PERSPECTIVES

MASS TIMBER FIRE RESISTANCE:
Sustainability, Code Compliance, and Fire Safety in Tall Buildings

Our perspectives feature the viewpoints of our subject matter experts on current topics and emerging trends.

What Is Mass Timber?

Mass timber is gaining popularity in multi-storey construction projects across both Canada and the United States. The benefits of mass timber in terms of efficient construction and reduced staffing requirements for erection are well established; however, current regulatory limitations remain, often based on outdated assumptions regarding fire safety.

In this paper, experts at the forefront of mass timber regulation in Canada discuss the benefits of these types of projects and advocate for additional changes to regulations governing them.

Benefits of Mass Timber Construction in Multi-Storey Projects

The use of mass timber in building construction offers numerous benefits in various aspects. Some of these benefits are often more apparent and significant when compared to conventional construction materials such as non-combustible concrete and heavy steel. Key benefits include a lower environmental impact, practicality in terms of construction time and quality, as well as human benefits for end-users.

Fire engineering experts at J.S. Held have a long history of working on construction projects featuring wood designs. Over the last decade, these experts have been involved in large-scale fire testing, code development for larger mass timber buildings, and pioneering demonstration projects in Canada, such as:

» Brock Commons at the University of British Columbia in Vancouver, British Columbia (Construction beginning in 2015).

» L'Origine in Quebec City, Quebec (Construction beginning in 2016).

These projects paved the way for fire engineering in the current era of tall mass timber buildings in Canada.

Figure 1 - A modern mass timber structure (Source: Naturally Wood).

Environmental Benefits: Embodied Carbon and Carbon Sequestration

As the industry moves toward more sustainable and lower embodied carbon designs, mass timber is becoming an increasingly sought-after option that reduces environmental impacts associated with construction material choices.

The most prominent environmental benefit of mass timber is its drastically lower embodied carbon footprint. Embodied carbon refers to the amount of emissions produced during the life cycle of the material from extraction to processing to installation. Low embodied carbon is considered a green approach, reducing the environmental footprint. Unlike steel and concrete, which require energy-intensive processes that emit large volumes of carbon dioxide, mass timber is made from wood—a renewable resource that sequesters carbon. Trees absorb atmospheric CO_2 during growth and store it in their biomass. When used in construction, this carbon remains locked in the building's structure, effectively turning buildings into carbon sinks. Studies show that mass timber buildings can achieve a significant reduction in embodied carbon compared to conventional steel or concrete construction.

Additionally, the manufacturing process for engineered wood products, such as cross-laminated timber (CLT), glulam, and nail-laminated timber, typically involves less energy-intensive processes compared to steel or concrete.

Moreover, mass timber buildings usually generate less construction waste and require fewer site deliveries due to their prefabricated nature. This reduces the environmental impact associated with transport emissions, construction debris, and on-site pollution. The lighter weight of timber structures also translates into potentially more efficient foundation design, which further reduces material use and the associated carbon footprint, particularly in areas of high seismic forces, such as the West Coast.

Additionally, the use of mass timber supports a circular material economy, which is becoming an increasingly important consideration in building design. Compared to concrete and steel construction, the possibility of reusing and repurposing wood materials in mass timber buildings is significantly greater, promoting resource-resilient design for buildings.

Construction Benefits: Efficiency and Engineered Wood Quality

Mass timber construction also offers advantages in terms of construction schedule, design efficiency, and build quality.

One of the most significant benefits is accelerated construction timelines. Mass timber components—such as cross-laminated timber (CLT) panels and glulam beams—are prefabricated off-site with high precision and delivered ready for rapid on-site assembly. This allows for a faster erection process, often significantly quicker than comparable steel or concrete buildings. For developers, this translates into shorter project durations, earlier occupancy, and reduced financing and labor costs. As mass timber gains momentum, with increasing volumes of construction, supporting a more efficient and streamlined process, construction cost savings are expected to become more significant in the future.

Figure 2 - CLT mass timber floor panel installation during construction.

From a construction design perspective, mass timber supports integrated and streamlined planning. Because the system relies heavily on prefabrication, architects, engineers, and builders must coordinate early, leading to more efficient design detailing, fewer clashes during construction, and fewer site-specific complications compared to a build-on-site approach. This early coordination enhances design accuracy and reduces costly change orders during the construction process.

