elementary Secondary School (School District 84) Zeballos, British Columbia (under 2400m^2)

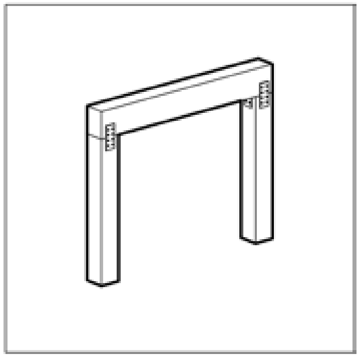
SOURCE: naturally:wood

Figure 23. Samuel Brighouse Secondary School (School District 38) Richmond, British Columbia—Undulating Roof Form (over 2400m^2)

SOURCE: naturally:wood

Figure 24. Samuel Brighouse Secondary School (School District 38) Richmond, British Columbia—Wood Roof Structure Exposed In Classrooms

SOURCE: naturally:wood



Heavy Timber

Definition

Heavy timber has a traditional and historic meaning often referring to large roughhewn timbers joined with all wood tenon-mortise and wood peg connections and other joinery techniques. Common examples use exposed steel connections.

Heavy Timber is a term used by building codes to denote minimum wood member dimensions that meet the relevant fire rating. Columns, beams, joists, and decking dimensions are provided and relate to code building types, sizes, and occupancy allowances. As far as the current building code is concerned, material choices vary, from glulams, PSLs, LVLs, and other engineered lumbers, to the typical Douglas-fir and other sawn lumber species to older or historic reclaimed timbers.

Building code

Heavy Timber is a term used by building codes to denote minimum wood member dimensions that meet the relevant fire rating, outlined in 3.1.4.7 of the BCBC. Although the term typically referred to solid-sawn timbers used in traditional construction featuring exposed connections, the term is used in the building code to include all wood products that meet the minimum dimensions. It is anticipated future building codes will reflect the more recent developments in mass timber products.

Examples of use

While the rise in what is classified as Heavy Timber construction has shifted to engineered mass timber products, traditional Heavy Timber construction is still used today as a testament to its trusted methods in construction and cultural significance.

One notable example can be found at Ripple Rock Elementary in Campbell River where there was a vision from the outset to represent the lumber and mill heritage of the city as well as the traditions of the local First Nations. This project was completed for School District 72 where local First Nations represent half of the student body (Figure 25).

Figure 25. Ripple Rock Elementary School (School District 72) Campbell River, British Columbia—Exposed Log Columns In Main Corridor

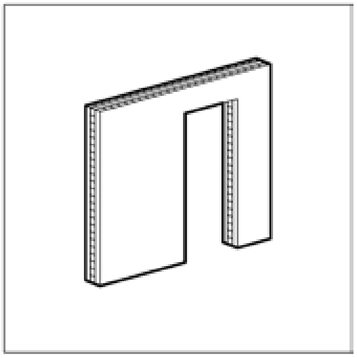
SOURCE: wood-works.ca/bc/wda/showcase-projects/ripple-rock-elementary-school/

Figure 26. Westview Elementary School (School District 47) Powell River, British Columbia – Post And Beam Construction With Glue Laminated Timber (GLT)

SOURCE: kmbr.com/projects/prek12-education/westview-elementary-school.html

The structure incorporates glulam columns, beams and struts with peeled and sanded exposed Douglas-fir log columns that create a strong, raw presence throughout the school. The design focused on sustainable solutions as well as the use of local wood products.

For Westview Elementary in School District 47, Powell River, post and beam construction—a traditional method of building with heavy timber—is used here with engineered mass timber products (Figure 26). Glulam columns/posts and glulam beams are sized to preform structurally and meet what is considered Heavy Timber and therefore can be left exposed as interior architectural finish.



