JOINT PROFESSIONAL PRACTICE GUIDELINES

ENCAPSULATED MASS TIMBER CONSTRUCTION UP TO 12 STOREYS

VERSION 1.0 MARCH 30, 2021

ARCHITECTURAL INSTITUTE OF BRITISH COLUMBIA

ENGINEERS & GEOSCIENTISTS BRITISH COLUMBIA

ARCHITECTURAL INSTITUTE OF BRITISH COLUMBIA

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1. Foreword

These *Joint Professional Practice Guidelines – Encapsulated Mass Timber Construction Up to 12 Storeys* were jointly prepared by the Architectural Institute of British Columbia (AIBC) and Engineers and Geoscientists British Columbia.

The AIBC and Engineers and Geoscientists BC regulate and govern the professions of architecture, engineering, and geoscience under the *Architects Act* and the *Professional Governance Act*. The AIBC and Engineers and Geoscientists BC each have a regulatory mandate to protect the public interest, which is met in part by setting and maintaining appropriate academic, experience, and professional practice standards**.**

Engineering Professionals are required per Section 7.3.1 of the Bylaws - *Professional Governance Act* to have regard for applicable standards, policies, plans, and practices established by the government or by Engineers and Geoscientists BC, including professional practice guidelines. For Engineering Professionals, these professional practice guidelines clarify the expectations for professional practice, conduct, and competence when providing engineering services for EMTC buildings.

For Architects, these guidelines provide important information and identify issues to be considered when providing architectural services for EMTC buildings.

These guidelines deal with the performance of specific activities in a manner such that Architects and Engineering Professionals can meet their professional obligations under the *Architects Act* and the *Professional Governance Act*.

These guidelines were developed in response to new classifications of building size and construction relative to occupancy introduced in the 2018 *British Columbia Building Code* (*BCBC*), under Division B, Article 3.2.2.48EMTC. Group C, up to 12 storeys, Sprinklered, and Article 3.2.2.57EMTC. Group D, up to 12 storeys, Sprinklered. These new classifications were introduced in Revision 2 of the 2018 *BCBC* on December 12, 2019 and in Amendment 12715 of the 2019 Vancouver Building By-law (VBBL) on July 1, 2020. Additionally, provisions related to Encapsulated Mass Timber Construction (EMTC) were introduced in Revision 1 of the 2018 *British Columbia Fire Code* (*BCFC*) on December 12, 2019.

These guidelines were first published in 2021 to provide guidance on architectural and engineering considerations relating to these significant changes to the 2018 *BCBC*, the 2019 VBBL, and the 2018 *BCFC*.

For Engineering Professionals, these guidelines are intended to clarify the expectations of professional practice, conduct, and competence when Engineering Professionals are engaged on an EMTC building.

For Architects, these guidelines inform and support relevant competency standards of practice to be met when Architects are engaged on an EMTC building.

As with all building and construction types, the EMTC-specific code provisions prescribe minimum requirements that must be met.

The majority of EMTC of 7 to 12 storeys are considered High Buildings, and as such are subject to the *BCBC*, Subsection 3.2.6. Additional Requirements for High Buildings.

Additional requirements include:

- limits to smoke movement;
- emergency operation of elevators;
- elevator for use by firefighters;
- venting to aid firefighting;
- central alarm and control facility;
- voice communication systems; and
- smoke control and venting testing.

Other considerations for EMTC of 7 to 12 storeys (High Buildings) include:

- increased reliance on prefabrication and trade coordination;
- increased lateral loads (wind and seismic);
- increased environmental loads (wind, rain, snow, and ice) on building enclosure assemblies;
- increase in pressure drop requirements;
- increased cumulative effect of wood shrinkage;
- increased potential for water ingress at column connections and through laminations of non-edge-glued Cross-Laminated Timber (CLT);
- increased dimensions of structural wood framing affecting such items as structural connections and timber checking allowances; and
- additional acoustical challenges due to lower mass and increased reverberation.

Architects and Engineering Professionals are advised that any type of building with hygroscopic interior finishes or structure may sustain considerable damage when exposed to any source of water. Sources of water may include:

- ingress from the exterior;
- flooding due to damage or defects of interior water sources such as piping or fixtures;
- flooding due to operation of or damage to fire suppression systems; or
- flooding due to occupant's actions (e.g., a distracted person leaves bathtub taps running, and the bathtub overflows).

Rehabilitation required after any building is damaged by water can be costly and can put the building or parts of the building out of service for a considerable length of time. The risk of water ingress from the exterior and leakage of plumbing systems can be mitigated through a building owner's use of permanent moisture-monitoring strategies, and by incorporating mitigation measures, such as waterproof membranes and floor drains, into the design. Water ingress is addressed in Part 5 of the *BCBC* or VBBL (referred to collectively as the Code); however, there are currently no provisions in the Code that require measures to address water damage from fire suppression or plumbing system component failures. Those risks are outside the scope of these guidelines. Refer to Section 5.3.4 Building Performance Considerations for more information.

As with any complex building, the careful coordination and focused collaboration between Architects and the various engineering disciplines is essential for EMTC up to 12 storeys. As this type of construction may be new to many practitioners, Architects and Engineering Professionals should consider collaborating with subject matter experts, such as other Architects and Engineering Professionals with greater experience in this building type, until they have gained the requisite expertise through firsthand experience. Additionally, it is advisable that Architects and Engineering Professionals engage in a significant amount of personal research and study before undertaking their first EMTC building. See Section 8 References and Related Documents.

It is important to confirm the type of construction prior to utilizing these guidelines. These guidelines clarify the expectations for professional practice to be followed by Engineering Professionals when providing professional services related to EMTC up to 12 storeys. Buildings of 1 to 6 storeys may be Combustible Construction (including Heavy Timber Construction), Noncombustible Construction, or EMTC; and buildings of 7 to 12 storeys may only be EMTC or Noncombustible Construction. These guidelines are intended only for EMTC up to 12 Storeys.

As is the case with all existing AIBC and Engineers and Geoscientists BC practice guidelines, these guidelines will be updated as required.

2. Definitions

2.1 DEFINED TERMS

The following definitions are specific to these guidelines. These words and terms are capitalized throughout the document.

Architect

An individual who is a member of the Architectural Institute of BC.

Architects Act

Architects Act [RSBC 1996], Chapter 17.

Architectural Institute of British Columbia (AIBC)

The Architectural Institute of British Columbia is an independent, professional self-regulatory body established in 1920 by provincial statute: the *Architects Act*. The AIBC's mandate is to regulate the profession of architecture in the interest of the public.

Authority Having Jurisdiction (AHJ)

The governmental body responsible for the enforcement of any part of the Code or the official or agency designated by that body to exercise such a function.

***British Columbia Building Code* (*BCBC*)**

The *British Columbia Building Code*, applicable throughout British Columbia, except in the City of Vancouver and on federal lands.

British Columbia Fire Code

The *British Columbia Fire Code*, applicable throughout British Columbia, except in the City of Vancouver and on federal lands.

Bylaws – *Architects Act*

The bylaws of the AIBC made under the *Architects Act.*

Bylaws – *Professional Governance Act*

The bylaws of Engineers and Geoscientists BC made under the *Professional Governance Act*.

Code

The *British Columbia Building Code* (*BCBC*) or the *Vancouver Building By-law* (VBBL). Unless otherwise noted, the use of "Code" as a defined term refers specifically to Division B.

Combustible

A material that fails to meet the acceptance criteria of CAN/ULC-S114, Standard Method of Test for Determination of Non-Combustibility in Building Materials.

Combustible Construction

That type of construction that does not meet the requirements for Noncombustible Construction or EMTC.

Coordinating Registered Professional (CRP)

An Architect or Engineering Professional retained under Clause 2.2.7.2.(1)(a) of Division C of the *BCBC* or VBBL to coordinate all design work and field reviews of the Registered Professionals of Record who are required for Code compliance for a project.

Cross-Laminated Timber (CLT)

A proprietary engineered wood product that is prefabricated using several layers of kiln-dried lumber, laid side-by-side on the flat, with each layer oriented at 90 degrees to those above and below it. The layers are face-glued together (and sometimes edge-glued within each layer). Panels typically consist of three, five, seven, or nine alternating layers of dimension lumber. ANSI/APA PRG 320, Standard for Performance-Rated Cross-Laminated Timber covers the manufacturing, qualification, and quality assurance requirements for Cross-Laminated Timber.

Dowel-Laminated Timber (DLT)

Solid timber panels consisting of multiple boards of dimension lumber arranged face-to-face and fastened together using dowels. The manufacture of DLT panels is typically automated but can also be done by hand.

Encapsulated Mass Timber Construction (EMTC)

That type of construction in which a degree of fire safety is attained by the use of encapsulated Mass Timber elements with an Encapsulation Rating and minimum dimensions for structural members and other building assemblies.

Encapsulation Rating

The time in minutes that a material or assembly of materials will delay the ignition and combustion of encapsulated Mass Timber elements when it is exposed to fire under specified conditions of test and performance criteria, or as otherwise prescribed by the Code.

Engineering/Geoscience Professional

Professional engineers, professional geoscientists, professional licensees engineering, professional licensees geoscience, and any other individuals registered or licensed by Engineers and Geoscientists BC as a "professional registrant" as defined in Part 1 of the Bylaws – *Professional Governance Act*.

Engineers and Geoscientists BC

The Association of Professional Engineers and Geoscientists of the Province of British Columbia, also operating as Engineers and Geoscientists BC.

Fire Code

The *British Columbia Fire Code* or the Vancouver Fire By-law.

Fire-Protection Rating (FPR)

The time in minutes or hours that a closure will withstand the passage of flame when exposed to fire under specified conditions of test and performance criteria, or as otherwise prescribed in the Code.

Fire-Resistance Rating (FRR)

The time in minutes or hours that a material or assembly of materials will withstand the passage of flame and the transmission of heat when exposed to fire under specified conditions of test and performance criteria, or as determined by extension or interpretation of information derived therefrom as prescribed in the Code.

Flame-Spread Rating (FSR)

An index or classification indicating the extent of spread-of-flame on the surface of a material or an assembly of materials as determined in a standard fire test prescribed in the Code.

Heavy Timber Construction

That type of Combustible Construction in which a degree of fire safety is attained by placing limitations on the sizes of wood structural members, and on the thickness and composition of wood floors and roofs, and by the avoidance of concealed spaces under floors and roofs.

High Building

Any building subject to the additional requirements of Subsection 3.2.6. of the Code.

Laminated Veneer Lumber (LVL)

A Structural Composite Lumber (SCL) product used most commonly as headers and beams, made of drive and graded wood veneer which is coated with a waterproof phenol-formaldehyde resin adhesive, assembled in an arranged pattern, and formed into billets by curing in a heated press.

Letters of Assurance

Documents set out in a schedule of Subsection 2.2.7. in Part 2 of Division C of the Code used to confirm and assure Code-compliant design and required field reviews by Architects and Engineering Professionals. Otherwise known as Schedules A, B, C-A, and C-B. Refer to *Guide to the Letters of Assurance in the BC Building Code* (Province of BC 2010).

Mass Plywood Panel (MPP)

Solid timber panels constructed of 25 mm thick plywood panels, laid up with alternating plywood layers at right angles to one another.

Mass Timber

See Structural Mass Timber.

Nail-Laminated Timber (NLT)

Solid timber panels constructed of parallel dimensional lumber members on edge, mechanically fastened together with nails. The term NLT is also sometimes applied to material that is lag-screw laminated.

Noncombustible

A material that meets the acceptance criteria of CAN/ULC-S114, Test for Determination of Non-Combustibility in Building Materials. The material, in the form in which it is used, and under the conditions anticipated, will not ignite, burn, support combustion, or release flammable vapours when subjected to fire or heat.

Noncombustible Construction

That type of construction in which a degree of fire safety is attained by the use of Noncombustible materials for structural members and other building assemblies.

Parallel Strand Lumber (PSL)

A Structural Composite Lumber (SCL) product used most commonly as headers, beams, and columns, made from flaked wood strands that are arranged parallel to the longitudinal axis of the member, coated with an exterior waterproof phenol-formaldehyde adhesive, formed into billets, pressed together, and cured using microwave radiation.

Peer Review

The independent evaluation of the work of an Architect or Engineering Professional for conceptual and technical soundness by another appropriately qualified Architect or Engineering Professional.

Professional Governance Act

Professional Governance Act [SBC 2018], Chapter 47.

Registered Professional of Record

An Architect or Engineering Professional retained to undertake design work and field reviews in accordance with Subsection 2.2.7. of Division C of the Code.

Structural Composite Lumber (SCL)

A term used to refer to the family of engineered wood products that includes and encompasses Laminated Veneer Lumber (LVL), Parallel Strand Lumber (PSL), and others.

Structural Mass Timber

Structural Mass Timber elements may consist of any number of large cross-section timber products, such as solid-sawn timber (heavy timber), glued-laminated timber (glulam), Structural Composite Lumber (SCL), Cross-Laminated Timber (CLT), Nail-Laminated Timber (NLT), and Dowel-Laminated Timber (DLT).

Supporting Registered Professional (SRP)

An Architect or Engineering Professional who provides supplementary design and/or field review services to the Registered Professional of Record for a particular component or subcomponent of a design. See *Joint Professional Practice Guidelines – Professional Design and Field Review By Supporting Registered Professionals* (AIBC and Engineers and Geoscientists BC 2020).

Vancouver Building By-law (VBBL)

The building bylaw used as the building code in the City of Vancouver, based on the *National Building Code of Canada*.

Vancouver Fire By-law

The fire bylaw used as the Fire Code in the City of Vancouver, based on the *National Fire Code of Canada*.

2.2 ABBREVIATIONS

AHJ: Authority Having Jurisdiction

AIBC: Architectural Institute of British Columbia

AIIC: apparent impact insulation class

APA: APA – The Engineered Wood Association

ASTC: apparent sound-transmission class

BC: British Columbia

***BCBC*:** *British Columbia Building Code*

BEC: building envelope consultant

CEC: Canadian Electrical Code

CLT: Cross-Laminated Timber

CMHC: Canada Mortgage and Housing Corporation

CNC: computer numerically controlled [machine]

CRP: Coordinating Registered Professional

DLT: Dowel-Laminated Timber

DX: direct expansion

EER: electrical engineer of record

EMTC: Encapsulated Mass Timber Construction

FRR: Fire-Resistance Rating

FPR: Fire-Protection Rating

FPE: fire protection engineer

FSR: Flame-Spread Rating

GLT: glue-laminated timber

IIC: impact insulation class

LV: low-voltage

LVL: Laminated Veneer Lumber

MC: moisture content

MEP: mechanical, electrical, and plumbing

MER: mechanical engineer of record

MPP: Mass Plywood Panels

NDS: National Design Specification for Wood Construction

NLT: Nail-Laminated Timber

NRC: National Research Council Canada

OITC: outdoor-indoor transmission class

PSL: Parallel Strand Lumber

RH: relative humidity

RPR: Registered Professional of Record

SCL: Structural Composite Lumber

SER: structural engineer of record

SFRS: seismic force resisting system

SLS: serviceability limit state

SRP: Supporting Registered Professional

STC: sound transmission class

TL: transmission loss

ULS: ultimate limit state

VAV: variable-air-volume

VBBL: Vancouver Building By-law

VRF: variable refrigerant flow

3. Overview

3.1 PURPOSE

Encapsulated Mass Timber Construction (EMTC) means that type of construction in which a degree of fire safety is attained using encapsulated Mass Timber elements with an Encapsulation Rating and minimum dimensions for structural members and other building assemblies.

For Engineering Professionals, these guidelines cover minimum qualifications, professional practice, roles and responsibilities, and quality assurance for projects designed using EMTC up to 12 storeys. These guidelines identify issues to be taken into consideration when providing architectural, building enclosure, fire protection, acoustical, structural, mechanical, and electrical professional services, as well as provide sources of information, and, in some instances, design options.

Following are the specific objectives of these guidelines:

1. Describe the standards of practice that Engineering Professionals should follow when practicing within the scope and applicability of these guidelines by:
    a) Specifying the required tasks and/or services that Engineering Professionals should complete; and
    b) Specifying professional obligations under the *Professional Governance Act* and the Bylaws – *Professional Governance Act*, other regulations/ legislation, and the established norms of practice in this area, including the primary obligation to protect the safety, health, and welfare of the public and the environment.
2. Describe the roles and responsibilities of the various participants/stakeholders involved in these professional activities. The document should assist in delineating the roles and responsibilities of the various participants/stakeholders, which may include Architects, Engineering Professionals, owners, Authorities Having Jurisdiction, and Constructors.
3. Define the skill sets that are consistent with the training and experience required to carry out these professional activities.
4. Provide guidance on the use of assurance documents, so the appropriate considerations are addressed (both regulatory and technical) for the specific professional activities that are carried out.
5. Provide guidance on how to meet the quality management requirements under the *Professional Governance Act* and the Bylaws – *Professional Governance Act* when carrying out the professional activities identified in these professional practice guidelines.

For Architects, these guidelines identify issues to be taken into consideration when providing architectural, building enclosure, fire protection, and acoustical professional services, and they provide sources of information, and, in some instances, design options.

These guidelines are written for Architects and Engineering Professionals; however, they are also useful for other consultants, developers, constructors, building officials, and the general public, as they establish a foundation of basic knowledge and a common level of expectation for all stakeholders with respect to appropriate practice for Architects and Engineering Professionals when providing professional services for these types of buildings.

3.2 SCOPE

These guidelines pertain to the professional practice of Architects and Engineering Professionals and their obligations associated with the architectural, building enclosure, fire protection, acoustical, structural, mechanical, and electrical professional services for EMTC buildings up to 12 storeys, or parts of such buildings, following the EMTC provisions of the Code.

3.3 APPLICABILITY

Notwithstanding the purpose and scope of these guidelines, the decision of Architects or Engineering Professionals not to follow one or more aspects of these guidelines on a particular project does not necessarily mean that they fail to meet their professional obligations.

Engineering Professionals may depart from these guidelines if it is appropriate to do so for an identified reason. In such circumstances, the Engineering Professional must document the reason for departing from any relevant portion of these guidelines. Engineering Professionals should consider supporting this decision through a documented risk assessment. The rationale must be consistent with the Engineering Professional's obligations under the *Professional Governance Act*, relevant regulations, and their organization's bylaws and codes of ethics. Given the potential risks to the public and the environment that such departures pose, Engineering Professionals should evaluate whether to have the departure reviewed before implementation by an independent Engineering Professional with relevant expertise who was not involved with the design.

3.4 ACKNOWLEDGEMENTS

These guidelines were prepared by members of the Professional Practice Guidelines: Encapsulated Mass Timber Construction up to 12 Storeys Steering Committee for the following organizations commissioning the work:

- Architectural Institute of British Columbia (AIBC)
- Engineers and Geoscientists British Columbia
- Province of British Columbia, Building and Safety Standards Branch, Office of Housing and Construction Standards, Ministry of Municipal Affairs and Housing

These guidelines were made possible with the funding and support of Forest Innovation Investment; National Research Council – Construction Research Centre; the AIBC; and Engineers and Geoscientists BC.

These guidelines were also made possible through the valuable contributions of the authors and the formal review group, who are all subject matter experts and either members of the AIBC or registrants of Engineers and Geoscientists BC. This document was also reviewed by various committees of the AIBC and Engineers and Geoscientists BC. These guidelines were approved by Engineers and Geoscientists BC's council and, prior to publication, underwent final editorial and legal review by both the AIBC and Engineers and Geoscientists BC.

Authorship and review of these guidelines does not necessarily indicate the individuals and/or their employers endorse everything in these guidelines.

See Appendix A: Authors and Reviewers for a list of contributors.

3.5 UPDATES TO THESE GUIDELINES

These guidelines inform and support the recommended standard of practice at the time they were prepared. However, this is a living document that is to be revised and updated as required in the future, to reflect the developing state of practice.