In terms of quality, factory-controlled manufacturing of timber components ensures tight tolerances, consistent finishes, and fewer on-site errors. Unlike cast-in-place concrete, which is subject to weather delays and variable curing conditions, mass timber components arrive fully cured and quality-assured with dimensional tolerances of 2mm to 4mm over a 40ft panel. The lighter weight of timber also reduces the demand on foundations, allowing for cleaner, quieter worksites with less disruption. In areas with high seismic forces, the potential for lighter floor plates can significantly reduce lateral design forces and, in turn, reduce foundation costs.

Biophilic Benefits & Occupant Well-Being

The biophilic advantages of mass timber materials for building construction have been studied, revealing that they enhance the health, well-being, and overall experience of building occupants.

Biophilic design is the integration of natural elements into the built environment to foster a connection between people and nature. Exposed mass timber interiors—such as visible cross-laminated timber (CLT) panels, glulam beams, and wood ceilings—create warm, natural environments that evoke this connection. Research suggests that wood-rich environments can have a positive impact on health metrics, including stress levels and cognitive performance.

Figure 3 - Use of exposed mass timber interior of an educational occupancy.

Economics of Mass Timber Construction

Although current projects tend to experience slightly higher costs than traditional construction methods, in both upfront materials and construction costs, it is our expectation that as design teams', contractors', and subcontractors' experience increases and mass timber construction volume increases, cost will diminish, and this form of construction will become economically competitive compared to concrete and heavy steel construction. Since projects such as Brock Commons and L'Origine, we have seen the economics for mass timber building continue to improve, and mass timber has become an increasingly popular choice.

Mass Timber Fire Resistance Rating and Code Requirements for Mass Timber Construction

Engineered Wood Construction and Types of Mass Timber

The IBC (2024 defines "mass timber" as structural elements of Type IV construction made primarily of solid, built-up, panelized, or engineered wood products that meet minimum cross-section dimensions specified for heavy timber. Common products include:

- Cross-laminated timber (CLT).
- Nail-laminated timber (NLT).
- Dowel-laminated timber (DLT).
- Glued-laminated timber (Glulam).
- Structural composite lumber (SCL).

The NBC (2020) defines "mass timber construction" differently than the IBC: the correct designation in Canada is "encapsulated mass timber construction," or "EMTC." It is a third type of construction (the others being "combustible" and "non-combustible" construction) in which a degree of fire safety is achieved by using encapsulated mass timber elements with an encapsulation rating and minimum dimensions for structural members and other building assemblies.

Minimum Dimensions for Mass Timber

Type IV construction, as defined in the IBC, requires that the mass timber dimensions be at least those of heavy timber:

- Columns (for floors)—Minimum 8in x 8in (nominal) for solid sawn, or equivalent net sizes for glulam and SCL.
- Floor framing—Minimum 6in x 10in for solid sawn or equivalent net sizes for glulam and SCL
- Roof framing—Minimum 4in x 6in for solid sawn or equivalent net sizes for glulam and SCL.

The NBC minimum sizes for EMTC sections vary by orientation and fire exposure:

- Horizontal elements/decks (floors, roofs)—At least 96 mm.
- Beams and columns—192 mm x 192 mm (for two- or three-sided exposure).
- Beams and columns—224 mm x 224 mm (for four-sided exposure).
- Walls (for two-sided exposure)—192 mm.

Mass Timber Fire Resistance and Fire Safety in Commercial Buildings

The IBC and the NBC have some differences regarding the fire resistance rating (FRR) and the methods for attaining it.

The IBC has three classifications for mass timber, namely Construction Type IV-A, IV-B, and IV-C. The FRR required is three hours, two hours, and one hour, respectively, for the primary structural frame. Fire resistance can be achieved through:

- Mass timber's inherent charring capacity
- Non-combustible protection (e.g., Type X gypsum board).
- A combination of the above.

The NBC has only one type of mass timber classification (EMTC). The EMTC elements must achieve a minimum of two hours of fire resistance, and the FRR classification is achieved in a manner similar to that of the IBC. However, the NBC requires that the encapsulation rating be determined by ULC S146 testing with a minimal rating of 50 minutes.

Another difference between the two codes is the requirement for an exposed wood surface.

The IBC allows full exposure for Type IV-C (except in some areas such as exits), partial exposure for Type IV-B, and full protection for Type IV-A. The NBC allows for EMTC construction of partial exposure within the building (interior surfaces), except in certain areas, such as exits.