Mass Timber

Definition

Mass timber typically consists of wood components (i.e., dimensional lumber, plywood, etc.) that are glued, nailed, or fastened together into larger panelized elements that are used for walls and decking, and on occasion wood beams. Mass timber typically provides greater fire resistance than light wood frame as there is less surface area for the wood to ignite. Common products include CLT, GLT, and NLT, with new innovations constantly emerging.

Building code

Structural Mass timber products are considered under the term "Heavy Timber construction" in the building code.

Mass timber is a general definition and can be used in buildings without being considered Heavy Timber in instances where the Fire Resistance Rating is not required.

Examples of use

Cordova Bay Elementary, in School District 63, Victoria, had all of its wall and roof panels constructed with mass timber when it went through a seismic upgrade (Figure 27). The school is the first composite NLT and CLT structure in Western Canada. CLT serves as shear walls, while NLT was chosen as an affordable alternative for the roof. The structure provides excellent stability and efficiency, while providing a cost-effective solution to create an aesthetically pleasing space.

In School District 70, Port Alberni Secondary School implemented the WoodWave which was first developed for the award-winning Richmond Olympic Oval (Figure 28). The structural panels were made from the lumber of mountain pine-beetle-affected forests. The staggered 2x4s of were arranged to optimize structural and acoustic performance.

The roof deck was assembled in one day and despite its perceived complexity and delightful aesthetic, it also proved to be an efficient and cost-effective alternative to a conventional open web steel joists and steel roof decking.

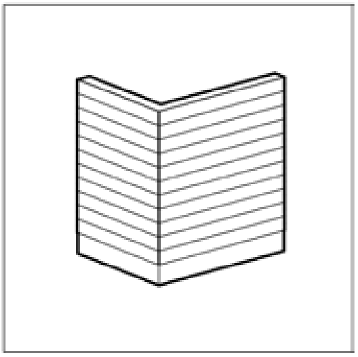
Figure 27. Cordova Bay Elementary School (School District 63) Victoria, British Columbia—Exposed CLT Walls and NLT Roofs

SOURCE: structurecraft.com/projects/cordova-bay-elementary-school

Figure 28. Port Alberni Secondary School (School District 70) Port Alberni, British Columbia—WoodWave Structural Panel System Used to Meet Structural, Architectural, Acoustic, and Sustainability Objectives

SOURCE: structurecraft.com/projects/cordova-bay-elementary-school

4.2 Non-structural Applications



Exterior Use

Definition

Wood has been used as an exterior building material for centuries. Cedar planks and shingles are common in residential projects for cladding. Douglas-fir, among others, can also be used without treatment as cladding. Other species including spruce, fir, and pine are generally treated either with chemicals such as boron, or more recently, preserved through thermal modification which improves the lifespan, strength, durability, and stability of the wood.

Building code

Combustible cladding is permitted to be used on exterior non-load bearing walls in a noncombustible building provided that the building is not more than 3 storeys, is sprinklered throughout, the interior surfaces of the wall assembly are adequately protected, and that the assembly satisfies the criteria when subjected to testing. The cladding must meet the requirements for limiting distance set out in the building code. It must also meet standards for flame-spread distance and heat flux measurement defined in the building code. Wood can also be used for soffits and canopies; canopies and soffits more than 1.2 m (4') require sprinklers.

Examples of use

The Crawford Bay Elementary School in Kootenay Lake uses wood extensively throughout the building (Figure 29). In addition to using wood structurally and on the interiors, the project incorporates wood throughout the exterior through cladding, soffits, and canopies. The project utilized locally-produced wood products and labour, providing many benefits including a reduced energy footprint and creation of local employment for lumber industry and carpenters. The school is carefully detailed to accommodate the extensive use of wood on the exterior, including the incorporation of substantial roof overhangs to protect exterior wood components from weather. Exterior sprinklers are used to allow for the large wood soffits on the exterior.