Questions specifically relating to these guidelines or professional practice of Architects and Engineering Professionals should be directed respectively to:

- AIBC: practiceadvice@aibc.ca
- Engineers and Geoscientists BC: practiceadvisor@egbc.ca

4. Roles and Responsibilities

4.1 PROJECT ORGANIZATION

Project organization for Encapsulated Mass Timber Construction (EMTC) differs from traditional design and delivery project organization in several ways. Design teams should consider the following, when organizing EMTC building projects:

- **Structural grids:** Structural Mass Timber span and support limits may differ significantly from those for traditional Noncombustible Construction of steel and concrete. The Architect and structural engineer of record (SER) should collaborate early to establish building grids and layouts. The Architect should consider collaborating with the SER as early as possible in the design process.
- **Manufacturer:** Structural Mass Timber is often a panelized or modular premanufactured system. Each manufacturer has certain capabilities and limitations when it comes to the type and size of Structural Mass Timber member and panel products. The fabrication capacity of the manufacturer and the size restrictions to accommodate the transportation of components to site should also be considered. The design team should confirm available product types and dimensions before committing to the structural grid and building layout. The design may need to utilize more than one Mass Timber product manufacturer.
- **Fire protection during construction:** All EMTC is subject to Fire Code requirements limiting the number of non-fire-protected storeys during construction. A common EMTC Encapsulation Rating method is gypsum board encapsulation. Gypsum board is hygroscopic and must be protected from damage due to moisture during construction. Due to the importance of fire safety during construction, and the potential complexity of EMTC, the involvement of a fire protection engineer (FPE) in the development of the Fire Code-mandated construction fire safety plan is recommended.
- **Alternative solutions:** When alternative solutions under the Code are considered for EMTC, they may be fundamental to the building design and involve multiple members of the design team. The design team should be engaged early to contribute to the development of alternative solutions. Likewise, the Authority Having Jurisdiction (AHJ) should be consulted as early as possible, to seek their concurrence on alternative solution proposals that, if not approved, could necessitate major project redesign.
- **Concealed spaces:** Code provisions for EMTC include the elimination of unprotected (unencapsulated) concealed spaces, both between structural members and between the structure and finishes or components, such as dropped ceilings. Exceptions under certain conditions allow sprinklers, small gaps, and mineral fibre to be used in lieu of encapsulation. However, not every condition is covered in the exceptions and, as such, alternative solutions under the Code may be required to address nonconforming conditions. Some examples of nonconforming conditions include manufactured units with integral but unencapsulated void spaces; service duct and plenum spaces that cannot be encapsulated, filled, or sprinklered; and voids around structural connections without encapsulation. The design team should identify where concealed spaces may be required, then

coordinate and detail them accordingly. Any nonconformance with the acceptable solutions in the Code will require the design team to propose alternative solutions to suit. Concealed spaces within Structural Mass Timber elements are addressed in Sentence 3.1.18.3.(4) of the Code; where concealed spaces are adjacent to Structural Mass Timber elements, the encapsulation requirements of those elements are addressed in Sentence 3.1.18.4.(1) of the Code.

There is no requirement in the Code or elsewhere for the retention of an FPE, a building envelope consultant (BEC), a Code consultant, or an acoustical engineer for an EMTC building. The responsibilities and services outlined in Section 5.4 Building Enclosure Considerations, Section 5.5 Fire Protection Considerations, and Section 5.6 Building Acoustical Considerations are the responsibility of the Architect, who can choose to provide these services or engage other specialty Architects or Engineering Professionals. In each of these areas, Architects designing EMTC buildings should assess their own skills and resources in relation to the project parameters, and accordingly they should determine the assistance from other professionals that is necessary for the project or that might otherwise be beneficial.

In order to differentiate the professional specialty services available, these guidelines are written as though specialty consultants are engaged, but it should not be inferred that specialty consultants should or must be engaged in each project.

4.2 RESPONSIBILITIES

The majority of EMTC buildings of 7 to 12 storeys are considered High Buildings, and as such are subject to the Code, Subsection 3.2.6. Additional Requirements for High Buildings. Examples of these additional requirements include additional smoke control measures, central alarm and fire alarm control requirements, lighting and emergency power requirements, and emergency elevator operation requirements. The design team should familiarize themselves with these provisions before commencing design. Special considerations for EMTC High Buildings are outlined below.

Architects and Engineering Professionals are obligated by their respective codes of ethics to undertake and accept responsibility for professional assignments only when qualified by education, training, and experience to do so. EMTC is a new construction type for Canadian codes. While Architects and Engineering Professionals are familiarizing themselves with this new type of construction, they may consider collaborating with or engaging others with more EMTC experience. For example, an Architect may choose to collaborate with or engage Supporting Registered Professionals (SRPs) in areas such as building enclosure, fire protection, and/or acoustics. Similarly, an SER may choose to engage or collaborate with an SRP.

The following sections on the roles and responsibilities of Architects, Engineering Professionals, and key stakeholders in EMTC buildings are not meant to provide an exhaustive list of either project participants or their responsibilities. Instead, they outline key considerations that such participants should take account of when embarking on this type of project. For additional information on the roles and responsibilities of Architects and Engineering Professionals, refer to discipline-specific professional practice guidelines, and to the *Guide to the Letters of Assurance in the BC Building Code* (Province of BC 2010).

4.2.1 OWNER

Each member of the design team needs to inform the owner of the responsibilities of each Registered Professional, so the design and construction of the project is carried out in a manner that meets appropriate standards of public safety, environmental legislation, and the requirements of applicable building regulations.

The owner should:

- retain or cause to be retained the requisite Registered Professionals of Record with responsibility for the design of all aspects of the building, including specialized consultants that may not typically be required on non-EMTC buildings;
- Retain or cause to be retained a Coordinating Registered Professional (CRP);
- before the commencement of the architectural and engineering services, confirm in writing the scope of services for each member of the design team, including specialized consultants that may not typically be required on non-EMTC buildings;
- coordinate with the CRP and the Registered Professionals of Record to establish a mutually agreeable and realistic schedule for the provision of each Registered Professional of Record's respective services;
- as necessary due to changes in the project or the challenges of EMTC that could not have been reasonably foreseen, authorize in writing any additional services that may be required from Architects and Engineering Professionals beyond the scope of the owner's initial agreements or the scope of services as originally understood by the parties;
- recognize that some design changes may be required, because interpretations of the Code can differ between the AHJ and the Registered Professional of Record; and
- understand that EMTC buildings require earlier engagement and coordination between the Architect and Engineering Professionals, and thus the consultants' fees may have to be distributed differently as compared to other types of projects, so that a greater percentage of the fees are paid for substantial work done at the initial stages of the project.

4.2.2 COORDINATING REGISTERED PROFESSIONAL

The role of the CRP, as described in the Letter of Assurance, Schedule A, Confirmation of Commitment By Owner and Coordinating Registered Professional, is to coordinate the design work and field reviews of the Architect and Engineering Professionals required for the project in order to ascertain that the design will substantially comply with the Code and other applicable enactments regarding safety.

The role of the CRP is clearly defined in the Code, and is discussed in Note A-2.2.7.2.(1)(a) of Division C.

4.2.3 ARCHITECT

Architectural considerations and responsibilities related to EMTC include, but are not limited to, the following.

The Architect should:

- communicate with the owner, advising the owner of the various implications of EMTC on design methodology, consultants required, construction budget, and construction schedule;
- identify and advise the owner and Engineering Professionals of special design criteria related to EMTC, including measures specific to High Buildings;

- consider the extent to which composite systems such as steel and concrete may be integrated into the design;
- determine in consultation with the SER the most appropriate gravity and lateral systems for the building that respond best to the building program (basis of design);
- coordinate with the RPRs and SRPs for the encapsulation requirements of the structural, mechanical, electrical, plumbing, and fire suppression designs;
- facilitate the design of details specific to EMTC, such as connections and Fire-Resistance Ratings (FRRs), in consultation with the SER and the fire protection engineer (FPE), if retained;
- facilitate early-stage (schematic design) coordination of EMTC-related issues with all Engineering Professionals, including RPRs and SRPs, and other Architect SRPs;
- facilitate early-stage coordination of EMTC-related issues with the fire department;
- determine, in consultation with the RPRs and SRPs, strategies for utilizing alternative solutions, as appropriate;
- facilitate early-stage coordination of EMTC-related issues, such as proposed alternative solutions, with the AHJ;
- facilitate early-stage coordination of EMTC-related issues with the constructor, where possible;
- consider the thermal transmission characteristics of the EMTC building envelope, paying particular attention to thermal bridging of structural components and the heat transfer performance of the specific materials, and utilizing tools such as whole building and component energy modelling;
- determine, in consultation with the mechanical engineer of record (MER) and the electrical engineer of record (EER), the mechanical and electrical systems, and the means by which these systems will be integrated into the building, including the routing of services, service spaces, and concealed spaces;
- prepare an integrated set of design and construction documents, including detailing as necessary for the concealed spaces required for building HVAC and electrical systems;
- coordinate with the FPE the requirements for concealed spaces for the fire suppression system, as well as any requirements for concealed spaces to be sprinklered;
- develop an acoustic strategy that addresses the specific acoustic characteristics of EMTC, consulting with an acoustical engineer, if required;
- prepare and manage an integrated EMTC model to consider construction sequencing and constructability, where applicable;
- coordinate the creation of early-stage mock-ups and testing, where applicable;
- review manufactured components at the fabrication site, as required;
- consider transportation limitations of manufactured components; and
- perform field reviews at intervals appropriate to the accelerated construction sequence characteristic of EMTC.

4.2.4 BUILDING ENCLOSURE CONSULTANT

The roles and responsibilities of the building enclosure consultant (BEC), who is either an Architect or a building enclosure engineer (BEE), varies, depending on the scope of the project. As with any other type of construction, the BEC should refer to the Code as it relates to EMTC, and the administrative requirements of the AHJ. Additionally, Engineering Professionals providing building enclosure services should refer to the *Professional Practice Guidelines – Building Enclosure Engineering Services* (Engineers and Geoscientists BC 2020c). Specific considerations and responsibilities related to EMTC include but are not limited to the following.

When retained, the BEC could provide any of the following services:

- assist the Architect with developing appropriate building enclosure assemblies and strategies to meet the design requirements, defining EMTC material and detailing considerations, and addressing Part 5 and Part 10 requirements of the Code;
- review preliminary drawings of assemblies for building enclosure elements in accordance with the agreed scope of services to confirm that they can meet the established design criteria, including reviewing walls, windows and other glazed elements, roofs, balconies, decks, below-grade and at-grade elements, and typical interface details between these assemblies, as well as considering fabrication and transport of components, if applicable;
- review the durability of building enclosure elements, and consider maintenance, renewal, and service life requirements of the building enclosure elements against the agreed design service life of the building, including providing disclosure of expected service lives and the impact of design decisions on the likely scope and frequency of maintenance and renewal activities;
- advise on long-term monitoring strategies to protect the structure from unanticipated water ingress from the exterior, or from other sources such as failure of plumbing system components;
- advise on moisture control during construction;
- review the construction documents to verify they adequately describe building enclosure elements and meet the intent of the Code, and ascertain that the design can achieve the established design criteria, particularly the continuity and placement of thermal insulation and moisture, air, and vapour barriers, and the confirmation of drainage paths;
- provide technical input for the specifications and advice on the development of specifications for new products, materials, or systems used in EMTC; and
- assist in establishing testing and mock-up requirements for EMTC enclosure components.

In addition to reviewing Section 5.4 Building Enclosure Considerations, the BEC should review all parts of these guidelines to gain an understanding of the various considerations relevant to EMTC up to 12 storeys.

4.2.5 CODE CONSULTANT

The Code consultant can be an Architect or Engineering Professional. Although all parts of the Code require consideration for EMTC, the term “Code consultant” in these guidelines relates primarily to consultation to determine compliance to Part 3 of the Code and to the Fire Code.

Consequently, the decision to retain a Code consultant depends on the scope of the project, and the roles and responsibilities of a

Code consultant will vary accordingly. Considerations and responsibilities related to EMTC may include but are not limited to the following.

When retained, the Code consultant could provide any of the following services:

- conduct an overall review of building size and area to confirm they meet EMTC provisions of the Code;
- review encapsulation methods;
- review protection of concealed spaces;
- review calculations of the Fire-Resistance Rating (FRR) and char rates, as well as protection of connections, with the Architect and SER;
- review cladding conditions where parts of the cladding have Combustible elements, or may be required to satisfy performance criteria based on testing in conformance with CAN/ULC-S134, Standard Method of Fire Test of Exterior Wall Assemblies or Article 3.1.5.5. of the Code;
- review firestopping of services to confirm compliance with appropriate testing or appropriately prepared engineering judgments;
- review any areas covered by engineering judgments or alternative solutions under the Code; and
- prepare and review alternative solutions.

4.2.6 FIRE PROTECTION ENGINEER

The roles and responsibilities of the FPE vary, depending on the scope of the project. As with any other type of construction, the FPE should refer to the *Guidelines for Fire Protection Engineering Services for Building Projects* (Engineers and Geoscientists BC 2013), the Code as it relates to EMTC, and the administrative requirements of the AHJ. Specific considerations and responsibilities related to EMTC include but are not limited to the following.

When retained, in addition to the responsibilities of the Code consultant, the FPE could provide any of the following services:

- develop fire protection engineering recommendations and design concepts;
- engage a specialty FPE—or recommend that a specialty FPE be engaged—for specific aspect(s) of the fire and life safety concepts of a building project, such as the development of an alternative solution under the Code that does not involve a broad overall project review by the specialty FPE;
- review aspects of fire and life safety in a broader context;
- advise on fire risk during construction and other applicable aspects of the Fire Code;
- advise on the construction fire safety plan; and
- consult with the AHJ and fire department to coordinate construction management requirements, including availability of active standpipes, sprinklers, and temporary means of egress, understanding that this may require modelling of construction sequencing.

In addition to reviewing Section 5.5 Fire Protection Considerations, the FPE should review all parts of these guidelines to gain an understanding of the various considerations relevant to EMTC up to 12 storeys.

4.2.7 ACOUSTICAL ENGINEER

The roles and responsibilities of the acoustical engineer vary, depending on the scope of the project. Specific acoustical performance considerations and responsibilities related to EMTC include but are not limited to the following.

When retained, the acoustical engineer could provide any of the following services:

- review the overall thickness of Mass Timber partitions to ensure they include an allowance for the build-up of additional layers to meet sound isolation requirements, which becomes more critical if the Mass Timber elements are exposed and acoustic controls are added to only one side of the Mass Timber;
- address impact noise control in Mass Timber buildings by adding layers of acoustic treatment above and/or below the Structural Mass Timber floor, and coordinating the thickness of the floor/ceiling system and desired aesthetic with the Architect and SER, while considering the cost of these additional layers (which may include proprietary isolation layers) in the owner's initial construction budget;
- consider sound isolation when detailing the interfaces between floor components and wall components, to reduce or eliminate potential flanking paths;
- assess room acoustics in spaces with timber or gypsum board finishes, which can be highly reverberant and result in poor speech intelligibility, to determine whether sound-absorbing finishes within occupied spaces should be added;
- assess mechanical, electrical, and plumbing (MEP) noise and vibration control systems, which may require added mass and stiffness to the floors and walls of mechanical and electrical rooms to improve sound isolation and enable the vibration isolation controls to function as designed, and coordinate these requirements with the Architect, MER, EER, and SER;
- where projects are located on transit routes, in industrial areas, or on other similar sites, mitigating the intrusion of noise from exterior sources can be challenging for all building types, and particularly for EMTC buildings with their inherently poorer sound isolation performance, so consider conducting site measurements and/or noise modelling to establish outdoor noise levels at the façade of the building to adequately assess the performance requirements for the building enclosure;
- where stair and elevator cores are constructed using EMTC rather than concrete, develop noise control guidelines to minimize the impact of noise on nearby suites; and
- review encapsulated wood assemblies (or the junctions between assemblies), in order to establish noise reduction criteria and performance standards.

In addition to reviewing Section 5.6 Building Acoustical Considerations, the acoustical engineer should review all parts of these guidelines to gain an understanding of the various considerations relevant to EMTC up to 12 storeys.

4.2.8 STRUCTURAL ENGINEER OF RECORD

The SER has overall responsibility for the design and field review of the primary structural system. As with any other type of construction, the SER should refer to the *Professional Practice Guidelines – Structural Engineering Services for Part 3 Building Projects* (Engineers and Geoscientists BC 2019a) and the requirements of the AHJ. Specific considerations for EMTC include but are not limited to the following.

The SER should:

- establish the EMTC structural system with the Architect, while considering the various means of procurement and construction of EMTC material and assemblies;
- consider the construction sequencing implications for the EMTC system selected;
- coordinate with the Architect on lateral systems unique to EMTC;

- coordinate with the Architect, the MER, and the EER on provisions for systems distribution;
- understand the requirements for HVAC, plumbing, electrical, and other penetrations, and the chase and plenum restrictions that are required for EMTC;
- coordinate with the Architect, and the FPE or Code Consultant, if engaged, on all members and connections that are fully or partially exposed to fire, and design for the FRR and associated load case, as well as all typical gravity, wind, and seismic load cases;
- indicate on the structural drawings the approach taken for fire design;
- coordinate with the Architect, and the FPE, if engaged, to confirm the design drawings include the necessary information for the minimum fire design requirements;
- where the SER relies on an FPE for fire design requirements related to structural and receives an FPE report, reference the FPE report in the structural drawings;
- where the structural design is dependent on the FPE report or alternative solutions under the Code, may request from the FPE Schedule S-B and Schedule S-C (see *Joint Professional Practice Guidelines – Professional Design and Field Review By Supporting Registered Professionals* [AIBC and Engineers and Geoscientists BC 2020]);
- coordinate with the Architect for locations where encapsulation is required, and locations where timber is exposed, and coordinate encapsulation design as needed to achieve the required FRR;
- coordinate with the Architect and FPE to identify and integrate any fire protection measures that may have to be installed during the erection of the structure;
- coordinate with the Architect and other Engineering Professionals on the integration of the Structural Mass Timber system with the MEP systems, considering construction sequencing, the design of concealed spaces, and differential movement;
- coordinate with the Architect and Engineering Professionals, including the acoustical engineer, in the development of the structural floor assemblies to meet the appropriate in-service deflection and vibration criteria;
- coordinate with the Architect, fabricators, and constructor in the development of a structural system that allows for moisture protection during construction, and in service;
- account for vertical shrinkage and consolidation considerations in the design of the structure; and
- coordinate with the Architect and the BEC for the detailing of interfaces between structural components, to achieve continuity of building envelope elements to meet enclosure and energy requirements.

4.2.9 MECHANICAL ENGINEER OF RECORD

The MER has overall responsibility for the design and field review of the mechanical systems. As with any other type of construction, the MER should refer to the *Guidelines for Mechanical Engineering Services for Building Projects* (Engineers and Geoscientists BC 1993) and the requirements of the AHJ. Specific considerations and responsibilities related to EMTC include but are not limited to the following.

The MER should:

- build allowances into the vertical pipe and duct distribution to deal with Mass Timber shrinkage and differential shrinkage of hybrid systems, in addition to the expansion and contraction that may occur with these systems through their operating temperature cycles;

- provide mechanical solutions, including use of sensors, that minimize the risk of water gaining entry to concealed spaces and sensitive and/or other inaccessible parts during construction and after occupancy, with special consideration for piping under pressure;
- provide mechanical solutions that control the relative humidity (RH) of the building to minimize moisture changes in the Mass Timber;
- coordinate fire protection requirements of concealed spaces and penetrations with the Architect, and the FPE, if engaged;
- advise on temporary firestopping during erection;
- consider the potential impact of char when specifying the firestopping of piping and ductwork and locations of fire and/or smoke dampers;
- specify the insulation requirements of piping and ductwork when penetrating through Mass Timber;
- coordinate services routing and all penetrations, particularly conduits, with the Architect and SER prior to fabrication, as openings are cut in the factory rather than on site;
- route the piping and ductwork so that generally, and wherever possible, they do not penetrate Structural Mass Timber beams and columns, unless absolutely necessary; in that case, seek approval of the SER and Architect;
- coordinate acoustical requirements of equipment rooms and construction penetrations with the Architect and acoustical engineer; and
- confirm and coordinate with the Architect the specific space requirements for components of the mechanical systems, to make sure all required concealed spaces are integrated and addressed with respect to spatial requirements and fire protection requirements.

4.2.10 ELECTRICAL ENGINEER OF RECORD

The EER has overall responsibility for the design and field review of the electrical systems. As with any other type of construction, the EER should refer to the *Professional Practice Guidelines – Electrical Engineering Services for Building Projects* (Engineers and Geoscientists BC 2019b) and the requirements of the AHJ. Specific considerations and responsibilities related to EMTC include but are not limited to the following.