Occupancy Types and Height Limits

The IBC allows up to 18, 12, and 9 storeys, respectively, for Type IV-A, IV-B, and IV-C. Moreover, several occupancy types are permitted, including commercial, business, residential, industrial, and boarding care.

The NBC is more restrictive; EMTC buildings are limited to 12 storeys, and only business or residential occupancies are allowed, with some exceptions (such as commercial and gathering occupancies) at the lowest storeys only. However, some provinces, such as British Columbia, Ontario, and Quebec, have significantly increased the allowable exposure time and building areas. Proposals are being reviewed on both sides of the Canada/US border for building heights of up to 24 storeys and increased use of exposed timber.

Types of Mass Timber and Engineered Wood Construction Options

Mass timber refers to large, engineered wood components used for structural framing, offering an alternative to typical, non-combustible materials such as steel and concrete. Mass timber is gaining popularity for its sustainability, speed of construction, and aesthetic appeal.

To reiterate, common mass timber products include cross-laminated timber (CLT), glue-laminated timber (Glulam), nail-laminated timber (NLT), and dowel-laminated timber (DLT). Each type has unique characteristics, benefits, and limitations.

Cross-Laminated Timber (CLT)

Description

CLT panels consist of multiple layers of lumber stacked crosswise (90°) and glued together, creating strong, dimensionally stable panels for floors, walls, and roofs. They have three, five, or seven plies, which increase their strength and fire resistance as they become thicker.

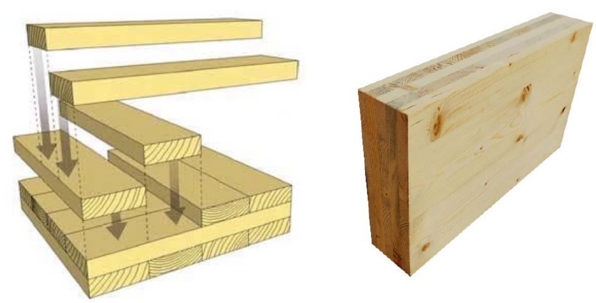

Figure 4 - Stacking configuration for cross-laminated timber (CLT) panels (Source: Le Conseil canadien du bois, juin 2018).

Benefits

- High strength and stiffness; suitable for multi-storey buildings.
- Two-way spanning capability.
- Prefabricated panels reduce on-site labor and construction time.
- Excellent fire resistance and thermal performance.

Limitations

- Requires specialized manufacturing and transport.
- Higher upfront cost compared to light-frame wood and steel frames.
- Limited flexibility for on-site modifications.

Glue-Laminated Timber (Glulam)

Description

Glulam consists of layers of lumber bonded with durable adhesives, typically used for decks, beams, columns, and curved elements.

Figure 5 - Glue-laminated timber, or Glulam (Le Conseil canadien du bois, juin 2018).

Benefits

» High load-bearing capacity; ideal for long spans.
» Can be shaped into curves or tapers for architectural flexibility.
» Strong and lightweight compared to steel.

Limitations

» Requires a controlled manufacturing environment.
» Vulnerable to moisture if not properly protected.
» Higher cost than traditional sawn timber.

Nail-Laminated Timber (NLT)

Description

NLT is made by nailing dimensional lumber together on edge, forming panels commonly used for floors and roofs.

Figure 6 - Structure/assembly style of nail-laminated timber, or "NLT" (Le Conseil canadien du bois, juin 2018).

Benefits

» Simple fabrication; no need for specialized facilities.
» Cost-effective and uses readily available materials.
» Provides a rustic aesthetic.

Limitations

» Limited structural performance compared to CLT.
» Requires additional layers for acoustic and fire protection.
» Labor-intensive assembly.

Dowel-Laminated Timber (DLT)

Description

DLT is similar to NLT but uses hardwood dowels instead of nails or glue, creating an all-wood product without adhesives or metal fasteners.

Figure 7 - Dowel-laminated timber (DLT) (Source: https://natural-resources.canada.ca/forest-forestry/forest-industry-trade/dowel-laminated-timber).

Benefits

» Sustainable and chemical-free.
» Good dimensional stability.
» Prefabrication is possible for faster installation.

Limitations

» Less common in North America as of the publication of this article; limited supply chain.
» Lower market familiarity may increase design complexity.