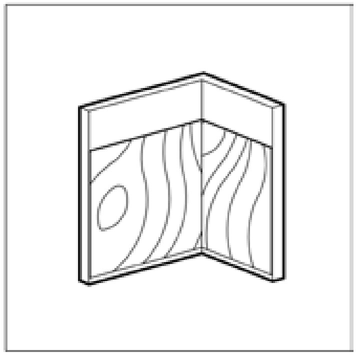
Figure 29. Crawford Bay Elementary School (School District 9) Crawford Bay, British Columbia—Exterior Wood Cladding and Soffits

SOURCE: kmbr.com/practice/crawford-bay-elementary-secondary.html

Figure 30. Lord Kitchener Elementary School (School District 39) Vancouver, British Columbia—Exterior Wood Cladding and Soffits

SOURCE: Michael Sherman Photo naturally:wood

In Vancouver, School District 39, a seismic mitigation project that included a heritage restoration and new addition to Lord Kitchener Elementary School involved a strong presence of wood throughout the design. (Figure 30) The original 900m^2 wood-frame structure dating back to 1914 was retained and seismically upgraded, while the main brick building of the school constructed in 1924 was demolished and replaced by a 4000m^2 concrete and steel structure. The restoration of the heritage building included new wood siding and replica wood windows to retain the aesthetic of the original building. This is contrasted by the exterior use of clear cedar siding on the new construction in combination with the glulam posts that support the exterior porch and canopy areas, which include wood soffits comprised of tongue and groove Douglas-fir boards. This example demonstrates how a new non-combustible construction project takes advantages of the visual and tactile qualities of wood to create a modern learning environment that responds to its history and regional context.



Interior Use

Definition

Wood is generally used in building interiors as a finish surface for various applications and purposes including walls, ceilings, floors and everything in between. It is often chosen for its unmatched aesthetic quality that brings natural elements into our interior environments. Interior wood products commonly come in the form of solid wood or wood veneer. Wood veneers are thin layers (usually less than 3mm) adhered onto core panels which are typically plywood, particle board, or MDF (medium-density fiberboard) and can come in a range of colors and tones. While interior wood is often thought of as a material applied onto a structure or assembly, wood structural elements can also be left exposed as a finish material.

Building code

As long as wood products follow the standards in the building codes, they can be used in any construction type for interiors. Exposed wood structural elements on the interior, such as an exposed glulam column, are considered a wood finish in the BCBC. These structural elements can be either Heavy Timber or mass timber products as discussed in the previous sections.

In noncombustible buildings, combustible (wood) wall and ceiling finishes must meet the maximum thickness, area, and flame spread rating (FSR) defined in the BCBC, specifically, Article 3.1.5.10 of the BCBC, “Combustible Interior Finishes” and Subsection 3.1.13, “Flame Spread Rating and Smoke Developed Classification.” Interior wall finishes may be used provided the thickness of the finish (including wood substrate) does not exceed 25 mm, and the FSR for the finish does not exceed 150 (generally wood is accepted as having a FSR of less than 150). For ceilings, the FSR must not exceed 25 or the wood must be Fire Retardant Treated (FRT). An area of no more than 10% of the fire compartment ceiling area can have a flame spread rating of up to 150. FRT wood must meet the test criteria in Article 3.1.4.4 and provide flame spread rating of not more than 25. Additional restrictions exist in small areas, unsprinklered buildings, exit enclosures, exit lobbies, covered vehicular passageways, and vertical service spaces, as well as tall buildings which contain Group B major occupancies.

Examples of use

The use of wood as interior cladding is fairly common in schools in British Columbia. While there are many examples throughout the province for use of wood in interiors, some particular ones stand out for their creative applications that take advantage of wood’s properties over other materials.

At the Southern Okanagan Secondary School in Oliver, British Columbia, wood plays an important role in defining the character of the project (Figure 31 and Figure 32). The project uses birch plywood paneling throughout the high-impact spaces as a durable and pleasing finish. This panel is also adopted in the theatre where it serves both as a wearing surface and an acoustic finish.