The EER should:

- coordinate penetrations through the Mass Timber panels with the Architect and SER;
- consider the potential impact of char when designing firestopping of conduits, cable trays, cable bus duct, busways, and arc flash ducts at places of penetrations;
- route the cables, conduits, and raceways so, to the greatest extent possible, they do not penetrate Mass Timber beams and columns;
- coordinate fire protection requirements of concealed spaces and penetrations required for electrical components with the Architect, and the FPE, if engaged;
- specify the insulation requirements of conduits, armored cables, and metal ducts when penetrating through Mass Timber;
- design with allowance for cable slacks and flexible raceway portions in the long runs;
- design with allowance for provision and adjustment of the rail sensors in the elevator shafts due to building vertical movement; and
- design with allowance for shrinkage of wood.

4.2.11 CONSTRUCTOR

The constructor's considerations and responsibilities related to EMTC include but are not limited to the following.

The constructor should:

- be familiar with large-scale prefabricated structural components, and understand that for EMTC, it is advised that the RPRs consider constructability and availability of products before specifying premanufactured components;
- be aware that the bidding process for an EMTC building may be very different than a conventional building, because there may be a limited number of manufacturers and fabricators with the capability and capacity to produce the specified premanufactured products;
- be prepared to provide input on constructability to aid design decisions made by the RPRs;
- be aware that engagement with the EMTC design team on virtual construction models of the building, including its MEP systems, may be required in order to identify potential conflicts between building systems prior to fabrication and construction or for construction sequencing, site organization, and component delivery scheduling;
- be aware of, and be responsible for, the requirements for moisture control on-site for EMTC;
- be responsible for compliance with Part 8 of the Code;
- be responsible for compliance with the Fire Code during construction;
- be responsible for developing and implementing the construction fire safety plan, and understand that it is recommended that the constructor consults and works closely with an FPE on the development of the construction fire safety plan (refer to Section 5.5.7 Construction Fire Safety Planning in EMTC); and
- be responsible for developing the construction schedule and communicating the schedule to the CRP and RPRs, as required, to allow the RPRs to plan field reviews at appropriate intervals, and understand that the construction schedule for EMTC is not the same as that of other construction methodologies, so the constructor must provide sufficient information and lead time to the RPRs to allow them to fulfill their obligations.

5. Professional Practice

5.1 OVERVIEW

This section offers guidance to Architects and Engineering Professionals providing services for EMTC buildings by identifying the some of the challenges of this technology and providing guidance on how to address them.

The services described below are not intended to be exhaustive, or to include all the services that may be provided by Architects and Engineering Professionals, and should be considered in conjunction with other provisions of these guidelines and other applicable professional practice guidelines.

5.1.1 CONSIDERATION OF RISK

Engineering Professionals have a professional responsibility to uphold the principles outlined in the Code of Ethics of Engineers and Geoscientists BC, including with respect to the protection of public safety and the environment. As such, the Engineering Professional must use a documented approach to identify, assess, and mitigate risks that may impact public safety or the environment when providing professional services.

One of the risk factors that must be considered is climate change implications on the building. Engineering Professionals have a responsibility to notify their clients of future climate-related risks, reasonable adaptations to lessen the impact of those risks, and the potential impacts should a client refuse to implement the recommended adaptations. Engineering Professionals themselves have the responsibility to be aware of and meet the intent of any climate change requirements imposed by a client or Authority Having Jurisdiction.

While the professional standards for Architects do not include these requirements for environmental responsibility, Architects are advised to consider the above advice to Engineering Professionals with respect to climate change.

Other areas of risk encountered in professional practice are quality, technical, financial, and commercial risks. Architects and Professionals should consider risks in such areas using techniques that are appropriate to their area of practice.

5.2 APPLICABLE CODES AND STANDARDS

5.2.1 APPLICABLE CODES AND BYLAWS

At the time of publication, the following codes and bylaws related to EMTC were in force:

- *BC Building Code* (BCBC) 2018
- *BC Fire Code* 2018
- Vancouver Building By-law (VBBL) 2019
- Vancouver Fire By-law 2019

Codes and bylaws are regularly revised, as knowledge and experience progress and new technologies are developed. Model codes are developed at the national level, then adopted at the provincial level, and finally enforced at the local government level. As such, there is sometimes a gap between best practices and the requirements of the Code.

Architects and Engineering Professionals are responsible for meeting the requirements of codes and bylaws that are currently in force.

Note that use of “Code” throughout these guidelines refers to Division B of the *BCBC* or VBBL unless noted otherwise.

5.2.2 ALTERNATIVE SOLUTIONS

Compliance with the Code may be achieved by following the relevant acceptable solutions in Division B, or by using alternative solutions acceptable to the Authority Having Jurisdiction (AHJ). Refer to Section 2.3. of Division C of the Code for further guidance.

While EMTC can conform to the Code by following the acceptable solutions, employing alternative solutions may also offer useful strategies for achieving compliance. The author of an alternative solution relative to EMTC should be an Architect or Engineering Professional with expertise in EMTC and/or the component or system for which the alternative solution is written.

Where the level of deviation from the Code for an EMTC building project is significant, Peer Review may be appropriate, either by an individual, a team, or a committee. The level and extent of the Peer Review should be commensurate with the degree of deviation from the Code's acceptable solutions.

It is recommended that the need for Peer Review and the related process be discussed with the AHJ. The Peer Review is most effective when it is collaborative.

Section 7.3 Peer Review provides guidance for Architects and Engineering Professionals when providing Peer Review services. Guidelines for Peer Review for fire designs can be found in the SFPE *Guidelines for Peer Review in the Fire Protection Design Process (2020 Edition)* (SFPE 2020).

Note that a Peer Review is not an acceptable substitute for a documented independent review of structural designs. Refer to Section 7.2.6 Documented Independent Review of Structural Designs for more information.

5.3 ARCHITECTURAL CONSIDERATIONS

Architects should read all sections of these guidelines, in order to understand how the requirements of EMTC affect the work of the other disciplines. When considering an EMTC building project, schematic design by the Architect benefits from the input of multiple professionals, such as:

- the structural engineer of record (SER), on the selection of the appropriate Structural Mass Timber system and grid;
- the mechanical engineer of record (MER) and the electrical engineer of record (EER), on the selection of appropriate mechanical and electrical systems (exposed or enclosed in protected concealed spaces); and
- the acoustic, building enclosure, and fire protection specialists.

For example, acoustic properties of EMTC vary significantly from traditional construction and may require additional layers on one or both sides of the Mass Timber floor and wall assemblies to achieve the desired performance. Enclosure considerations for EMTC building projects are very different from those of traditional construction, and adequate weather protection, control of moisture and thermal bridging, and durability considerations are key to the success of EMTC enclosures over time. As well, the approach to both fire protection and structural design for EMTC building projects differs from those of traditional construction due to the contribution to structural fire resistance from the charring effect.

Numerous other requirements and characteristics of an EMTC building should be considered early in the design process:

- The unique aspects of this technology will impact the way in which the project is designed and delivered. For example, Mass Timber components are pre-manufactured to extremely tight tolerances (+/- 2 mm); penetrations for mechanical and electrical services are predrilled and precut; protection of concealed spaces is required; and specialized firestopping details should be determined and coordinated early in the design process.
- The coordinated process for the design of an EMTC building project utilizes digital fabrication software unique to Mass Timber for design, shop drawings, and construction, where the embedded design data within the Mass Timber model can be verified using survey equipment during construction.
- All drawings of Mass Timber components should include detailed dimensions and specifications of finishes to be pre-installed at the factory. Gaps and concealed spaces that may be of little or no concern with other materials will require careful consideration and detailing.
- It is likely that field reviews of components and assemblies will be required at the Mass Timber manufacturing facility. Because of the length, width, and height requirements for transportation to site by road, rail, or ship, it is critical that the size and configuration of all Mass Timber components and restrictions on delivery routes be considered. This recommended practice of considering and coordinating transportation routes is a variation from traditional construction projects.
- Fire safety requirements may impact the sequence of construction; for example, the Fire Code restricts the number of unencapsulated floors to not more than the four uppermost contiguous storeys at any time. This may have consequences for the installation sequencing, or require temporary fire protection (e.g., a “sacrificial” layer of drywall).

The *BCBC* and VBBL have been revised to permit EMTC. These guidelines reference the *BCBC* and VBBL (defined in this document as the “Code”).

These changes include but are not limited to, the following:

- Division A, Part 1, Section 1.4. Terms and Abbreviations
- Division B, Part 1, Article 1.3.1.2. Applicable Editions (note especially CSA O86-19)
- Division B, Part 3, under the following:
  - Article 3.1.3.1. Separation of Major Occupancies
  - Sentence 3.1.7.5.(4) Rating of Supporting Construction (note Noncombustible Construction in buildings or portions of buildings permitted to be of EMTC)
  - Article 3.1.11.5. Fire Blocks in Horizontal Concealed Spaces
  - Sentence 3.1.13.12.(1) EMTC Flame-Spread Rating (FSR)
  - Article 3.1.15.2. Roof Covering (note must be Class A above 25 m from floor of the first storey)
  - Subsection 3.1.18. Encapsulated Mass Timber Construction (note especially Article 3.1.18.4.), Encapsulation of Mass Timber elements - exposure of wood is limited
  - Article 3.1.18.7. Exterior Cladding must be Noncombustible, or tested to CAN/ULC S134, Standard Method of Fire Test of Exterior Wall Assemblies

- Sentence 3.1.18.3.(4) Concealed Spaces within Mass Timber elements are not permitted unless protected as per the accompanying Code provisions
- Subsection 3.1.19. Determination of Ratings
- Article 3.2.2.48EMTC. Group C, up to 12 storeys, Sprinklered (note limits occupancy to Group C Up to 12 Storeys Sprinklered plus Group A2, E and storage garage allowances)
- Article 3.2.2.57EMTC. Group D, up to 12 storeys, Sprinklered (note limits occupancy to Group D, up to 12 storeys, Sprinklered plus Group A2, E, F2, F3 allowances)
- Article 3.2.3.7. Construction of Exposing Building Face

5.3.1 MANAGEMENT OF THE PROJECT

5.3.1.1 Early Commitment from Owner/Client and AHJs

EMTC buildings require significantly more cross-disciplinary coordination during the early design phase than do traditional building projects. This redistributes the consultant fees and requires the client to make a larger investment in the early stages to facilitate this design process. This approach should be reviewed with the owner at the outset of the project.

Also, meeting with the Authority Having Jurisdiction (AHJ) early in the design process contributes to clarity and a mutual understanding of any special requirements related to the project, including submittals and approvals.

5.3.1.2 Early Appointment of Consultants and Constructor

It is beneficial to engage structural, mechanical, and electrical Engineering Professionals, as well as fire, building enclosure, and acoustical Engineering Professionals, if retained, early in the design process. This will enable the design team to identify the interfaces, areas of overlap, and potential conflicts between their various scopes of work. Equally importantly, this up-front collaboration can also identify synergies, possibilities for optimization, and consequent economies that might otherwise have been missed.

When conflicts or synergies between disciplines such as structural, mechanical, and other requirements can be identified and resolved or capitalized upon in a virtual model, the likelihood of changes and uncertainties on site is greatly reduced. This enables the project to benefit from the speed at which Mass Timber components can be assembled on site, which is a key advantage of EMTC.

Care should be taken when establishing a fee schedule for professional services, to reflect the increased responsibilities at the front end of the project.

As with the selection of key consultants, it is desirable to select a constructor who is familiar with the complexities of EMTC, prefabricated building systems, and the associated lead times for ordering and delivery of materials and components. Engaging the constructor at the project planning and preconstruction phase is advantageous. The design team can benefit from the constructor’s expertise in identifying realistic project goals and timelines, together with strategies for early procurement of key components. EMTC buildings typically require a greater focus on logistics than other types of projects. See Section 5.3.5 Constructability Considerations for further discussion.

5.3.1.3 Selection of the Design Team

When assembling a design team, experience with EMTC is highly desirable. EMTC is new to Canadian codes. As with any new type of construction, project, or material, Architects and Engineering Professionals are required under their respective regulator's codes of ethics (AIBC and Engineers and Geoscientists BC) to have or acquire the skills required to take professional responsibility for a project, prior to doing so. Architects and Engineering Professionals may consider including a contingency in their fees and/or schedule for research and professional development specific to EMTC. They may also consider collaborating with others who have more experience.

The most valuable qualities of a design team member include those who have experience in EMTC, are prepared to collaborate early in the design process, are familiar with the regulatory requirements of the AHJ, are open to exploring new or innovative construction techniques, and are adept at using virtual construction tools.

5.3.2 DESIGN CONSIDERATIONS

5.3.2.1 Building Use Considerations

The Code permits EMTC up to 12 storeys, as per the requirements of Article 3.2.2.48EMTC. for Group C (residential) occupancies and Article 3.2.2.57EMTC. Group D (business and personal services) occupancies. EMTC is permitted in combination with Noncombustible Construction (hybrid systems).

Multiple major occupancies in EMTC are limited to the following:

- In both Group C and Group D major occupancies, Group A Division 2 (assembly) major occupancies are permitted if located below the fourth story.
- In both Group C and Group D major occupancies, Group E (mercantile) major occupancies are permitted if located below the third storey.
- In Group D major occupancies, a Group F Division 2 (medium hazard industrial) or Group F Division 3 (low hazard industrial) major occupancies are permitted if located below the third storey.
- In both Group C and Group D major occupancies, a storage garage (Group F Division 3 used for storage of motor vehicles) is permitted if located below the fifth storey.

The maximum height in storeys for EMTC is 12. In addition, the height is limited to not more than 42 m, measured between the floor of the first storey and the uppermost floor level, excluding any floor level within a rooftop enclosure that is not considered a storey.

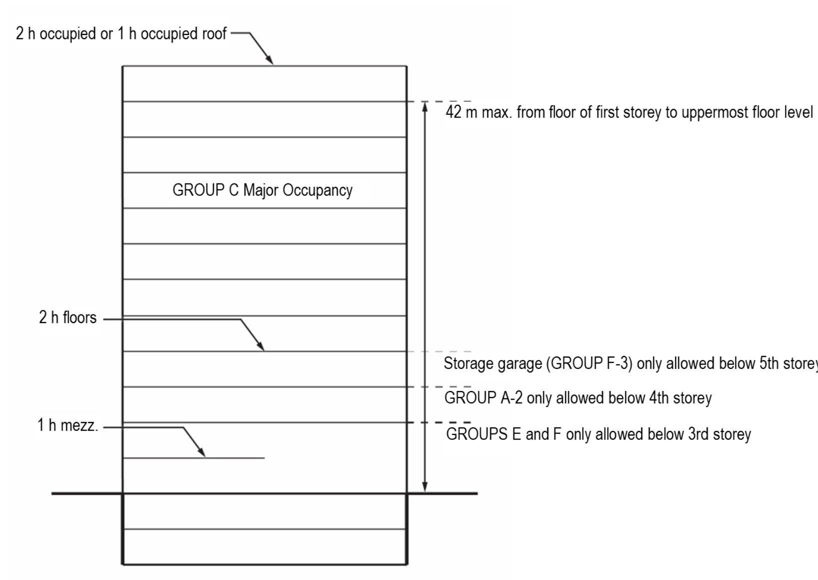
The building area per the Code (the "footprint") is limited to 6,000 m^2 in Group C, and is limited to 7,200 m^2 in Group D.

EMTC articles require fire separations with a Fire-Resistance Rating (FRR) of 2 hours between different major occupancies, and at floor assemblies. Per Article 3.2.2.13. of the Code, occupied roofs are required to have the same 2-hour FRR as the floor assemblies. Unoccupied roofs are not required to have an FRR. Whether or not a fire separation is required between the interior and the roof, encapsulation of the Mass Timber is still required. Figure 5-1 describes the construction articles that relate to EMTC and their required FRRs.

The Code requires that an EMTC upper structure be supported only by EMTC or Noncombustible Construction (Article 3.1.7.5. of the Code).

Figure 5-1: Sample diagram for Article 3.2.2.48EMTC. Group C up to 12 Storeys (3.2.2.57EMTC. Group D similar) of the Code

CONSTRUCTION ARTICLE	3.2.2.48EMTC, GROUP C, UP TO 12 STOREYS, SPRINKLERED	DIAGRAM
Major Occupancy	Group C	
Building Height (storeys)	12	
Building Height (m)	42 m from floor of first storey to uppermost floor level	
Sprinklered	Yes	
Allowable Building Area	6,000 m^2	
Construction Type	Encapsulated Mass Timber or Noncombustible construction	
Floor Assembly FRR	2 h	
Mezzanine FRR	1 h	
Loadbearing FRR	Equal to supported	
Roof FRR (Occupied / Unoccupied)	2 h / none	



NOTES:

Abbreviations: h = hour(s); FRR = Fire-Resistance Rating; m = metres; mezz. = mezzanine

5.3.2.2 Space-Planning Considerations

As a building technique, EMTC for High Buildings is still relatively new. As such, Architects and SERs continue to explore its possibilities and constraints, with no definitive conclusions yet drawn on optimal solutions. Structural Mass Timber spans and grids in EMTC will be different (especially in commercial applications) from those traditionally used in concrete or steel construction. Refer to Section 5.3.3 Structural Systems Considerations.

As noted previously, for any prefabricated product that is being transported, restrictions on length and width will apply to fit shipping containers, roads, rail, etc. These restrictions may influence design and planning decisions at the early stages of a project. Refer to Section 5.3.2.4 Procurement Considerations, under the subsection Transportation.

5.3.2.3 Material Considerations

Properties of Wood

Wood is both organic and hygroscopic; as such, it exhibits natural variations in strength perpendicular and parallel to grain, and it expands and contracts as its moisture content (MC) changes with that of its surroundings. Wood also has other physical properties that set it apart from concrete and steel—the materials traditionally used for High Buildings. The light weight and stiffness of wood affect its acoustic performance; its moderate thermal resistance and vulnerability to moisture damage are important considerations in building enclosure design; and its performance when exposed to fire influences the approach taken to fire protection design.

Mass Timber and EMTC

EMTC is a construction method by which fire resistance is attained by enclosing Mass Timber elements of a minimum required dimension with gypsum board or other Noncombustible materials. The detailed encapsulation criteria described in Article 3.1.18.4. of the Code are expanded upon in Section 5.3.2.7 Encapsulation Criteria and Allowable Exposed Surfaces.

Non-encapsulated, exposed Mass Timber elements can provide a degree of fire resistance, due to their inherent low surface area to volume ratio and the highly predictable charring characteristics of wood. They can be designed with sacrificial depth or layers that will char during fire exposure while the remaining uncharred portions continue to provide the required structural capacity. The sacrificial char layer depth can be reduced or eliminated where encapsulation is provided. Refer to Section 5.5.2 Encapsulation and Fire-Resistance Rating for more detail on encapsulation requirements.

Compared with light wood frame construction, Structural Mass Timber typically has greater dimensional accuracy, stability, and mass. There are numerous Structural Mass Timber beam and panel products on the market that, in terms of overall dimensions, would appear to be interchangeable. However, they may differ considerably in terms of structural properties, spanning capabilities, moisture movement characteristics, and availability in the local market. It is recommended that manufacturers be consulted before making final material choices.

Familiar panel products include Cross-Laminated Timber (CLT), Nail-Laminated Timber (NLT), and Dowel-Laminated Timber (DLT), all of which are commonly used for floor and roof systems and sometimes for wall systems. CLT is also used for shearwalls. Laminated Veneer Lumber (LVL) can also be used for floors, either on its own where structural loads permit, or in timber-concrete composite assemblies.

The most commonly used product for posts and beams is glue-laminated timber (glulam), but both Parallel-Strand Lumber (PSL) and LVL are sometimes used. Glulam consists of layers of dimensional lumber bonded together with durable, moisture-resistant structural adhesives. In glulam beams, the grain of all laminations runs parallel with the length of the member.

Adhesives used in Mass Timber manufacturing are evolving, becoming more fire resistant, more environmentally sustainable, and stronger. The adhesives are subject to testing that includes bond strength under fire, moisture, and weathering criteria.

Refer to Sentence 3.1.18.3.(3) of the Code for the requirement that adhesives meet the elevated temperature performance of ANSI/APA PRG 320, Standard for Performance-Rated Cross-Laminated Timber. Note that the elevated temperature requirements of ANSI/APA PRG 320 are the only requirements reiterated in, and therefore mandated by, the Code. Structural adhesives used in other Structural Composite Lumber must meet the CSA O112 Series, Evaluation of Adhesives for Structural Wood Products and ASTM 5456, Standard Specification for Evaluation of Structural Composite Lumber Products.