Comparison of Modern Fire and Safety Codes: Mass Timber Structures vs. Traditional Non-combustible Construction

In the context of building code, building fire safety concerns with respect to construction material type, i.e., combustible versus non-combustible, are primarily considered in terms of degrees of combustibility, fire resistance rating, flame spread rating, impact on compartment tenability, occupant safety, emergency responder safety, and firefighting capabilities. Code provisions are designed and developed to address these concerns, establishing a safety level deemed acceptable. The level of safety can be achieved, evaluated, and demonstrated based on the level of performance offered by a design. For the use of mass timber, which is considered a combustible material (compared to steel and concrete), building codes have provisions to address these key areas of fire safety measures.

Fire Performance and Structural Behavior

It is essential to acknowledge that all materials have their advantages and disadvantages. Mass timber is combustible, and while it contributes to the fire load, large-scale room fire tests have demonstrated its ability to withstand fire durations of four hours or more, during which the fire has significantly decayed. Mass timber charring is highly predictable, and mass timber does not expand with heat. While concrete and steel are non-combustible, concrete spalling can be explosive and lead to unpredictable loss of strength. Steel structures can also expand significantly, placing significant forces on members and connections.

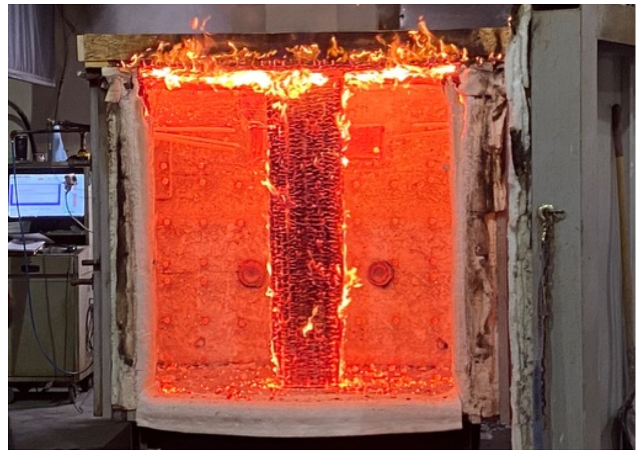

Figure 8 - Fire testing of the column supporting a CLT panel.

Figure 9 - Large-scale compartment fire test of CLT construction.

Mass Timber Fire Resistance Rating and Code Compliance

In terms of fire resistance rating, the evaluation of mass timber is the same as non-combustible materials, whose performance is determined based on the fire test standard. Essentially, mass timber undergoes the same standard fire exposure conditions as non-combustible materials to obtain its fire resistance rating. In simple terms, a mass timber assembly that has been tested to have a two-hour fire resistance rating is deemed to have the same level of specific fire safety performance as a two-hour fire-rated concrete assembly, taking into account the combustibility of mass timber. It is important to note that while mass timber is not considered a non-combustible material, its intrinsic capabilities to retain its structural capacity, limit passage of flame, and limit heat transfer are demonstrated through standard fire tests for code compliance purposes.

Mass Timber Char Rate

In addition to standard fire testing, numerous studies have been conducted to develop methods for evaluating the fire resistance of mass timber members. One method is to consider the charred layer when exposed to fire. As mass timber chars in a fire, its structural capacity is maintained for a certain period as the charred layer gradually deepens.

Other fire safety concerns uniquely associated with mass timber, such as flame spread and firefighting, are addressed by building code provisions through similar approaches, including standard fire testing and design standards to ensure the minimum level of fire safety or performance is met.

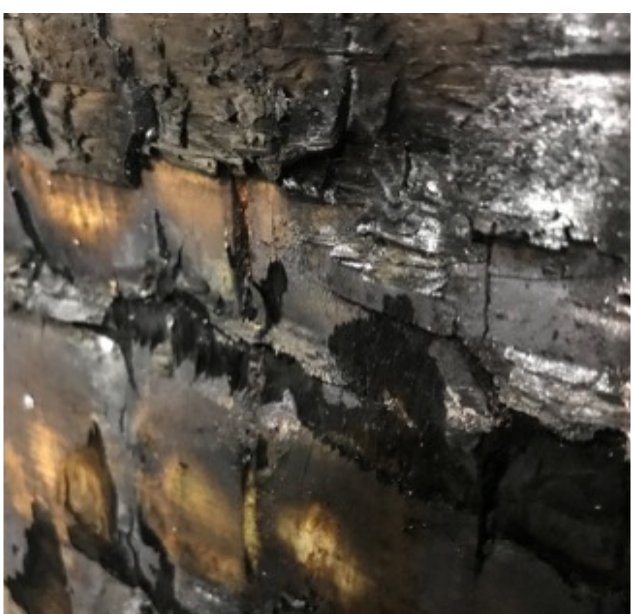

Figure 10 - Charred CLT surface (top) and uncharred layer of CLT panel (bottom) after fire exposure.