At L’Ecole au Coeur de L’ile in Comox, British Columbia, wood is showcased throughout to create a sense of community and place (Figure 33). In this case, often structural elements also serve to provide finishes. In the library, intimate gathering spaces are created with the use of mass timber panels and left exposed to create welcoming collaborative spaces.

Figure 31. Southern Okanagan Secondary School (School District 53) Oliver, British Columbia—Science Labs Use Birch Plywood In High-Impact Spaces

SOURCE: Ed White Photographic

Figure 32. Southern Okanagan Secondary School Venebles Theatre (School District 53) Oliver, British Columbia—Wood Panels Used Throughout Performance Theatre for Acoustic Finish

SOURCE: Ed White Photographic

Figure 33. L'Ecole au Coeur de L'ile (School District 93) Comox, British Columbia—Mass Timber Used to Create Warm and Intimate Learning Spaces

SOURCE: Mcfarland Marceau Architects

Conclusion

5.0 Conclusion

Designing today's school buildings demand economically and environmentally sustainable solutions that can simultaneously create safe and inspiring learning environments for educating our youth. This report considers the varying capacities in which wood can meet or exceed those demands as a building material for structural and non-structural applications. Important factors related to the use of wood in the context of school buildings in British Columbia have been identified and expanded upon to provide an overview of the opportunities and challenges. Information provided on life and fire safety; matters of construction; cost considerations; material performance; sustainability performance; social and cultural impact; demonstrate the versatility of wood as a building material. Beyond the individual buildings, the use of wood can also further support the province's initiatives on climate and economic development.

While wood has been historically used as a trusted building material, recent innovations in the building industry have created a wider range of possibilities for design and construction. The application of wood has also modernized to meet our expectations for safety, performance, as well as the health and wellbeing of building occupants. As the use of wood becomes widespread, efficiencies in production and construction methods will continue to be improved upon, and products and technologies will continue to be developed to address our needs. This will serve to augment the economic, social, sustainability, and cultural impacts gained from wood use and open new possibilities to improve our relationship to our natural and built environment.

Appendix A

Wood Use Matrix

Wood Use Matrix for Kindergarten to Grade 12 Schools in British Columbia				
Building Elements		Under 2,400 m^2	Up to 2 storeys over 2,400 m^2	Up to 6 storeys over 2,400 m^2
Primary Structural System	Columns, Beams & Braces	1	2	3
	Floor Structure	1	2	3
	Exterior Walls	1	2	3
	Foundation (iv)	3	3	3
	Shear Walls	1	2	3
	Bearing Walls	1	2	3
	Fire Walls	4	4	4
	Roof Structure (inc. columns and braces)	1	1	1
	Stairway & Elevator Shafts	1	2	3
Secondary Structure	Convenience Stairs	2	2	2
	Entrances & Canopies	1	2	2
	Fire Separations	1	2	2
	Enclosures for Mechanical Equipment	1	2	2
Architectural	Partitions (interior)	1	1	1
	Exterior Curtain Walls	1	3	3
	Ceilings (ii)	1	1	1
	Exterior Cladding	1	3	3
	Parapets (excluding Parapets of Firewalls)	1	1	1
	Ceiling Bulkheads	1	1	1
	Flooring	1	1	1
	Doors	1	1	1
	Windows	1	1	1
	Skylights	1	1	1
	Trim, Paneling & Features	1	1	1
	Millwork	1	1	1
	Wall and Corner Guards	1	1	1
	Other Architectural Woodwork	1	1	1
	Hard Landscaping & Structures	1	1	1
	Perimeter Fencing	1	1	1