Table 5-1 below is adapted from Table 3.1.18.3. of the Code, which specifies the minimum dimensions for Structural Mass Timber members such that the members maintain sufficient mass and volume to perform as Structural Mass Timber members after the specified 2-hour fire duration.

Note that while a wall that is a fire separation is not usually exposed to a fire on both sides, a wall that is not a fire separation could be exposed to a fire on both sides. Row 2 in Table 5-1 below addresses that situation.

Table 5-1: List of Minimum Dimensions of Structural Mass Timber Elements in EMTC(1) [a]

STRUCTURAL WOOD ELEMENTS	MINIMUM THICKNESS, mm	MINIMUM WIDTH x DEPTH, mm x mm
Walls that are fire separations or exterior walls (1-sided exposure)	96	--
Walls that require Fire-Resistance Rating, but are not fire separations (2-sided exposure)	192	--
Floors and roofs (1-sided exposure)	96	--
Beams, columns, and arches (2- or 3-sided fire exposure)	--	192 x 192
Beams, columns, and arches (4-sided fire exposure)	--	224 x 224
Notes to Table 3.1.18.3.: (1) See Note A-Table 3.1.18.3.		

NOTE:

[a] Adapted from: *BCBC 2018*, Table 3.1.18.3.

Mass Timber Products

Cross-Laminated Timber Panels

CLT is a proprietary engineered wood product that is prefabricated using several layers of kiln-dried lumber, laid flat, and glued together on their wide faces. The glue is applied either to both the faces and edges of each board (edge-glued) or on the faces of each board only (non–edge-glued). Boards may also be finger-jointed and glued in the longitudinal direction. CLT has good dimensional stability and, in the case of panels having five layers or more in thickness, two-way spanning capability.

CLT panels are fabricated with an odd number of layers so the outermost layers have the same orientation of grain. When used in a one-way spanning application, the grain of the outer layers is aligned parallel to the span.

Laminations typically vary in thickness from 17 mm to 35 mm, with typical panel depth dimensions ranging from 51 mm to 385 mm, depending on the manufacturer's capabilities. Current technologies can create panels with 3 to 11 lamellas. Panel widths in North America are typically 2.4 m and 3.0 m, with a maximum of 3.5 m. The maximum length of a panel is in the range of 12 m to 19.5 m, depending on the manufacturer.

CSA O86-19 and ANSI/APA PRG 320 both outline recommended constructability and manufacturing criteria for CLT manufacturers and performance requirements for Mass Timber. The ANSI/APA PRG 320 standard is used to certify CLT products and has requirements for lumber, Structural Composite Lumber (SCL), adhesives, end joints, face joints, edge joints, panel dimensions, and panel structural performance. This standard provides the CLT classifications for appearance and wood species and, most importantly, adhesive criteria, that are needed to meet the EMTC provisions of the Code. As previously discussed, this adhesive criteria for elevated temperature performance requirements, outlined in Sentence 3.1.18.3.(3), is the only requirement and reference to this document in the Code. The standard adhesives used for CLT panels may vary between manufacturers, and not all products meet the required standard for EMTC.

Nail-Laminated Timber Panels

NLT panels are made up of regular solid sawn framing members (e.g., 38 mm x 89 mm, 38 mm x 140 mm) arranged side-by-side on edge and fastened together with nails. The thickness of NLT panels therefore follows standard dimension lumber sizes (e.g., 89 mm, 140 mm), although when diaphragm action is required, a layer of plywood or other sheathing material is applied on top, increasing the thickness. See Section 5.7.3.5 Diaphragms for more information. Widths are in increments of 38 mm, with 1,216 mm (32 laminations) being typical.

NLT panels can be made from a variety of wood species and fabricated by experienced carpenters without specialized equipment. Dimensional lumber is typically available in lengths up to 6 m, but longer spans can be achieved by overlapping and staggering adjacent members. It is worth noting that NLT panels are extremely difficult to recycle at end of life, due to the presence of so many nails.

Specification is based on the grade of solid sawn material used and design is based on the nail-laminated decking section of CSA O86-19; and there are no applicable standards for the finished panels. Because these panels are made from solid sawn material, they are more susceptible to moisture damage than other engineered products, so protection during transportation, throughout construction and construction, and prior to closing in, is particularly important. Having no continuous glue bonds, NLT panels are permeable to both vapour and smoke and must be sealed where such permeability would be a problem. In-service shrinkage of all wood products is related to the difference between the MC at the time of the fabrication and the equilibrium MC when in service. As solid sawn lumber typically has a higher MC at the time of fabrication, in-service shrinkage is likely to be greater than that for glued products fabricated at a lower MC.

Dowel-Laminated Timber Panels

DLT panels are similar to NLT panels in that they are fabricated using solid sawn dimension lumber arranged side by side on edge. Like NLT panels, a variety of wood species can be used, and the design is based on the nail-laminated section of CSA O86-19. However, rather than being nailed together, the members are connected using tight-fit hardwood dowels. These dowels are dried to a lower MC than the softwood panel members, installed, then left to expand until their MC equals that of the panel. The result is an extremely tight fit, which enables the panels to be handled and installed as a single component. While fabrication is most often mechanized, it is possible to fabricate DLT panels by hand using jigs, similar to NLT panels.

Panel sizes are similar to those cited for NLT panels above, although sometimes DLT is planed a second time, which reduces the size of the individual members by a few millimetres in each direction. When long-span panels are required, individual members are finger-jointed and glued to increase the length. These joints are staggered to avoid creating weak spots in the panel. It is worth noting that the dowels do not contribute to the overall strength of the panels once installed but simply facilitate handling, as noted above. Like NLT panels, DLT panels require sheathing if they are to contribute to the lateral resistance of a structure, and must be sealed if their inherent permeability to vapour and smoke is an issue.

Similar to NLT panels, it is important to account for shrinkage and swelling when coordinating and detailing tolerances of DLT panels.

Laminated Veneer Lumber Panels

LVL is produced by bonding thin wood veneers together in a large billet. Because LVL is made with scarfed or lapped jointed veneers, LVL panels are available in lengths far beyond conventional lumber lengths. As an engineered panel product, it is uniform in appearance and highly predictable in performance. The veneers used in LVL panels are dried and graded (similar to plywood) and bonded with waterproof glues.

Because knots, slope of grain, and splits have been dispersed throughout the material or eliminated altogether, LVL panels are virtually free from warping and splitting. In its standard form (in which all veneers are oriented with their grain parallel to the length of the panel), LVL panels can be used for floors, walls, and roofs. When diaphragm action is required to resist lateral forces, joints between panels can be detailed to transfer these loads.

LVL panels can also be manufactured with approximately 20% of the veneers oriented perpendicular to that of the other veneers in the billet. This partially cross-laminated panel has greater shear strength and effective span than conventional LVL panels.

Panel sizes may vary according to manufacturer, but common LVL panel thicknesses are 45 mm and 90 mm. Available widths also vary according to manufacturer and could be limited to 1.2 m or 2.5 m. Lengths are generally available from 7.2 m to 13.2 m, in 1.2 m increments, with special orders of up to 18 m.

Mass Plywood Panels

Mass Plywood Panels (MPP), a recent arrival in North America, are manufactured in a similar manner to LVL panels, with partial cross lamination of veneers so the grain differs. These panels are built up in increments of 25 mm-thick plywood panels, and can be produced in lengths up to 15 m and thicknesses from 50 mm to 600 mm. MPP have been fire tested and approved for buildings up to 18 storeys in the United States. As the name suggests, MPP is laid up with alternating plywood layers at right angles to one another, has two-way spanning capability, and has similar structural characteristics to regular plywood, but with the fire performance of Mass Timber.

Glue-Laminated Timber Panels

Glue-laminated timber (GLT) panels use solid sawn framing members arranged side by side on edge and glued together under pressure in a billet style manufacturing process. They are similar to glulam beams, but rather than being oriented vertically, they are laid flat to span between walls or beams; the same fabrication standards which apply to glulam beams and columns apply to GLT panels. These one-way spanning panels are typically up to 600 mm wide, 44 mm to 327 mm deep, and up to 12 m in length. Since GLT panels are limited in width, diaphragm action between each panel must be achieved through the use of plywood or similar sheathing. Because the individual boards are bonded face to face with glue, GLT panels are more dimensionally stable than either NLT or DLT panels.

5.3.2.4 Procurement Considerations

Manufacturing Capabilities

The introduction of EMTC provisions in the Code is expected to increase both capacity and choice in BC’s Structural Mass Timber industry, although this transformation may take some time.

At present, differences in manufacturing capabilities among fabricators of Structural Mass Timber products may impact design and detailing choices. For example, a fabricator with a 5-axis computer numerically controlled (CNC) machine will be capable of milling more complex shapes than one with a 3-axis machine; and whether or not a particular fabricator has machinery capable of flipping a Mass Timber panel will have a direct impact on the cost of milling panels on both faces.

As well, production capacity and market demand for a particular product may influence both price and availability; therefore, it is recommended that Architects work closely with manufacturers to optimize solutions and evaluate the implications of market fluctuations. In addition, lead times for Structural Mass Timber products can be long, so it is important to engage regularly with preferred manufacturers to optimize lead times and stay informed of any changes in production schedules.

The design team should endeavour to achieve the requisite understanding of tolerances and material constraints. It is beneficial for the Architect and the SER (and in some cases other members of the design team) to visit the manufacturing facility to gain a better understanding of the physical constraints, machining techniques, tolerances, and other aspects of fabrication.

For procurement for large projects, it can be advantageous to source from multiple manufacturers. When considering new or unfamiliar products (particularly those from Europe), design teams should first determine if the products have been tested and approved for use in Canada, and must consider the implications of using the products if they have not.

Constructability Considerations

Premanufactured Structural Mass Timber presents various advantages and challenges; one of the most important considerations in prefabricated component design is constructability. Often the greatest stresses on individual components are experienced during transportation and construction, usually while being lifted on or off a truck or into place on site. These stresses may influence the overall depth or length of components and must be considered during the design process.

Another consideration is the sequencing and placement of Structural Mass Timber components during construction, particularly their interface with structural elements that have differing construction tolerances and erection schedules. The erection of precisely machined Mass Timber components can be fast and efficient but becomes less so when they interface with other materials with different tolerances. Therefore, the construction sequence and schedule should take this possibility into consideration. A more detailed discussion on this topic from the constructor's perspective can be found in Section 5.3.5 Constructability Considerations.

Procurement considerations relating to constructability are further described in the following subsections.

Off-Site Prefabrication

Premanufactured Structural Mass Timber is typically precision-milled using CNC machines. Also, 3D software capable of using design documents or shop drawing files to create instructions for automated milling machines for Mass Timber fabrication is typically used in production. See Section 5.3.5.2 Advantages of Factory Prefabrication for more information.

Mass Timber Availability

Mass Timber components can be sourced from different parts of the world, and their attributes may vary in terms of wood species, structural performance, finish, lamella thickness, and specification (e.g., edge-glued or non-edge-glued CLT), among others. Therefore, there will be differences in cost and the logistics of transportation. CLT must meet the requirements of ANSI/APA PRG 320, Standard for Performance-Rated Cross-Laminated Timber, as per Sentence 3.1.18.3.(3) of the Code. Note that some

European manufacturers do not meet that standard.

Mass Timber as Part of a Building System

Increasingly, the beam and panel products that are fundamental components of EMTC are designed and manufactured as part of a prefabricated Mass Timber building system. These systems typically include floor panels, wall panels, columns, and/or façade panels, which used together reflect a more integrated approach to building design.

Volumetric prefabrication, in which the structural elements are assembled in the factory to create three-dimensional modular units, requires special attention to the logistics of transportation and construction. The requirement for factory inspections during fabrication should be carefully considered, as should the sequencing of site assembly to facilitate the required field inspections by the AHJ. This may have time and cost implications.

Design for Manufacturing and Staging

The design of EMTC buildings requires the coordination of key aspects of design and construction, such as optimal component sizing, fabrication, transportation, site staging, sequencing, and construction logistics.

The use of off-site prefabricated elements for projects with constrained sites and limited setbacks may present particular challenges for the protection of adjacent properties. Similarly, life-safety considerations during construction may affect construction sequencing and may require consultation with the AHJ and adjacent property owners.

Integration of Services

Mass Timber should be prefabricated off site in a controlled environment, as modifications on site can be difficult and costly. Therefore, careful planning of details and the integration of mechanical, electrical, and plumbing (MEP) services should be carefully coordinated during design.

Transportation

As noted previously, the design team should identify and confirm size and weight limitations for the transportation of Mass Timber components by road, by rail, or in shipping containers, and acquire any required special permits.

For components transported by road, the standard maximum width for a loaded truck without any special permits is 2.6 m, the maximum length is 12.5 m, and the maximum height is 4.15 m. In addition, the load cannot project more than 1 m ahead of the front bumper, 1.85 m behind the back of the vehicle, or 4.5 m behind the centre of the last axle. For a truck, the load cannot be wider than the sides of the vehicle. Some routes may have tighter height and width restrictions. If oversize loads cannot be avoided, the design team should be aware that additional restrictions may be imposed regarding routes, timing, and a requirement for pilot cars.

For products transported by ship from Europe or elsewhere (as both CLT and glulam frequently are) the maximum width of a standard container is 2.35 m, the maximum height is 2.39 m, and the maximum length is 12 m.

5.3.2.5 Lateral Systems

For taller wood buildings, such as EMTC up to 12 storeys, the more stringent requirements for the design of lateral systems may impact the plan arrangement of the building and the integration of building systems.

Shear-resisting elements in the vertical plane, whether shearwalls or cross-bracing, are required in both directions and should generally be evenly spaced throughout the floor plan.

If these elements are constructed using Structural Mass Timber panel products, they are likely to be more numerous, longer, and more closely spaced than a concrete or steel lateral system. The ability of horizontal Structural Mass Timber members to transfer lateral loads efficiently and in a small structural depth is less than that of a similarly configured concrete or steel system. As such, there is considerable benefit to stacking Mass Timber lateral-force–resisting elements for the height of the structure. There are Code restrictions for CLT shearwalls that limit the overall building height to 20 m or 30 m, depending on the seismicity of the site.

The other critical component of lateral systems is diaphragms; diaphragms are needed to transfer lateral forces to the vertical elements and hence to the ground. CLT diaphragms offer more stiffness and strength, compared to plywood diaphragms used in conjunction with one-way systems (e.g., NLT, DLT, GLT), and can generally span greater distances between braces or shearwalls of any type. Providing the required lateral resistance by using concrete stair and elevator shafts, or by using vertical steel cross-bracing, may offer more flexibility in plan. See Section 5.7.3 Lateral Considerations for more information on shearwalls.

5.3.2.6 Strategies for the Transfer of Vertical Loads

Preferably, lateral and gravity load paths through EMTC should be continuous, without horizontal offsets. While it is possible to have horizontal offsets in wood construction by using transfer slabs or trusses, such offsets are more challenging and require greater structural depth than they would in steel or concrete construction.

These considerations in EMTC building projects require both rigour in the design of the structural system, and a commitment to the optimal plan layout earlier in the design than might be required in traditional steel or concrete construction. Additional consideration should be given to mixed-use buildings, where changes in program from one floor to the next may require a change in the structural grid.

5.3.2.7 Encapsulation Criteria and Allowable Exposed Surfaces

All exposed surfaces of Mass Timber elements should be protected from other adjacent spaces in the buildings, including concealed spaces, as per Sentence 3.1.18.4.(1) of the Code. An Encapsulation Rating of no less than 50 minutes can be achieved using gypsum board, gypsum concrete, Noncombustible material, or materials that conform to Sentences 3.1.5.1.(2) to (4) of the Code. Encapsulation requirements for EMTC can be met by using a combination of the following two strategies:

- A concrete or gypsum-concrete topping of 38 mm on the upper side of Mass Timber floor or roof assembly.
- Two layers of 12.7 mm, Type X gypsum board covering all other elements.

Alternatively, performance can be tested following the CAN/ULC-S146, Standard Method of Test for the Evaluation of Encapsulation Materials and Assemblies of Materials for the Protection of Structural Timber Elements.

When the majority of interior surfaces meet the encapsulation criteria for EMTC, the Code permits certain other surfaces to have an exposed Mass Timber finish. While this may be desirable to showcase the material, exposing Mass Timber in rated assemblies creates additional challenges, such as meeting acoustic performance and FSR requirements. See Subsection 3.1.19. of the Code for more information.

The allowable percentage of exposed Mass Timber surfaces varies from 10% to 35% within a fire compartment or suite, based on the following criteria:

- Per Sentences 3.1.18.4.(1), (2), and (3) of the Code,
  - the total exposed surfaces with an FSR not more than 150 of Mass Timber beams, columns, and arches within a suite, calculated in 3D, may not exceed 10% of the total wall area of the perimeter of the suite.
  - In Vancouver only, the provisions are more restrictive. Permissions for exposed Mass Timber within residential suites per Sentence 3.1.18.4.(3) of the BCBC do not apply to residential suites in the VBBL.
- Per Sentences 3.1.18.4.(1), (2), (4), and (5) of the Code,
  - the total exposed surfaces with an FSR not more than 150 of walls facing the same direction within a suite is unlimited, except that the total area of exposed surfaces within the suite, including walls, ceilings, beams, columns, and arches, may not exceed 35%.
  - In Vancouver only, the provisions are more restrictive. Permissions for exposed Mass Timber within residential suites per Sentence 3.1.18.4.(4) of the BCBC do not apply to residential suites in the VBBL.
- Per Sentences 3.1.18.4.(1), (2), and (6) of the Code,
  - the total exposed surfaces with an FSR not more than 150 of ceilings within a suite is 10%, or it can be 25% if the suite has no exposed walls and the FSR of the exposed ceiling is not more than 75.
  - In Vancouver only, the provisions are more restrictive. Permissions for exposed Mass Timber within residential suites per Sentence 3.1.18.4.(6) of the BCBC do not apply to residential suites in the VBBL.

The FSR of Structural Mass Timber panels usually ranges between 40 and 70, but the actual FSR must be determined based on wood species and manufacturer’s data.

These can be specified as “finish grade” and sealed for long-term protection. Special care may be needed to avoid physical or moisture damage from occurring during manufacture, delivery, and construction. These measures may result in additional cost.

5.3.2.8 Flame-Spread Rating Requirements for EMTC High Buildings

Unencapsulated Mass Timber has an FSR greater than 25; therefore, it cannot be used in an exit, including a lobby used as an exit.

Per Sentence 3.1.13.7.(12) EMTC of the Code, FSRs required by Subsections 3.1.13. and 3.1.18. apply to exits for EMTC buildings, except for doors and for exposed Structural Mass Timber beams, columns, and arches conforming to Sentence 3.1.18.4.(3) of the Code.

Table 5-2: List of Flame-Spread Ratings [a]

OCCUPANCY, LOCATION, OR ELEMENT	MAXIMUM FLAME-SPREAD RATING FOR WALLS AND CEILINGS	
	SPRINKLERED	**NOT SPRINKLERED**
Group A, Division 1 occupancies, including doors, skylights, glazing, and light diffusers and lenses	150	75
Group B occupancies	150	75
Exits[(1)]	25	25
Lobbies described in Sentence 3.4.4.2.(2)	25	25
Covered vehicular passageways, except for roof assemblies of heavy timber construction in the passageways	25	25
Vertical service spaces	25	25
Notes to Table 3.1.13.2.: (1) See Articles 3.1.13.8. and 3.1.13.10.		

NOTES:

[a] Adapted from: *BCBC 2018*, Table 3.1.13.2.

5.3.2.9 Combustible Interior Elements, including Concealed Spaces

The combustibility of interior elements is a critical issue for fire safety. EMTC has specific requirements to minimize fire load in the interior of the building. Concealed spaces that may exist between Mass Timber elements and encapsulation material, exposed ceiling finishes, or small service cavities require careful consideration.

Per Sentence 3.1.18.3.(4),) of the Code, concealed spaces, when they are present, must be limited in size by fire blocks and sprinklered, or be completely filled with mineral fibre insulation, or be limited in size by fire blocks and lined with gypsum board or other Noncombustible material with an Encapsulation Rating of at least 25 minutes.