Fire Protection for Connections

Currently, the greatest challenge with these buildings is the fire protection of connections. The simplest form of protection for connections is to bury them in two layers of gypsum wallboard or four inches of timber; however, extreme care must be taken with any connections that are exposed, as this draws heat into the connection and can cause premature failure.

Figure 11 - Exposed connections of mass timber building.

In summary, while mass timber can behave differently from steel or concrete in a fire, building codes contain additional specific provisions to address mass timber-related fire safety concerns, especially for taller buildings, through a standardized approach to safeguard the target level of fire safety for buildings.

Future of Mass Timber Construction: Regulatory Updates and Canada-US Code Comparisons

On a national level within Canada, the permitted use of mass timber for building construction, namely EMTC, is expected to expand in terms of greater building sizes (both height and area), occupancy types, and flexibility as it concerns exposed mass timber surfaces. Currently, taller mass timber buildings are limited to 12 storeys for residential and office buildings (in the Canadian model code, i.e., National Building Code). The expansion of uses for EMTC is expected as provinces including British Columbia, Quebec, and Ontario have since introduced permissions for EMTC up to 18 storeys in a wider range of occupancy types. These expanded permissions by the three provinces are comparable to those permitted by the IBC (2021 Edition) in the US. GHL led a technical review of relevant mass timber provisions in the IBC for application in the provincial building code from a fire standpoint. It is noted that the mass timber provisions of the current 2024 edition are largely similar to those of the 2021 edition.

Further developments are expected to be introduced in future code change cycles for both NBC and IBC to better address areas such as fire safety during the construction of taller mass timber buildings, standardized protection measures for mass timber connections, and other relevant issues. It is worth mentioning that while the provisions of NBC and IBC are expected to advance and allow more flexibility as the level of fire safety offered by mass timber is refined and established through research, it is possible to achieve fire safety through an "alternative solution" design approach that supports designs not envisioned by the code. Numerous large-scale mass timber projects across Canada have been designed with the assistance of code and fire engineering experts at J.S. Held, who have helped develop alternative solution approaches and unlock design potential for these projects. Critical design considerations, such as fully exposed mass timber surfaces (unencapsulated), increased height, expanded building area, and mass timber infill, are examples where alternative solutions can be proposed to the Authority Having Jurisdiction to allow unique designs that highlight the use of mass timber.

Figure 12 - The Hive in Vancouver, BC, Canada, is a 10-storey mass timber building.

Figure 13 - 10-storey mass timber Limberlost Place of George Brown College in Toronto, Ontario, Canada.

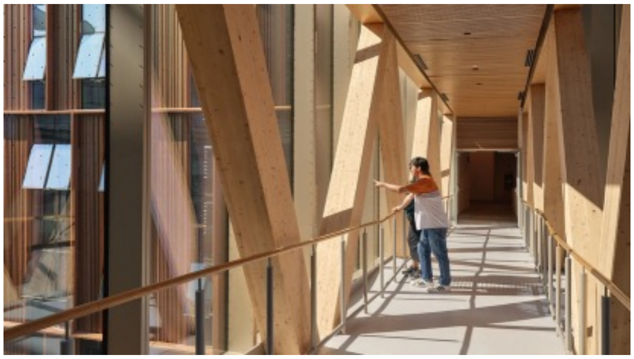

Figure 14 - Featured exposed mass timber interior in Limberlost Place.

Advancing Mass Timber Construction: Safety, Sustainability, and Expert Collaboration

Mass timber offers a promising path toward sustainable, reliable, and aesthetically sound construction, but its success depends on rigorous fire safety measures and continued research. Collaboration among experienced and knowledgeable architects, engineers, and building code experts will be essential to successful implementation. If you or your organization are considering using mass timber for your project, it is advisable to engage with experts in mass timber construction, design, and safety starting at an early stage. Having expert insights is key, particularly during the design stage, wherein there are opportunities to develop alternative approaches and solutions for unlocking the potential for innovative design.

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