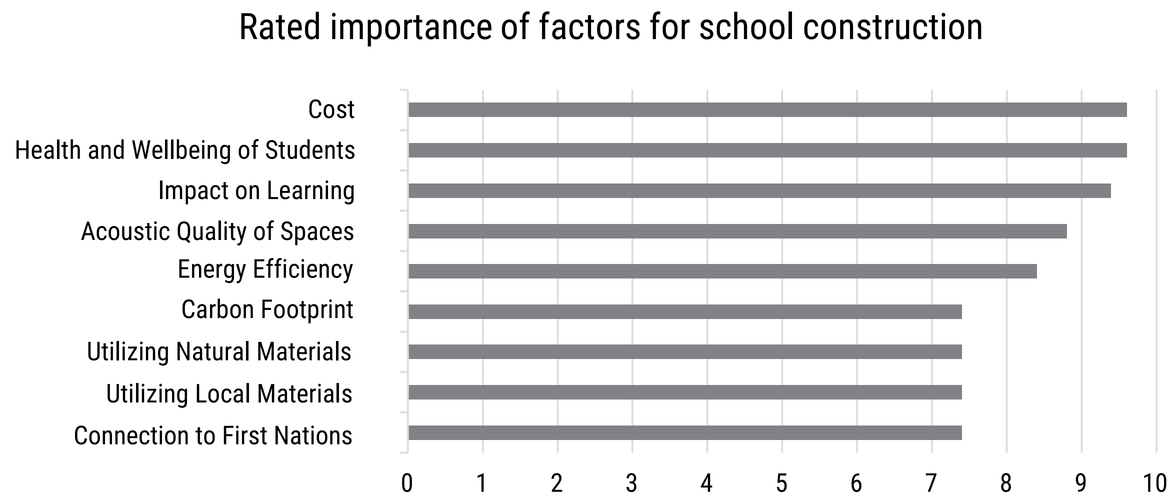
This tool summarizes the current best practices in the use of wood building materials and systems, using the simplified building categories outlined in the main report. This Matrix is based on the BC Building Code 2018; school buildings fall under the Major Occupancy Classification Group A Division. The matrix is a guideline that uses a scale from 1 to 4 which indicates where:

1. **An Acceptable Solution with wood is permitted;**
2. **An Alternate Solution with wood is relatively easy to implement;**
3. **An Alternate Solution with wood will require advanced analysis;**
4. **An Alternate Solution with wood will require extensive research**

Appendix B

Survey Summary

Summary of Wood Use in Bristish Columbia Schools Survey



Important Factors for School Construction

According to the survey of eight school district respondents, the following factors for school construction ranked in order of importance are:

1. Cost, Health and Wellbeing of Students, Impact on Learning (Average 10/10)
2. Acoustic Quality of Spaces, Impact on Learning (9/10)
3. Energy Efficiency (Average 8/10)
4. Utilizing Natural Materials, Utilizing Local Materials, Carbon Footprint, Connection to First Nations (Average 7/10)

Cost and Health & Wellbeing of Students were determined as the most important factors for school construction with the highest total number.

Primary Structural System of Capital Projects

- Of all capital projects completed since 2009, concrete was most often selected as the material of choice.
- When wood was selected as the material of choice, ease of construction and local trade knowledge were contributing factors that were not found to be true of other materials.
- Speed of construction, cost, contractor expertise, and site or environmental conditions were factors that contributed to both wood being chosen and not being chosen.
- Design team expertise was a factor when a material other than wood was selected. A comment was added that the contractor that performed a design-build ultimately determined the material and cost.
- Durability and Maintenance were additional factors for why wood was not chosen.
- An additional factor not specified in the survey included code challenges for a non-combustible building.

Advantages and Disadvantages for Wood Use

All respondents have indicated that wood is currently being used in building interiors within their district. When considering the main advantages for wood use in school interiors, durability, aesthetic, and acoustic qualities were mentioned, as well as its ability to create a "warm" environment. One of the main disadvantages for selecting wood that was mentioned by most respondents is the premium cost.

One third of respondents indicated that wood was being used for exterior applications and cited aesthetic qualities as well as cost as advantages. The disadvantages for wood in exterior applications included concerns about long-term durability and maintenance.