Some considerations for common concealed spaces in EMTC include the following:

- Spaces between Mass Timber and encapsulation material in a ceiling for the use of wood nailing elements used for fastening the encapsulation material can be up to 25 mm, per Sentence 3.1.18.9.(1) of the Code.
- Spaces between Mass Timber and interior finishes that require insulation or space for attaching interior finishes can be up to 50 mm, per Sentence 3.1.18.9.(2) of the Code. If the assembly has an FSR of 25, or mineral fibre insulation, the requirements can be met without testing.

In addition to meeting the criteria for encapsulation and interior finishes, concealed spaces within ceilings must conform to the following:

- Requirements for fire blocking (Article 3.1.11.7. of the Code) at nailing and supporting elements.
- Concealed spaces not more than 2 m^2 divided with fire blocks are allowed where exposed ceiling finishes have an FSR more than 25, per Sentence 3.1.11.3.(3) of the Code.
- Concealed spaces of 10 m^2 are allowed for raised platform floors, if the FSR is less than 25, per Sentence 3.1.11.3.(4) of the Code.

- Concealed spaces not more than 600 m^2 with a dimension not more than 60 m are allowed, if exposed construction materials have an FSR less than 25. Alternatively, concealed spaces not more than 300 m^2 with a maximum dimension of 20 m are allowed if exposed construction materials have an FSR more than 25, per Sentence 3.1.11.5.(4) of the Code.

To better understand the intent of the EMTC provisions, it is useful to compare the Code requirements for fire blocking and concealed spaces in other construction types with those for EMTC. The maximum permitted dimensions of concealed spaces in EMTC are less than those in other construction types, to minimize the potential for the spread of fire within the concealed spaces. Refer to the tables and diagrams in Section 5.4.4 Building Enclosure Assemblies and Materials and to Section 5.5.4 Concealed and Service Spaces for more information on concealed spaces.

Following are additional Code requirements for Combustible interior elements.

- Flooring elements, per Article 3.1.18.10. of the Code:
  - Wood members greater than 50 mm but not greater than 300 mm can be used on Structural Mass Timber elements in a raised platform if the platform meets fire block and concealed space requirements outlined in Subsection 3.1.11. of the Code.
- Stairs, per Article 3.1.18.11. of the Code:
  - Exit Stairs can be of EMTC, and wood stairs within a suite do not need to conform to requirements for Structural Mass Timber elements or encapsulation requirements.
- Interior finishes, per Sentence 3.1.18.12.(1) of the Code:
  - Combustible Interior wall and ceiling finishes of not more than 1 mm thickness are permitted.
- Interior finishes, per Sentence 3.1.18.12.(2) of the Code:
  - Combustible Interior wall finishes, other than foamed plastics, not more than 25 mm thick are permitted, provided they have an FSR of not more than 150 on any exposed surface, or any surface exposed if cut through the material in any direction.
- Interior finishes, per Sentence 3.1.18.12.(3) of the Code:
  - Combustible interior ceiling finishes, other than foamed plastics, not more than 25 mm thick are permitted, provided they have an FSR of not more than 25 on any exposed surface, or any surface exposed if cut through the material in any direction, except that up to 10% of the ceiling in the fire compartment may have a FSR of not more than 150.
- Interior finishes, per Sentence 3.1.18.12.(4) of the Code:
  - Combustible interior ceiling finishes made of fire-retardant–treated wood are permitted, provided they are not more than 25 mm thick, or are exposed fire-retardant–treated wood battens.

- Partitions, per Article 3.1.18.13. of the Code:
  - Solid lumber partitions and light wood frame stud wall partitions with a minimum dimension not less than 38 mm are not required to conform to Article 3.1.18.3. of the Code, provided:
    - they are protected by 12.7 mm, Type X gypsum board on both sides, taped and filled; or
    - they are solid lumber partitions, protected by a single layer of 19 mm fire-retardant–treated wood on both sides; or
    - they are light wood frame partitions, with a single layer of 19 mm fire-retardant–treated wood on both sides, and filled with Noncombustible insulation.
  - Such walls cannot be enclosures for fire exits or vertical service spaces.
- Outlet box penetrations, per Sentence 3.1.9.4.(2) of the Code, and cutouts, per Article 3.1.18.15. of the Code:
  - Outlet box penetrations and cutouts for television, data, electrical, and similar elements can penetrate the Mass Timber with Noncombustible outlet boxes, provided they do not exceed 0.016 m^2 in area and an aggregate area of 0.065 m^2 in any 9.3 m^2 of surface area. There must not be a gap larger than 3 mm between an outlet box and fire separation material. Outlet box penetrations and outlet boxes on opposite sides of Mass Timber elements must be separated by 600 mm. See Note A-3.1.9.4. of the Code for examples of what is considered an outlet box.

For EMTC, Noncombustible outlet boxes are required. Combustible outlet boxes may be more readily available, so it is important that the correct outlet boxes be specified and reviewed for compliance in the field. Per Sentence 3.1.18.15. (1) of the Code, the minimum dimension requirements for Structural Mass Timber elements in Clause 3.1.18.3.(2)(c) of the Code—need not apply to the locations where outlet boxes are installed in the element in accordance with Article 3.1.9.4. of the Code. Additionally, per Sentence 3.1.18.15.(2) of the Code, the exposed surfaces within the penetration do not require protection in accordance with Sentence 3.1.18.4.(1) of the Code.

See also Section 5.8.3 Fire Protection Considerations**.**

5.3.2.10 Combustible Exterior Elements

Special attention is required when designing the exterior enclosure of EMTC buildings, particularly if the design includes Combustible elements. Exterior enclosure elements include walls, cladding (Article 3.1.18.7. of the Code), roofing (Article 3.1.18.5. of the Code), and windows (Article 3.1.18.6. of the Code). See Section 5.4.4 Building Enclosure Assemblies and Materials for detailed diagrams of enclosure-related Code provisions and requirements.

Following are additional Code requirements for Combustible exterior elements.

- Combustible roofing materials, per Sentences 3.1.18.5.(1) and (2) of the Code:
  - Wood sheathing and their supports are permitted to be Combustible if they are above the 50 mm Noncombustible concrete topping or an encapsulated assembly. See the diagram in Section 5.4.4.2 Roof Assemblies.
- Parapets, per Sentence 3.1.18.5.(3) of the Code:
  - Wood nailing facings on parapets can only be 600 mm high and require sheet metal.

- Combustible window sashes and frames, per Article 3.1.18.6. of the Code:
  - Windows can be Combustible if they meet a minimum of 1 m distance from one another, and they are separated by Noncombustible or EMTC with a total area of a maximum of 40% of the total area of exterior wall face in a fire compartment. See Section 5.4.4.4 Windows for further explanation.
- Exterior cladding, per Article 3.1.18.7. of the Code:
  - Exterior cladding can be Combustible if it meets the requirements of maximum area, distance between members, fire spread rating criteria, and dimensions. See Article 3.1.18.7. of the Code for critical dimensions. The cladding requirements under Article 3.1.18.7. of the Code do not supersede the provisions in Subsection 3.2.3. of the Code regarding spatial separation and exposure protection.

5.3.2.11 Systems Integration

Integration and coordination of systems in EMTC during the design stage has considerable impact on the success of the project. Careful consideration should be given to completely eliminating, or at the very least minimizing, the need for modifications to Structural Mass Timber columns, beams, and panels in the field to accommodate integration of systems. Such modifications are difficult to achieve accurately, and they cause delays, negating the advantage of speed of construction that is inherent in Mass Timber construction.

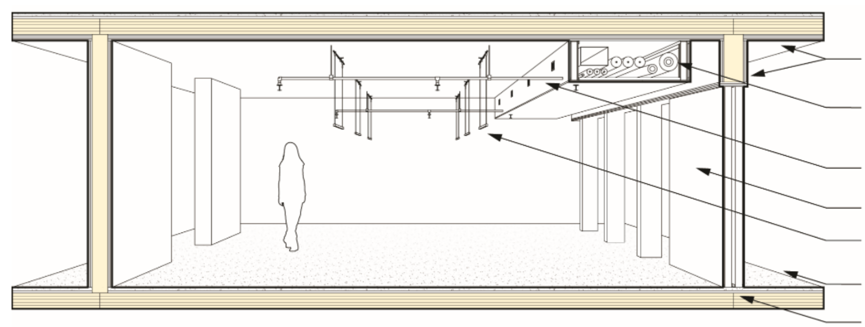
Avoiding such changes in the field requires MEP consultants to confirm all routing, diameters, gradients, suspension details, and insulation requirements for ducts, conduits, and pipes—particularly where these pass through Structural Mass Timber elements—much earlier in the design process than is required in other methods of construction.

Identifying and coordinating all systems and services and the associated Code requirements requires a significant level of cooperation, with a rigorous, systematic approach, as all the required penetrations will be milled off-site.

Developing a strategy for the routing and integration of MEP services should be considered early in the design process, and should include calculations to confirm final duct and pipe sizes, and the routing pathway throughout the building. Vertical service runs may be placed in a fire-rated shaft or within a service wall, with appropriate EMTC treatment of any concealed space. Some services can be exposed, specifically if the piping is Noncombustible. There are both benefits and challenges regarding the use of fire-rated shafts, including but not limited to potentially less stringent coordination for duct, pipe, and insulation requirements, as well as access to services. The same considerations for fire dampers and services travelling through fire compartments apply to EMTC as they do to a conventional concrete or steel building. Ventilation systems, whether decentralized or centralized, should be defined early in the design process. See Figure 5-2: Illustration of systems integration design below.

See Section 5.8.2.2 Routing Considerations and Section 5.8.7.1 Prefabrication for more on mechanical and electrical systems integration.

Figure 5-2: Illustration of systems integration design



5.3.2.12 Exposed Building Faces and Windows

Spatial separation requirements in the Code must be considered when designing the exterior elevations. The area of openings in an exposing building face is limited to the percentages prescribed in the Code. As the limiting distance (i.e., the distance from building face to property line) increases, the percentage of allowable openings increases.

Structural Mass Timber walls are not permitted when the maximum area of unprotected openings is from zero to 10%. This will be an important early consideration for zero lot line and urban infill sites. Generally, an EMTC wall cannot be closer than 1.2 m to a property line.

As with any building, considerations for natural ventilation, daylighting strategies, and overall appearance of the building will be impacted by the maximum areas of unprotected openings, as per Table 3.2.3.7. of the Code (see Table 5-3 below).

Combustible Window Sashes and Frames

Some clients may prefer wood windows instead of aluminum windows, to maximize the amount of wood in the building. Per Clause 3.1.18.6.(1)(b) of the Code, Combustible windows on exterior walls in contiguous storeys must be separated by not less than 1 m of Noncombustible wall, or by a wall constructed of Structural Mass Timber that is at minimum 96 mm thick.

For Combustible windows, the aggregate area of openings in an exterior wall face of a fire compartment cannot be more than 40% of the area of the wall face. See Section 5.3.2.10 Combustible Exterior Elements and Section 5.4.4.4 Windows for details.

5.3.2.13 Additional Requirements for High Buildings

EMTC buildings where the floor level of the highest storey is greater than 18 m above grade must comply with the High Building requirements, as per Sentence 3.2.6.1.(1) of the Code. Note that the requirements for EMTC limits the building height to not more than 42 m, measured between the floor of the first storey and the uppermost floor level.

High Buildings have limits for smoke movement, restrictions on connected buildings, and requirements for the emergency operation of elevators, elevator use by firefighters, venting to aid firefighting, central alarm and control facilities, and voice communication systems. For buildings taller than 25 m, a roof covering of class A is required, per Sentence 3.1.15.2.(4) of the Code.

Table 5-3: List of Minimum Construction Requirements for Exposing Building Faces [a]

OCCUPANCY CLASSIFICATION OF BUILDING OR FIRE COMPARTMENT	MAXIMUM AREA OF UNPROTECTED OPENINGS PERMITTED, % OF EXPOSING BUILDING FACE AREA	MINIMUM REQUIRED FIRE-RESISTANCE RATING	TYPE OF CONSTRUCTION REQUIRED	TYPE OF CLADDING REQUIRED
Group A, B, C, D, or Group F, Division 3	0 to 10	1 h	Noncombustible	Noncombustible
	>10 to 25	1 h	Combustible, encapsulated Mass Timber, or Noncombustible	Noncombustible
	>25 to 50	45 min	Combustible, encapsulated Mass Timber, or Noncombustible	Noncombustible
	>50 to <100	45 min	Combustible, encapsulated Mass Timber, or Noncombustible	Combustible or Noncombustible(1),(2)
Group E, or Group F, Division 1 or 2	0 to 10	2 h	Noncombustible	Noncombustible
	>10 to 25	2 h	Combustible, encapsulated Mass Timber, or Noncombustible	Noncombustible
	>25 to 50	1 h	Combustible, encapsulated Mass Timber, or Noncombustible	Noncombustible
	>50 to <100	1 h	Combustible, encapsulated Mass Timber, or Noncombustible	Combustible or Noncombustible(1)

Notes to Table 3.2.3.7.:

(1) See also Article 3.1.4.8. for additional requirements for exterior cladding on buildings conforming to Article 3.2.2.50. and Article 3.2.2.58.

(2) The cladding on Group C buildings or parts thereof conforming to Article 3.2.2.48EMTC. and on Group D buildings or parts thereof conforming to Article 3.2.2.57EMTC. must conform to Sentence 3.1.18.7.(2) or be Noncombustible.

NOTE:

[a] Adapted from: *BCBC 2018*, Table 3.2.3.7.

5.3.2.14 Constraints on Certain Architectural Features

Balconies

Architects should consider the implications of thermal bridging. Also, balconies greater than 610 mm in depth are required to be sprinklered. The floor assembly must be of Noncombustible Construction or in accordance with the minimum Structural Mass Timber elements in Table 3.1.18.3. of the Code, but need not be encapsulated per Sentence 3.1.18.4.(1) of the Code. See Sentence 3.2.2.11.(2) of the Code for balcony construction with no encapsulation.

See also Section 5.4.4.5 Balconies, under the subsection Balcony Designs and Structural Connection Types for diagrams and tables describing various types of balconies.

5.3.2.15 Opportunities for Certain Architectural Features

While design teams have many Mass Timber products to choose from, material selections and technology will continue to evolve to meet the needs of the Mass Timber industry.

Since EMTC is relatively new to North America, choice of local products and systems may be limited. Different wood species, adhesives, and lamination processes, along with advances in connection systems and other technologies, will begin to appear on the market. More established Mass Timber markets may offer proven solutions to fabrication and construction challenges not previously encountered in Canada. It is important to confirm with the manufacturer that such solutions and their associated standards meet the Code-mandated Canadian standards.

5.3.2.16 Tolerances

As with steel and concrete components, the tolerances required for site assembly of prefabricated Structural Mass Timber elements can accumulate during installation. This situation can be mitigated by early consideration of junction details and site sequencing.

EMTC requires particular attention with regard to prefabricated panel layouts, column alignments, shop drawing verification, and tolerances between prefabricated and site-built elements or between different materials. Site-built concrete and steel structures, such as cores, elevator shafts, and fire exit stairs, have significantly larger tolerances than Structural Mass Timber elements, making the use of these non-EMTC materials in some locations an important consideration in hybrid construction. Other considerations include the potential for steel and concrete to transfer heat and moisture to adjacent Mass Timber elements.

Refer to Section 5.3.5.5 Tolerances for Factory versus Site Construction.

5.3.3 STRUCTURAL SYSTEM CONSIDERATIONS

Careful consideration of the architectural design in relation to the structural system is necessary in EMTC buildings. It is not possible for the architectural design to be effectively implemented without careful consideration of the structural system requirements. See Section 5.7 Structural Considerations. Note that common span assumptions for concrete and steel structural grids do not apply to EMTC buildings.

Structural gravity systems used for EMTC can be divided into four general types, including:

- loadbearing panel systems;
- post and beam frame systems;
- post and panel systems; and
- hybrid systems.

In addition to hybrid gravity systems (see Section 5.3.3.4 Hybrid Systems), hybrid lateral systems allow the use of complementary concrete or steel construction in cores and shear walls, further expanding the structural options. Architects should consult with the structural engineer of record (SER) on suitable gravity and lateral systems for the building, and should confirm the proposed structural approach well ahead of the architectural design development.

The choice of system is determined by a number of factors, including:

- availability of the desired components and related manufacturing technology within a reasonable distance and a competitive market;
- the building program and its requirements for clear spans and spatial flexibility;
- lateral system optimization of materials and assemblies (e.g., the more pieces there are to install for a given floor area, the more expensive the building is likely to be);
- integration with services; and
- parameters affecting transportation.

Depending on whether system components are being delivered by shipping container or truck, this last consideration may conflict with the desire to minimize the number of components. Optimization of these parameters is therefore required very early in the design stage.

5.3.3.1 Loadbearing Panel Systems

Loadbearing panel systems have been used for more than a decade in Europe, primarily in residential buildings as a replacement for traditional techniques, such as loadbearing brick or concrete masonry. In these structures, CLT is used for floors, for interior and exterior walls, and sometimes for stair and elevator cores. Most loadbearing CLT projects are rigorous in the structural layout.

Typically constructed in single storey, platform format, this system can use a smaller number of longer panels, resulting in greater efficiency and economy, as well as more flexibility in plan arrangement. However, this system may also have structural redundancies if all the walls in a residential building are CLT, and hence have the potential to carry structural loads. See Figure 5-3: Illustration of loadbearing panel system design.

Because this system is platform-framed, the CLT floor panels form part of the vertical load path. In taller buildings, the effects of cumulative cross-grain shrinkage or crushing may become significant. Potential solutions should be discussed with the SER. See Section 5.3.4.6 Moisture Content of Materials and Components, Section 5.3.5 Constructability Considerations, and, for tolerance descriptions, Section 5.7 Structural Considerations.

Some examples of applications and modifications of this system include:

- factory prefabricated modular volumetric units, prefinished and with services pre-installed; and
- CLT floor panels supported on a central concrete stair and elevator core and interior and perimeter CLT wall panels.

5.3.3.2 Post and Beam Frame Systems

Post and beam frame systems can use either one-way spanning or two-way spanning Structural Mass Timber panels, and can include primary beams or both primary and secondary beams. These variables allow for flexibility in the system and opportunities for optimization of both the panels and beams. See Figure 5-4: Illustration of post and beam frame system design.

Avoiding cross-grain material in the vertical load path is required to minimize shrinkage and crushing. Whether columns are single storey or multi-storey, an effective strategy is to create a modified balloon frame system, in which the base of one column sits directly on the top of the column below it, achieving an end-grain to end-grain bearing condition.

Some effective variations of post and beam systems include:

- installing a fire-protected steel saddle with projecting plates on either side of the column, on which paired beams can be supported;
- notching the columns to provide “shoulders” on which beams can be supported;
- installing primary beams on either side of the columns;
- installing beams of equal depth supported on all four sides of the columns; and
- milling a slot through the centre of the column, enabling a beam to pass through it, and allowing columns above to transfer loads to the remaining end grain of the columns below.

Although optimization of the structural system may result in relatively shallow beams or overall structural depth, the floor-to-floor heights will need to take into account the required clearance in the occupied spaces and the accommodation of horizontal runs of ducts and pipes.

Figure 5-3: *Illustration of loadbearing panel system design*

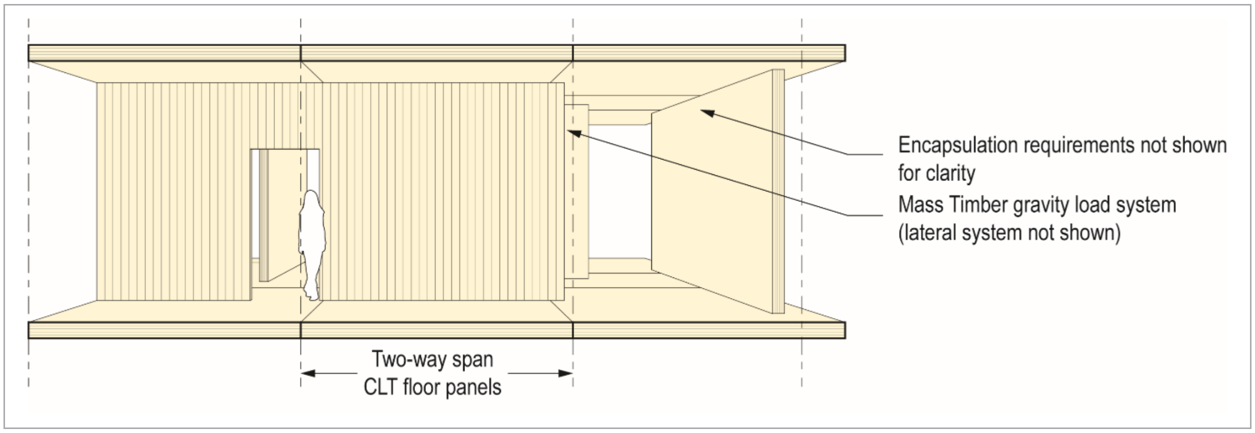
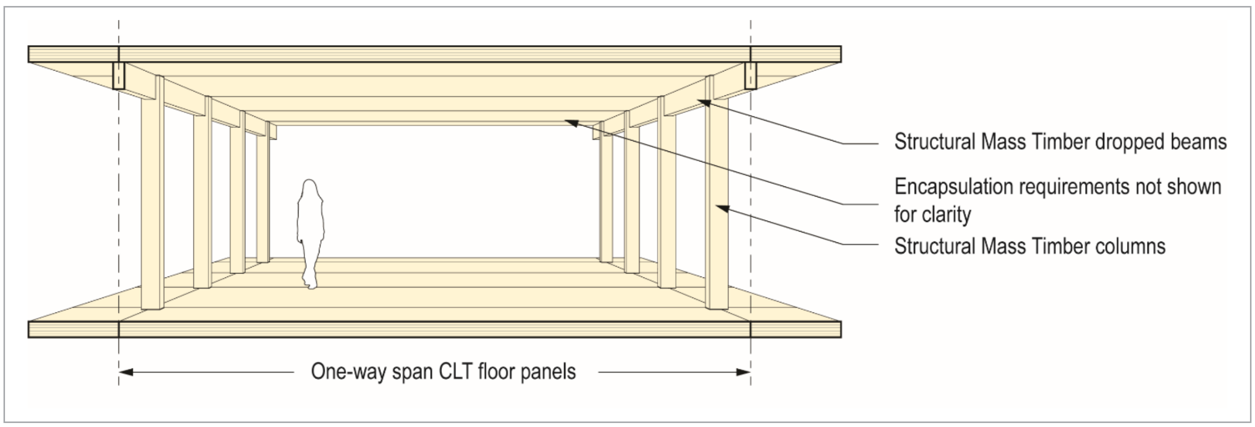


Figure 5-4: *Illustration of post and beam frame system design*



5.3.3.3 Post and Panel Systems

Post and panel systems use the two-way spanning capabilities of CLT panels to eliminate the need for beams, with loads transferring directly from the CLT panels into the columns, and from column to column. An advantage of this system is that it reduces floor-to-floor heights, compared with post and beam frame systems.

The width of the structural grid for these buildings is typically determined by the maximum width of CLT panels, which is currently 3 m in North America. Glulam or steel columns are used to support the four corners of the CLT, with additional columns spaced along either side, as required. It should be noted that CSA O86-19 does not currently provide prescriptive guidance on the design of point supported CLT panels. See Figure 5-5: Illustration of post and panel system design.

5.3.3.4 Hybrid Systems

Hybrid systems are practical in many cases, as structural materials are used in combination for reasons of efficiency and economy.

A variation on the post and panel system is a hybrid concrete and Structural Mass Timber floor panel that is cast-in-place or precast in panels (see Figure 5-6: Illustration of a hybrid system design). These systems use the benefit of continuity of concrete for efficiencies from both materials.

Composite panel systems, which use a combination of manufactured panels and beams to form the structure, may allow for larger spans with a minimal amount of material. These prefabricated systems minimize the number of pieces that need to be erected on site, allowing for the larger spans. These systems are efficient because of the decreased weight of floors, while providing ample depth for concealed spaces for insulation and services between suites.

Another variation of this system is the use of continuous perimeter columns and/or prefabricated wall panels, where the floor panels are hung from the continuous vertical members. The floor panels span from the interior face of the perimeter columns, or are notched around them, to a concrete or steel stair and elevator core. This system is often referred to as “balloon” framing and facilitates the minimization of cross-grain material, and therefore shrinkage, in the vertical load path. See Table 5-11: Overview of Typical Mass Timber Wall Structure Types Used in EMTC.

Figure 5-5: Illustration of post and panel system design

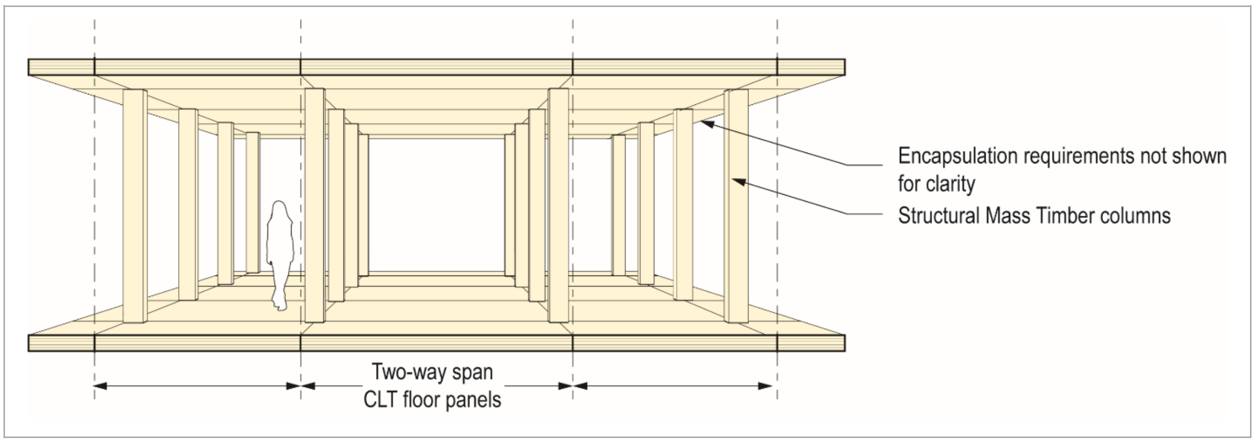
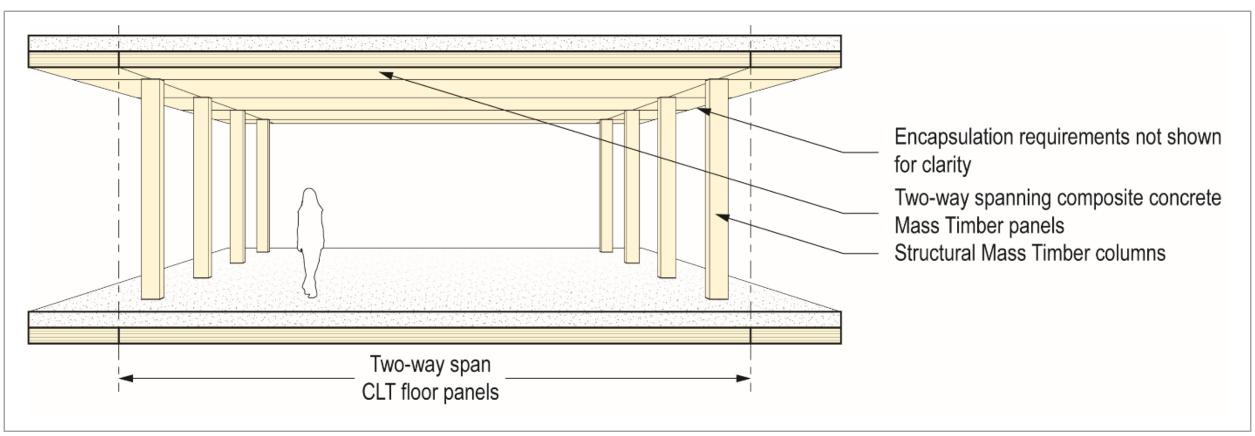


Figure 5-6: Illustration of a hybrid system design



5.3.4 BUILDING PERFORMANCE CONSIDERATIONS

5.3.4.1 Implications of Flooding After Occupancy

The protection of Structural Mass Timber elements during fabrication, transportation, installation, and construction is discussed in Section 5.4.6 Moisture Exposure and Protection of Mass Timber. However, strategies for managing and minimizing the impact of post-occupancy water damage should also be considered. The impact of sprinkler malfunction or plumbing failures in bathrooms and kitchens could be limited if plumbing is arranged back-to-back and connected into a single vertical stack, and if the specification and detailing of floor finishes are carefully considered.

One strategy for protecting against water damage after occupancy is to apply a vapour-permeable waterproof membrane to floor panels, then tape the joints between the panels. Left in place, this membrane can provide additional protection against in-service water damage, as well as protecting against moisture ingress to the panels if a poured-in-place concrete topping is subsequently installed.

A supplemental contingency could be considered to mitigate potential flood damage. Strategies might include installing a secondary drainage system to ensure safe removal of water if there is flooding within the building, or decoupling wood from other materials in areas with significant plumbing and water service runs to promote drying. A moisture management plan could be created that covers the operation of the building.

Installation of moisture sensors to detect the presence of water within wall, floor, and roof assemblies is a measure that could be incorporated to mitigate the risk of extensive water damage post occupancy. Moisture monitoring will allow for early identification of plumbing system or sprinkler system leaks, or building envelope moisture ingress, so it can be addressed before substantial damage occurs.

5.3.4.2 Implications of Fire After Occupancy

As described in the Code, EMTC is intended to give occupants time to exit during a fire, and to prevent structural collapse—the same strategy used for other types of construction. However, the post-fire remediation for Mass Timber will differ from concrete and steel, because the Mass Timber may have been charred to a degree that it no longer provides the required protection against future fires.

To avoid this situation, the design team may consider encapsulation, increasing the depth of the charring layer, or using hybrid systems to facilitate replacement of char-damaged members.

5.3.4.3 Sound Transmission of Mass Timber Panels

Without acoustic treatment, Mass Timber performs poorly in terms of airborne and impact sound control. Many factors should be considered to make sure the building meets its acoustic targets, including Code requirements for residential occupancy. Extra space to allow for greater build-up of walls and ceilings should be included, which may affect floor-to-ceiling heights, floor areas, and clearances required for equipment and access for persons with disabilities.

Structurally, improving acoustic performance may also require that isolation materials be included between Structural Mass Timber panels, to reduce the transfer of noise through the structure.

See Section 5.6.2 Sound Isolation and Section 5.6.3 Impact/Footfall Sound Insulation for more information on acoustical considerations.

5.3.4.4 Susceptibility to Moisture Damage

The susceptibility of different Mass Timber products to moisture damage during fabrication, transportation, installation, and construction varies according to their materials and their manufacturing processes. Generally, those with smaller component parts, such as strands and veneers (and hence a higher percentage of glue content), perform better when exposed to moisture. Those with solid sawn wood members, such as glulam, NLT, DLT, and GLT (and hence a lower percentage of glue content) tend to be more susceptible to moisture damage, particularly when the end grain is exposed. LVL panels can be susceptible to cupping, if exposed to too much moisture.

When Mass Timber products are used in exterior applications, they should be raised off the ground to avoid prolonged exposure to standing water or snow, and should be protected from weather by overhangs or flashings, with connections designed to drain water and permit airflow for drying.

The function and aesthetics of some products and adhesives could deteriorate over time. It is important to consider and agree on the appearance expectations for exposed Mass Timber elements before specifying product types and species, sealants, and fabrication techniques. Such considerations include:

- reviewing test reports and prototypes, to ascertain the extent to which the product is subject to discoloration from UV or water damage;
- determining whether to specify pickled or acetylated wood for increased durability;
- specifying stains or other finishes that protect the wood;
- specifying appropriate coatings and sealants where a maximum FSR is mandated by the Code; and
- creating maintenance schedules and water mitigation strategies, to protect against weathering and deterioration.

5.3.4.5 Permeability of Mass Timber Panels

Unlike concrete, some Mass Timber panels are not inherently smoke tight (unless detailed as such). When considering smoke containment, the permeability of the Mass Timber panel products specified in the area in question is important.

Experience has demonstrated that NLT, and occasionally non-edge-glued CLT, need special attention in order to ensure airtightness. Seams and joints between adjacent panels must be sealed, to achieve the airtightness crucial to the safety of egress routes in case of smoke or fumes from fire or other events.

5.3.4.6 Moisture Content of Materials and Components

Mass Timber panels dry slowly, with most of the moisture being released from the end grain. See Section 5.4.6 Moisture Exposure and Protection of Mass Timber. During installation and prior to the final enclosure of the building, it is very important that the MC does not exceed 19%.

Development of an on-site moisture management plan that addresses monitoring with moisture sensors, installing proper membrane protection, using sealants, employing squeegees, and following procedures for drying CLT, including using on-site heaters and dehumidifiers, is recommended. Moisture testing prior to encapsulation is required to confirm Code compliance

Generally, the equilibrium MC for Mass Timber products installed in buildings in BC is between 8% and 12%, depending on the location and season of the year. Mass Timber products will shrink or expand by roughly 1% perpendicular to grain for every 5% change in MC. Most

Mass Timber products are manufactured to an MC of around 12% plus or minus 3%, while solid sawn lumber may have an MC of as much as 19%.

Depending on the installed MC of a particular product, the maximum MC the product experiences during construction, and how much cross-grain material will be contributing to the overall shrinkage in a building, the cumulative shrinkage over 12 storeys may be significant and will need to be accounted for in the design.

5.3.4.7 Implications of Axial Shortening

In addition to minimizing the effect of moisture movement by controlling the amount of cross-grain material in the vertical load path of EMTC High Buildings, consideration should also be given to the potential issue of axial shortening parallel to grain.

Axial shortening is the result of both shrinkage from changes in MC and compression of loadbearing members as the dead and live loads are applied during construction and after occupancy. Although axial shortening is likely small on any given floor, even 3 mm on each floor could accumulate to more than 30 mm in a 12-storey building. This shrinkage should be considered in addition to the shrinkage caused by any cross-grain material in the vertical load path.

The Architect should consult with the SER to obtain an estimate of how much axial shortening to expect, and where it is most likely to occur. Issues may arise with cladding, services, and other components, if provisions are not made to isolate shrinkage and axial shortening on a floor-by-floor basis. In hybrid buildings with steel or concrete cores, differential shortening may also need to be considered.

5.3.5 CONSTRUCTABILITY CONSIDERATIONS

5.3.5.1 Capabilities and Expertise of Constructors

The success of EMTC buildings is heavily dependent on mutual trust between the members of the design and construction teams. It is important that the design team has confidence in the constructor’s ability to erect EMTC.

Early procurement is required for smooth project delivery. The constructor should be clear and transparent about their plans and protocols for sequenced delivery and on-site staging, if required.

If the constructor does not have in-depth experience of EMTC, advice may be obtained from another constructor who is an expert in Mass Timber and acts as a subconsultant for the constructor. Supply chain management, factory prefabrication, installation sequencing, crane logistics, and delivery/staging space allocations should be considered in the design phase. Any gaps or overlaps in scope should be limited and resolved at the design stage.

Quality assurance and quality control protocols should be followed by every consultant on the design team. Refer to Section 7 Quality Assurance for further guidance.

5.3.5.2 Advantages of Factory Prefabrication

In factory prefabrication, the integration of material supply and the manufacturing process offers advantages in the delivery of EMTC buildings; however, it also requires investigation of staggered scheduling, critical path monitoring, and optimization of both off-site and on-site work.

Mass Timber panels may be the only building components manufactured off-site, complete with milled door and window placements. Alternatively, full assemblies can be fabricated that address concealed space criteria, integrated services, and encapsulation measures. Conducting a full comparative analysis may determine that carrying out these additional tasks at bench height in a controlled factory environment is a cost-effective approach.

Factory prefabrication has many advantages over on-site construction, including:

- better moisture protection for vulnerable Structural Mass Timber components;
- reduced exposure to direct water and/or moisture;
- controlled environment, including temperature and humidity for curing;
- improved accuracy, with tolerances of 1 mm or less being achievable;
- superior quality in precision of components, if managed correctly;
- increased fabrication speed, either through automation or by having manual work done at bench height;
- shorter construction schedules, because components form a kit-of-parts that can be assembled quickly on site;
- superior airtightness; and
- less on-site noise and neighbourhood disturbance.

In the factory environment, it is valuable to combine internal quality control with field review. Since the panelization of Mass Timber elements is relatively new to North America, prefabricators should consider certification by a third party as a further assurance of quality.

Quality management considerations include:

- conducting pre-planning exercises that consider sequencing and integration of MEP components at the fabrication facility;
- selecting a fabrication facility that is factory-certified to the CSA A277, Procedure for Certification of Prefabricated Buildings, Modules, and Panels standard;
- managing the supply chain of Mass Timber components, and refining material choices, therefore optimizing performance, availability, and price;
- optimizing off-site components, to minimize the risk of error during construction; and
- reducing on-site waste and site disturbance, with full commitment to prefabricated components.

For off-site construction requirements, see the Code, Article 3.1.5.7. Factory Assembled Panels.

5.3.5.3 Virtual Construction

Speed of construction is one of the most compelling advantages for EMTC, so using virtual construction can be advantageous. Virtual construction uses a 3D model that incorporates major components of the building to optimize the construction sequence, site organization, and delivery of components. Advantages include:

- refining the schedules on-site, and refining the critical path earlier;
- minimizing the risk of errors in the construction process, with problem solving occurring in the design phase;
- providing greater clarity in 3D design discussions among the design team;
- promoting accurate and timely prefabrication, as the model can be used as a working model for continued development of detail by the design consultants;
- improving processes for collaboration, integration, prefabrication, and construction, since advanced digital design tools bridge 3D CAD/BIM modelling to 4-6D modelling that includes considerations of schedule, cost, and environmental performance;
- solving coordination issues prior to construction, to minimize costly adjustments and reduce change orders during construction; and

- utilizing digital fabrication modelling data that can be uploaded to survey equipment, to direct the rapid installation of prefabricated Mass Timber elements.

5.3.5.4 Commitment and Adherence to Schedule by Trades

Just as the design of EMTC buildings requires the early engagement of all members of the design team, the construction of these buildings requires a similar level of cooperation and commitment from all the trade constructors. An understanding of the various constructors' scopes of work, and their interfaces and interdependence with the work of others, is critical to maintaining the construction schedule and limiting the possible exposure of Mass Timber elements to adverse weather.

Preconstruction activities that promote proper project execution, site planning and clearing, procurement lead time management, critical path modelling, Gantt scheduling, and proper documentation of quality control planning are encouraged during the design and preconstruction phases. These preconstruction exercises are all complemented by virtual construction. Due to the inherent staggering of schedules with prefabrication, and more frequent use of the crane for delivery of larger prefabricated elements, more attention to accurate sequencing of complementary trades is necessary. This exercise can help avoid delays to the schedule and the additional cost that might otherwise result. The confirmation of scope for each discipline, together with the related procurement schedules should be completed and integrated before work commences. Once planning is complete and site preparation begins, weekly monitoring of progress by trades on site and the schedule of trades due in the near future, together with quality control reviews, checklists, and management protocols, contribute to a successful project.

EMTC, specifically Article 5.6.4.3. of the Fire Code, requires that not more than four storeys of Mass Timber remain unencapsulated during construction, to minimize the risk of a fire occurring before the building is complete, and before the fire detection and suppression systems are installed and activated. Temporary fire protection within four-storey sections is required to have a minimum 25-minute Encapsulation Rating, which can be achieved with one layer of 12.7 mm Type X gypsum board. While the gypsum board is likely to be exposed to moisture and damage during construction, the MER, EER, and the MEP trades should expect to install the recessed services prior to installation of the first layer of encapsulation. Refer to Section 5.4.6.3 Scheduling and Sequencing, Section 5.5.8 Encapsulation for Construction Fire Safety Plan, and Section 5.8.7.2 Encapsulation for more information on construction encapsulation requirements and sequencing. Given the susceptibility to moisture of the construction encapsulation, constructors should consider whole building weather protection for EMTC.

5.3.5.5 Tolerances for Factory versus Site Construction

A cast-in-place concrete ground or suspended podium slab for a large building will likely have a tolerance in the order of 25 mm from end-to-end. A concrete stair and elevator shaft for a 12-storey structure may have a tolerance of between 25 mm and 40 mm (the CSA S23.1 tolerance is 1:400 up to a maximum of 40 mm) in its vertical alignment.

When assembling the Structural Mass Timber elements, which are built to much tighter tolerances (1 mm to 3 mm), it will be necessary to detail junctions that accommodate these potential differences in tolerances, while maintaining the integrity of the lateral and gravity load-bearing systems.

5.3.5.6 Requirement for Field Review

When EMTC is constructed from factory-built components, the nature and scope of traditional field reviews may change. While the review of simple Structural Mass Timber elements may be no different than it is for other buildings, the nature of pre-engineered connection systems, sophistication of CNC machining, and importance of minimizing the modifications and changes required in the field, all combine to make field reviews at the factory during manufacture of critical importance.

The constructor and manufacturer retain responsibility over quality control of the project, but the Architect and Engineering Professionals conduct reviews to ascertain if the manufactured components are constructed in accordance with the design drawings and the shop drawings, if required and provided. Where CLT or other panels are concerned, the milling of notches and rebates, or the pre-drilling of penetrations and holes for services, should also be checked.

Prefabricated wall assemblies should be reviewed both for conformance with design drawings, and for thermal performance. Continuity of seals between panels, continuity of the air barrier, and the overall integrity of the building enclosure should be reviewed.

Refer to Section 7 Quality Assurance for additional requirements for field review, both on the construction site and at the fabrication location.

5.3.5.7 Seasonal Considerations for the Construction Schedule

In the province of BC, the climate varies greatly from coastal to inland regions, and from the north to the south. The ideal season for construction of EMTC buildings may vary from place to place, given different climatic conditions. Conditions to consider include the frequency and intensity of rain, the prevalence and accumulation of snow, and the freeze/thaw cycle.

Many circumstances that are outside the design team's control may negatively impact the date at which construction can start and the subsequent progress of the work. Even with an ideal construction window based on analysis of the local climate and weather patterns, Mass Timber components may get wet at some time during transportation or construction. These components must be dried to an MC of 19% or less, prior to encapsulation or application of other finishes. Refer to Section 5.4.6 Moisture Exposure and Protection of Mass Timber.

Required moisture protection measures should be specified, to ensure materials and assemblies can be installed without suffering moisture damage that compromises their integrity or performance. It is recommended that moisture management plans for every phase of the project be developed.

5.3.5.8 Handling Requirements for Exposed Mass Timber Components

The Code permits a certain amount of the Mass Timber surfaces to be exposed within the building. If choosing components that are to be left exposed, the special handling and protection they will require before, during, and after installation should be considered. They are, in effect, finishing materials and should be specified and treated as such.

5.4 BUILDING ENCLOSURE CONSIDERATIONS

In this section, general considerations for all enclosure assembly types are discussed as they relate to their interaction with the Structural Mass Timber. However, this section pertains primarily to EMTC enclosure assemblies used for EMTC and, where applicable, Structural Mass Timber assemblies that may have to temporarily resist enclosure loads while being exposed during construction (e.g., Structural Mass Timber floors).

5.4.1 ENCLOSURES IN EMTC

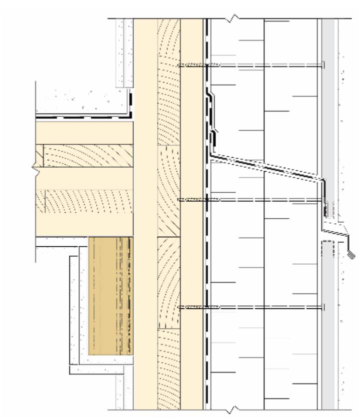
If EMTC is to be durable, it is necessary to protect the structure from moisture and temperature fluctuations. EMTC may use any number of roofing and façade systems as the enclosure, from conventional site-built systems to panelized and unitized components.

For EMTC up to 12 storeys, the Structural Mass Timber may be separate from the enclosure assemblies, or the EMTC enclosure assemblies may form part of the structure (i.e., be loadbearing). The figures below illustrate these EMTC enclosure types.

5.4.2 ENCLOSURE LOADS

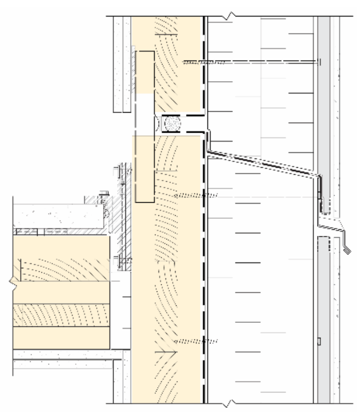
One function of the building enclosure is to control the environmental loads acting on the building; it must provide environmental separation under Part 5 of the Code, between the interior and the exterior. Water, air, vapour, and heat flow are the focus of this section, but fire and acoustics are also discussed, where appropriate. Other loads such as solar radiation, wind, insects, pests, fungi, lightning protection system, and smoke should also be considered.

Figure 5-7: Illustration of loadbearing EMTC enclosure (CLT panel), also acting as part of the EMTC primary structure



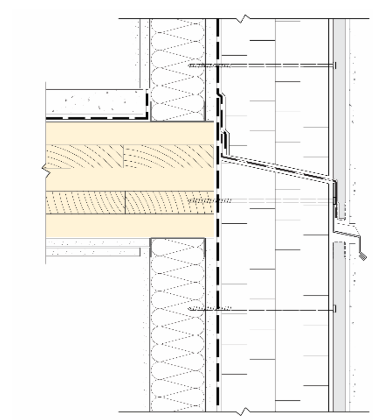
Cross Section

Figure 5-8: Illustration of non-loadbearing EMTC enclosure (CLT panel), separate from the EMTC primary structure



Cross Section

Figure 5-9: Illustration of EMTC floor assemblies forming part of the "temporary" enclosure during construction



Cross Section

5.4.2.1 Climate

The location or climate zone in which a building is constructed dictates the magnitude and duration of those environmental loads on the building enclosure. Basic climatic design data (e.g., average air temperatures, heating and cooling degree days, design wind pressures, rainfall, snow, moisture index) is provided in Division B, Appendix C of the Code (see Figure 5-10*)*. Supplemental data that can assist with climate change resiliency considerations, can be found on the website "Climate Data for a Resilient Canada" (ClimateData.ca).

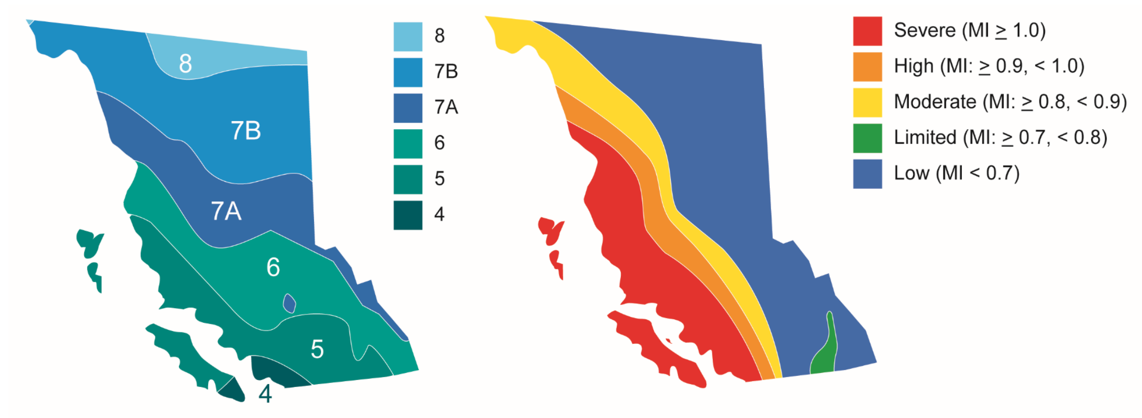
Every climate zone carries unique design considerations for controlling the loads. Colder climate zones will have more stringent requirements for insulation than warmer climate zones, as per Part 10 of the Code, and the need for condensation control (e.g., greater control of vapour and airflow) is likewise more significant. In addition, low indoor relative humidity (RH) during winter in drier interior climate zones can cause issues with excessive wood shrinkage or surface checking. Rainy or marine climates also pose a challenge to EMTC and enclosures, in terms of keeping wood elements dry during construction.

5.4.2.2 Critical Barriers

In EMTC enclosure assemblies, control of enclosure loads is provided by critical barriers (Figure 5-11). These include the water-shedding surface, water-resistive barrier, air barrier, vapour retarder, and thermal insulation. For detailed discussion on control layers and each of these critical barriers, see Section 8 References and Related Documents.

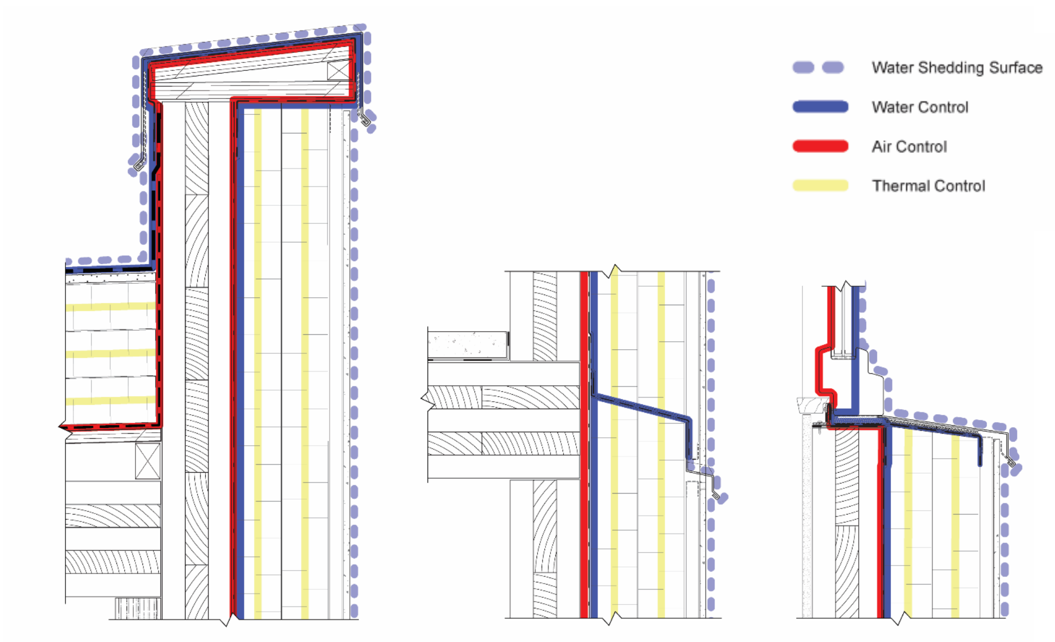
Mass Timber enclosure assemblies must control the various loads while remaining compliant under the specific EMTC requirements of the Code, and must provide durable protection of the Mass Timber itself. These additional requirements add an extra layer of complexity to the design of EMTC enclosure assemblies compared to other enclosure assemblies.

Figure 5-10: Map of British Columbia climate zones (left) and moisture index zones (right) [a]



NOTES: [a] Adapted from: *BCBC*, Division B, Appendix C

Figure 5-11: Illustration of continuous water, air, and thermal critical barriers in typical EMTC enclosure assemblies in typical transition cross section details



5.4.3 ENERGY EFFICIENCY REQUIREMENTS

EMTC and enclosure elements must comply with applicable codes and standards, including the energy codes currently in force in British Columbia (BC). These include all requirements applicable to buildings up to 12 storeys in Part 10 of the Code and, in some jurisdictions, the BC Energy Step Code, Subsection 10.2.3. of the BCBC.

5.4.3.1 Energy Modelling

EMTC utilizing the performance-based energy efficiency requirements of the Code (i.e., under ASHRAE 90.1, NECB, or the BC Energy Step Code) requires whole building energy modelling that accounts for the specific enclosure thermal performance (i.e., heat loss in W/m^2, rather than the R-value of materials) achieved.

Refer to those documents and the Code for further information on regulatory requirements and the *Joint Professional Practice Guidelines – Whole Building Energy Modelling Services* (AIBC and Engineers and Geoscientists BC 2018) for professional practice requirements.

As noted in the following section, the thermal insulation value of the encapsulated Mass Timber assemblies, including the Mass Timber portions of the roof, wall, and floor panels, must be included in the heat loss calculation. Thermal bridges created by Mass Timber components (e.g., floor slabs, parapets, connections) must also be calculated as part of the energy modelling calculations.

5.4.3.2 Thermal Modelling and Thermal Bridging

A catalogue of the thermal performance of EMTC enclosure assemblies and interface details relevant to construction in BC is available in the *Building Envelope Thermal Bridging Guide* (BC Housing 2020).

The various current Code compliance pathways may lack direct guidance or resources on EMTC enclosure assemblies. Where Codes and referenced standards may include typical R-values that could be used for what may be considered conventional wood frame and steel assemblies, the thermal performance for EMTC enclosure assemblies likely requires specific thermal calculations and, potentially, component thermal modelling.

Where enclosure thermal bridging must be accounted for in detail, per the City of Vancouver *Energy Modelling Guidelines* (referenced in the Code for projects utilizing energy modelling), the various Mass Timber penetrations or protrusions must be considered. Although wood has a relatively low thermal conductivity compared to other common structural materials, like concrete and steel, wood's thermal bridging effect can still be significant, such as at continuous parapet or balcony interfaces. Other thermal bridges that interface with the wood components, such as structural penetrations through insulation, should also be accounted for.

All enclosure assembly interfaces and penetrations require multidisciplinary reviews and details; this includes all mechanical, electrical, and plumbing penetrations through the enclosure.

Project-specific thermal modelling using two-dimensional and three-dimensional modelling software may also be required, to determine the effect of specific details on the overall thermal performance of an assembly. (See Figure 5-12.)

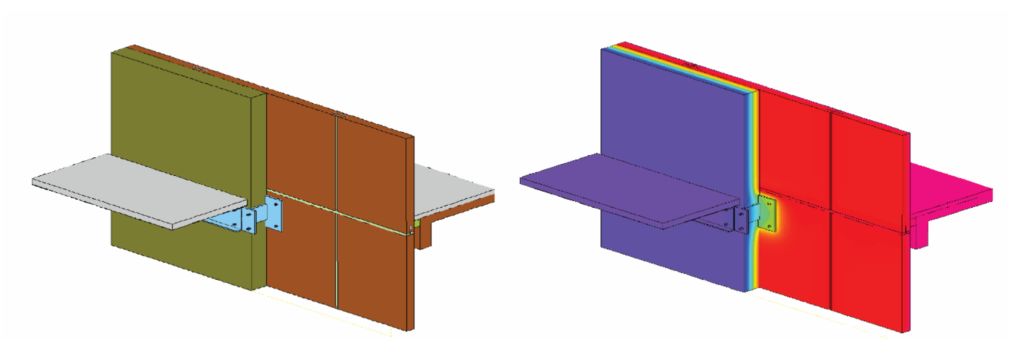
Refer also to the BC Housing design guides listed in Section 8.4 Related Documents for further information on calculating the thermal performance of EMTC enclosure assemblies.

5.4.3.3 Greenhouse Gas Emissions and Embodied Carbon

In some jurisdictions, such as the City of Vancouver, greenhouse gas emissions, including consideration of all materials in the building, are regulated and limited. If this is a requirement, the embodied carbon of the materials in the building must be calculated and reported.

EMTC has been shown to have lower embodied carbon than concrete and steel construction, and as a building approach represents a potential reduction in the building's overall carbon footprint.

Figure 5-12: Illustration of thermal modelling of an EMTC enclosure with bolt on balcony



5.4.4 BUILDING ENCLOSURE ASSEMBLIES AND MATERIALS

5.4.4.1 Control Layers and Critical Barriers

Control layers are stand-alone materials or systems of materials in the building enclosure that are designed to manage the indoor and outdoor loads of a building.

Beyond the discussion in this section, see the guidance documents listed in Section 8 References and Related Documents for further direction on building enclosure critical barriers and control layers.

Water-Resistive Barrier/Waterproof Membrane

For moisture-sensitive products like wood, the most critical enclosure load is often liquid water. Liquid water can occur in many forms, including rain, snow, and ice melt. Water at wall assemblies and sloped roofs is managed first by the water-shedding surface, which includes the drainage and deflection surfaces facing the exterior environment (e.g., cladding, flashings, sloped roofing materials). The water-resistive barrier system manages water that may bypass this exterior surface. Water at a low-slope roof is managed in part by the drainage surface where present (e.g., ballast, pavers) and, ultimately, by the waterproof roof membrane.

Note that floor assemblies with exterior space below interior space, such as enclosed overhangs, have similar characteristics to wall assemblies in-service (i.e., the underside of the floor is similar to the exterior of the wall).

When floors are exposed to moisture on the top side during construction, they are similar to roof assemblies, and should be considered as such.

The following tables present options for water-resistive barriers and waterproof roof membranes that can be used in EMTC enclosure assemblies.

Table 5-4: Overview of Waterproof Roof Membranes Used in EMTC Enclosure Assemblies

WATERPROOF ROOF MEMBRANE	KEY CONSIDERATIONS
Two-ply adhered/torch-on systems use a self-adhesive and/or heat welding to affix it to the substrate and at laps and are typically comprised of a base sheet and cap sheet. Most commonly SBS-modified bitumen roofing.	• Can provide redundancy in the roofing, since multiple layers are used, with offset seams and joints. • Typically results in robust durable membrane system. • Requires fire protection measures, where applied near or on wood substrates. • Like all waterproof roof membrane systems, relies on careful detailing at interfaces and penetrations, and correct installation according to manufacturer's requirements.
Single-ply fastened/adhered/loose laid systems use a single waterproof membrane affixed to the substrate with watertight fasteners, adhesive, or ballast. Examples include EPDM rubber and TPO systems.	• Typically intended for larger areas of less complex roof assemblies with fewer penetrations. • Like all waterproof roof membrane systems, relies on careful detailing at interfaces, penetrations, and especially at membrane laps, and correct installation according to manufacturer's requirements.
Recommended practice for EMTC: • Two-ply membrane system (e.g., SBS modified bitumen) is used, with at least the top ply heat-welded in place.	

Table 5-5: Overview of Water-Resistive Barriers (Walls and Sloped Roofs) Used in Encapsulated Mass Timber Enclosure Assemblies

WATER-RESISTIVE BARRIER	KEY CONSIDERATIONS
Loose laid/mechanically attached membranes use a water-resistive layer attached to the exterior with fasteners and washers. Examples include asphalt-saturated building paper and spun bonded polypropylene.	• Mechanically attached membranes must be adequately secured to the building during construction and retained against the substrate by strapping or a continuous layer, such as exterior insulation. • May allow liquid moisture to transfer laterally at the back face of the membrane, where breached. • Mechanically attached systems are not suitable for buildings that will experience high wind loads and where physical durability of the material is a concern.
Self-adhered membranes use a water-resistive layer attached to the exterior with pre-applied adhesive on the membrane. Examples include permeable synthetic woven with acrylic adhesive and impermeable polyethylene-faced with bitumen-based adhesive.	• Self-adhered sheathing membranes rely on adhesion to both the substrate and at membrane laps, and must accommodate potential building movement and substrate shrinkage to remain watertight. • The membrane must be installed onto suitable substrate that provides continuous backing and fully adhered to the substrate upon initial installation. • Generally, a more robust membrane approach compared to loose-laid membranes, since they are fully adhered in place and restrict moisture transfer laterally behind the membrane. • Impermeable membranes must be installed with provision for drying, and vapour permeance must be carefully considered (see Table 5-8).[a]
Liquid-applied membranes use a water-resistive monolithic coating sprayed or rolled onto the exterior substrate. Examples include moisture-cure silicone-based and silyl terminated polyether (STPE) products.	• Exterior liquid-applied membranes share many of the advantages of self-adhered membranes and are especially useful for complex detailing. • Liquid-applied membranes rely upon the supporting substrate to provide a continuous backing to achieve a watertight barrier. Cross-Laminated Timber (CLT) is generally not a suitable substrate since joints and gaps may open between boards. Other more monolithic Mass Timber panels such as mass plywood may be more suitable. • Joints in liquid-applied systems typically require specific detailing considerations and often incorporate membrane reinforcement. The substrate and weather conditions can have a significant impact on curing time and adhesion. • Impermeable membranes must be installed with provision for drying and vapour permeance must be carefully considered (see Table 5-8).[a]
Recommended practice for EMTC: • Vapour-permeable self-adhered membrane is applied to the exterior substrate, with primer used as necessary. Refer to Table 5-6 for vapour-permeable and vapour-impermeable air-barrier approaches.[b]	

NOTES:

[a] Table 5-8: Overview of Vapour Control Strategies Used in Encapsulated Mass Timber Enclosure Assemblies

[b] Table 5-6: Overview of Exterior Air Barrier Approaches Used in Encapsulated Mass Timber Enclosure Assemblies

Air Barriers

An effective air barrier uses a three-dimensional system of materials to control airflow across and within the building enclosure. For all building types, including EMTC, an air barrier system has five basic requirements:

- continuity;
- strength;
- durability;
- stiffness; and
- air impermeability.

While Mass Timber panels may have a very low air permeability as a material when tested in a laboratory setting, the *in-situ* interfaces between panels allow for the passage of air (Figure 5-13). As such, the Mass Timber panels themselves cannot be relied upon as part of the air barrier system. Instead, a continuous air barrier membrane is used over the surface of the Mass Timber elements as the primary air barrier, coupled with interface detailing accessories such as tapes and sealants, where needed. The exterior surface of the Mass Timber components is the typical air barrier location, where a self-adhered membrane or other robust approach is used, and as such the detailing and structural approach should account for this strategy.

Note that while an interior air barrier approach is possible, it is typically more difficult to achieve good building airtightness than with an exterior air barrier approach. The exterior air barrier is also typically used as the water-resistive barrier on walls and sloped roofs and should be installed and detailed as such. For low-slope roof assemblies, the waterproof roof membrane may be the air barrier, or a dedicated air barrier may be used. A vapour-impermeable air barrier membrane may be used within some exterior-insulated assemblies, though a hygrothermal analysis should be performed to verify that the assembly can safely dry towards the interior within an acceptable period of time.

See also Table 5-8: Overview of Vapour Control Strategies Used in Encapsulated Mass Timber Enclosure Assemblies for more key considerations for vapour control strategies in EMTC enclosure assemblies. The table below presents typical exterior air barrier approaches that can be used in EMTC enclosure assemblies.

Whole-building and partial-building airtightness testing is used to confirm the continuity of the air barrier both quantitatively, as required by the various energy standards and the Code, and qualitatively, to assess details and penetrations. Air barrier commissioning is best conducted as early as possible, followed up with air barrier compliance testing conducted at the end of construction. This includes testing of performance mockups before testing the whole building, to provide early identification of potential air leakage issues. Early testing is the best way to verify the enclosure is on track to meet the performance requirements and to allow improvements to be made to the enclosure, if necessary.

For further design guidance on effective air barrier approaches and airtightness testing, refer to the *Illustrated Guide – Achieving Airtight Buildings* (BC Housing 2017). (See also Section 8.2 References.)

Figure 5-13: Illustrations showing examples of potential air leakage paths through the roof perimeter (left), floor panel joints (centre), and panel corner joints (right), indicating the need for a dedicated continuous air barrier membranes and transitions for Mass Timber wall and roof details

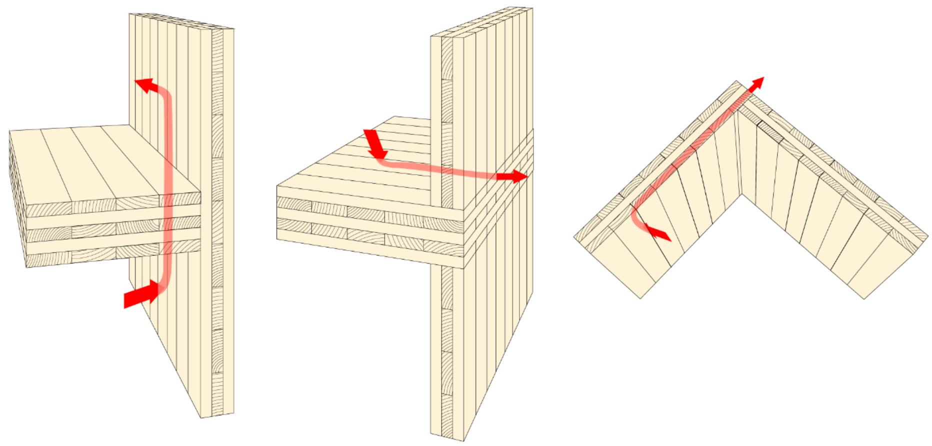


Table 5-6: Overview of Exterior Air Barrier Approaches Used in Encapsulated Mass Timber Enclosure Assemblies

AIR BARRIER	KEY CONSIDERATIONS
Sheathing membranes use an airtight layer that is mechanically fastened or adhered to the exterior substrate. Joints, penetrations, and laps are made airtight using sealant and/or tape, or using the membrane adhesive for self-adhered systems. See Table 5-5 for typical examples.[a]	• Membrane must be installed onto suitable substrate that provides continuous backing, and loose-laid systems must be retained by strapping or a continuous layer such as exterior insulation. • Mechanically attached systems are commonly used on low-rise construction, but this approach is not typically appropriate for taller buildings or those with higher design wind loads. • Self-adhered sheathing membranes rely on adhesion to both the substrate and at membrane laps, and they must accommodate potential building movement and substrate shrinkage.
Sealed sheathing systems use a rigid exterior sheathing (plywood, OSB [oriented strand board], or gypsum) with sealed airtight joints. Joints are sealed with a compatible sealant, tape, or membrane, and details are interfaced to the airtight sheathing substrate.	• Interfaces between the sheathing panels must consider potential building movement. • Note that a dedicated sheathing membrane is often required with this approach, to provide the water-resistive barrier.
Liquid applied membranes use a water-resistive monolithic coating, sprayed or rolled onto the exterior substrate. See Table 5-5 for typical examples.[a]	• Exterior liquid applied membranes share many of the advantages of self-adhered sheathing membranes and are especially useful for complex detailing. • The substrate and weather conditions can have a significant impact on curing time and adhesion. • Surface imperfections and discontinuities at joints in wood substrates can become a quality control issue when installing a liquid-applied membrane. Cross-Laminated Timber (CLT) is generally not a suitable substrate, since joints and gaps may open between boards. Other Mass Timber panels such as mass plywood may be more suitable.
Recommended practice for EMTC: • Vapour-permeable self-adhered membrane is applied to the exterior surface of the Mass Timber wall (inboard of insulation). • Vapour-impermeable self-adhered or heat-welded membrane is applied to the exterior of the Mass Timber roof (inboard of insulation).	

NOTES:

[a] Table 5-5: Overview of Water-Resistive Barriers (Walls and Sloped Roofs) Used in Encapsulated Mass Timber Enclosure Assemblies

Insulation

Dedicated insulation layers are the primary means of thermal control in EMTC enclosure assemblies. Table 5-7 presents the insulation layer options that can be used in EMTC enclosure assemblies.

Mass Timber panels can also contribute to the thermal performance of the assembly, because wood has a relatively low thermal conductivity when compared to other common structural materials like concrete and steel. The thermal resistance of most commonly used North American softwood species in Mass Timber products is RSI 0.21 per 25 mm. The mass of the Mass Timber panel can also impact the thermal performance of the assembly by moderating heat flow through thermal storage and thermal mass. Prescriptive compliance methodologies in the Code and its referenced standards do not recognize this property of Mass Timber; however, it is accounted for when energy modelling is used to determine compliance with the Code.

Table 5-7: Overview of Insulation Options Used in EMTC Enclosure Assemblies

INSULATION	KEY CONSIDERATIONS
Exterior insulation is installed on the exterior side of the Mass Timber and retained with fasteners or adhesive.	• Continuous exterior insulation can reduce thermal bridging from the Structural Mass Timber and its connections. • The insulation must not be sensitive to moisture when installed outboard of the water-resistive barrier or waterproof membrane. • Insulation retention and cladding attachment systems through exterior insulation can be a source of significant thermal bridging. Optimizing these to reduce the number of penetrations is important for improving the thermal efficiency. • The vapour permeability of the exterior insulation is important to consider. See Table 5-8 for discussion on insulation permeability.[a]
Interior insulation is installed on the interior side of the Mass Timber within interior framing or as a continuous layer.	• Interior insulation results in a complex hygrothermal EMTC enclosure assembly, since the Mass Timber layer generally has a low vapour permeability. In cold climates, interior insulation may lead to a risk of condensation at the interior face of the Mass Timber. • Interior insulation is also interrupted at interior structural interfaces and connections such as beams and floors, so it is difficult to achieve a continuous layer.
Combustible insulation burns when subjected to a fire (as defined by relevant fire-test standards).	• Combustible insulations including foamed plastics may have a higher R-value/mm than Noncombustible insulation. • Foamed plastic insulation generally has low vapour permeance and may lead to complex hygrothermal scenarios. See Table 5-8 for discussion on insulation permeability.[a] • The use of Combustible insulation in EMTC enclosure assemblies is restricted, as outlined in Table 5-9 and Table 5-12.[b, c]
Recommended practice for EMTC: • Vapour-permeable Noncombustible continuous exterior insulation with thermally efficient attachment and support is used on walls. • Vapour-impermeable exterior insulation could be used in low-slope roof assemblies.	

NOTES:

a Table 5-8: Overview of Vapour Control Strategies Used in Encapsulated Mass Timber Enclosure Assemblies

b Table 5-9: Overview of Mass Timber Roof Assembly Design Considerations for EMTC

c Table 5-12: Overview of Mass Timber Wall Assembly Design Considerations for EMTC

Vapour Control

The transport of water vapour across an EMTC enclosure assembly can be managed both by the inherent ability of the Mass Timber to function as a vapour retarder and by controlling air leakage. Airflow transports significantly larger amounts of water vapour than vapour diffusion; however, both transport mechanisms must be controlled.

Since Mass Timber inhibits the flow of water vapour across the assembly, it also inhibits potential drying through it. For this reason, vapour control and other impermeable materials should be used carefully, with the long-term durability aim of allowing drying and avoiding water vapour accumulation within the assembly. Table 5-8 outlines the key considerations for the various vapour-control strategies available in EMTC enclosure assemblies.

Table 5-8: Overview of Vapour Control Strategies Used in Encapsulated Mass Timber Enclosure Assemblies

VAPOUR CONTROL STRATEGY	KEY CONSIDERATIONS
Mass Timber elements greater than 25 mm thick can function as an effective vapour-control layer.	• EMTC enclosure assemblies detailed with the Mass Timber as the only vapour-control layer allow for drying in both directions of the Mass Timber, if they do get wet. • Integral glue layers in the Mass Timber can decrease the vapour permeance of the material, but most Mass Timber products have some ability to dry. However, significant amounts of moisture held within the material for extended periods may lead to damage, so this should be avoided nevertheless. • It is important that layers and components exterior of the Mass Timber are resistant to moisture exposure from condensation that may occur with outward vapour drive in cold climates. See Section 5.4.4.2 Roof Assemblies.
Dedicated interior vapour-control strategies are installed inboard of the Mass Timber and insulation. Examples include mechanically attached polyethylene, vapour-retarder paint at the interior finish, and low-vapour-permeance interior insulation.	• Dedicated interior vapour control inboard of the Mass Timber results in a complex hygrothermal EMTC enclosure assembly, since the Mass Timber also acts as a vapour-control layer, and moisture could get trapped between these layers.
Dedicated exterior vapour-control strategies are installed outboard of the Mass Timber but are still inboard of or concurrent with the insulation. Examples include impermeable air-barrier/water-barrier membranes and low-vapour-permeance exterior insulation.	• Dedicated exterior vapour control slows outward vapour diffusion and reduces the outward drying capacity of Mass Timber assemblies overall. The primary direction of drying in walls (if needed) is to the exterior, so the EMTC enclosure assembly may remain wet for extended periods until drying of the interior can occur. • In conventional roof assemblies, there is no outward drying through the impermeable waterproof membrane, so a dedicated self-adhered vapour-control layer inboard of the insulation is needed, to reduce the risk of condensation at the underside of the roof membrane (see Table 5-10).[a] • Inverted roof assemblies use an exterior vapour-impermeable membrane (see Table 5-10).[a]
Recommended practice for EMTC: • Wall assemblies are configured to have the Mass Timber element as the only vapour-control layer in the assembly. • Roof assemblies are configured to have a dedicated vapour-control layer outboard of the Mass Timber and inboard of the insulation.	

NOTES:

[a] Table 5-10: Overview of Typical Mass Timber Roof Assemblies Used in EMTC

5.4.4.2 Roof Assemblies

Design Considerations

Encapsulated Mass Timber roof assemblies present many challenges, with respect to concealed spaces, roof coverings, and the use of additional wood roof sheathing for slope. Roof coverings in EMTC must be classified as Class A, B or C, except where the highest point on the roof is greater than 25 m above the floor of the first storey, the roof must have a Class A rating, per Sentences 3.1.15.2.(3) and (4) of the Code. Non-contiguous roof heights may be evaluated separately.

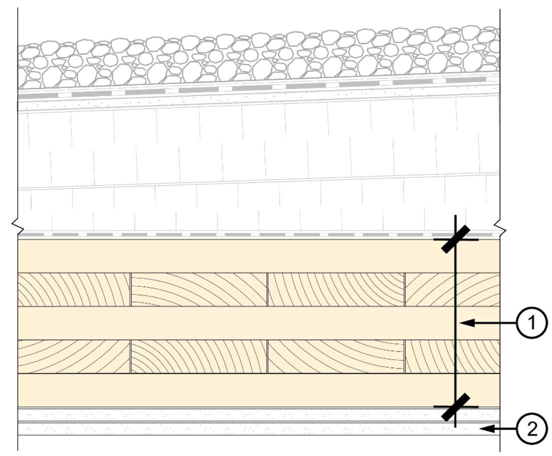
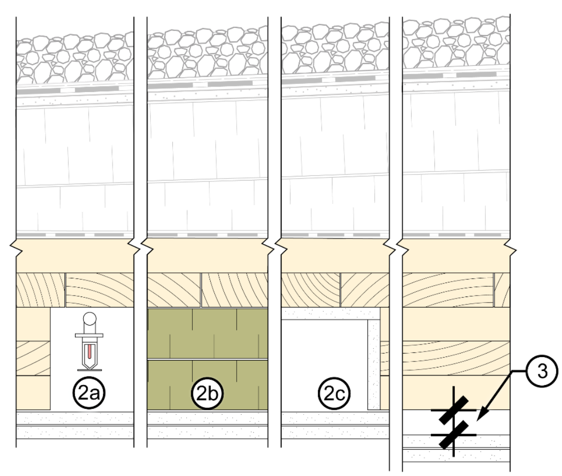
- Because of the solid nature of EMTC enclosure assemblies, additional concealed spaces may be needed to run building utilities.
- Using secondary sloped wood sheathing may help achieve roof slope for low-sloped roofs.
    - Structural Mass Timber elements can be installed flat, using sloped blocking to position the sheathing for drainage, as needed. With this approach, challenges may arise if water is able to get into concealed spaces, such as unvented spaces between sheathing and Mass Timber, during construction; therefore, attention to sequencing and moisture protection is critical.
    - Tapered insulation packages could also be used to achieve low-sloped roofs on flat Structural Mass Timber elements. Combustible tapered insulation can be used in EMTC roof assemblies, provided the insulation is installed above a roof deck.
- An alternate approach is to install sloped concrete topping (possibly lightweight systems) to achieve the desired roof slope. However, concrete can pose challenges to moisture control in Mass Timber roof panels, so appropriate attention to sequencing and moisture protection is needed. See Section 5.4.6.4 Exposure to Moisture from Concrete.
- Fire-related requirements for roofing materials must be considered, such as resistance to flame and encapsulation (see Table 5-9).
- Mass Timber components are sensitive to moisture and must be protected from wetting during construction and while in service. The constructor must develop a robust quality assurance/quality control strategy to keep Mass Timber dry during construction, while meeting requirements for roof slope, fire protection, and acoustics. The design team must specify the acceptable MC range for components.
- Concealed service spaces (in roofs and other assemblies) require careful planning, both for Code compliance and to effectively run building services. Concealed service spaces should be incorporated early in the design process, and not be left for detailed design after the mechanical, electrical, and plumbing (MEP) system designs are complete.
- All concealed spaces must be protected, per the Code. Limiting the size of concealed spaces to avoid having to take additional measures may be advantageous.

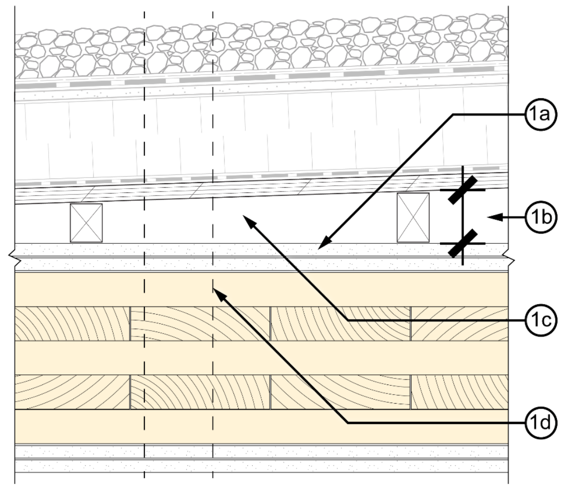
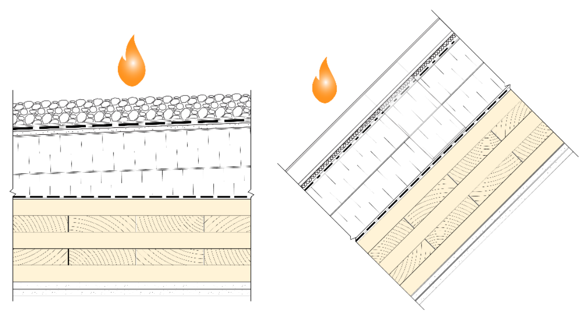
Basic design considerations for EMTC roof assemblies, based on relevant Code requirements, are outlined in Table 5-9 under Roof Assembly Diagrams below.

Roof Assembly Diagrams

The following table outlines the basic design considerations for EMTC roof assemblies based on the relevant Code requirements.

Table 5-9: Overview of Mass Timber Roof Assembly Design Considerations for EMTC

DESCRIPTION AND CODE REFERENCE	ROOF ASSEMBLY CROSS SECTION DIAGRAMS
BASIC ASSEMBLY CONSTRUCTION [a]	
1. Article 3.1.18.3. Structural Mass Timber Elements: Sentence (2) sets out the basic assembly requirements for typical EMTC elements, including floors and roofs, which must: a) be arranged in heavy solid masses containing no concealed spaces (except as permitted); b) have smooth flat surfaces with no thin sections or sharp projections; and c) have the minimum dimensions as listed in Table 3.1.18.3., which lists 96 mm for floors and roofs. 2. Article 3.1.18.4. Encapsulation of Mass Timber Elements: Sentences (1) and (2) require the protection of all exposed surfaces of Mass Timber with a material that provides an Encapsulation Rating of at least 50 minutes. Materials include gypsum board, concrete, or other Noncombustible material per Article 3.1.19.2. Encapsulation Materials. **NOTE**: [a] For this assembly, consideration for the pre-application of the vapour barrier/temporary roof membrane in a dry conditioned environment prior to installing the Mass Timber panels is strongly recommended in British Columbia, due to the potential for the Mass Timber to get wet during construction.	 Cross Section
CONCEALED SPACES WITHIN THE ASSEMBLY (EXCLUDING SPACE BENEATH WOOD ROOF SHEATHING)	
1. Article 3.1.11.5. Fire Blocks in Horizontal Concealed Spaces: Sentence (4) sets the maximum area/dimension limits for horizontal concealed spaces. 2. Article 3.1.18.3. Structural Mass Timber Elements: Sentence (4) lists the options for the protection of (larger) concealed spaces, which must be: a) sprinklered and divided into compartments per Article 3.1.11.5.; b) completely filled with minimum 32 kg/m² mineral wool insulation [a]; or c) lined with 12.7 mm, Type X gypsum board or other material providing 25-minute encapsulation. 3. Per Article 3.1.18.14. Exposed Construction Materials and Components in Concealed Spaces, and Article 3.1.18.9. Nailing Elements, a 25 mm concealed space is permitted between the Mass Timber and the encapsulation material. A 50 mm space is permitted if its surfaces have a Flame-Spread Rating of 25 or less, or if it is filled with Noncombustible insulation. **NOTE:** [a] Mineral fibre for the purpose of filling concealed mass timber spaces must be rock or slag fibre insulation conforming to CAN/ULC-S702, Standard for Mineral Fibre Thermal Insulation for Buildings.	 Cross Section

DESCRIPTION AND CODE REFERENCE	ROOF ASSEMBLY CROSS SECTION DIAGRAMS
WOOD ROOF SHEATHING [a]	
1. Article 3.1.18.5. Combustible Roofing Materials: Sentence (1) permits wood roof sheathing and supports above the Mass Timber roof deck, provided: a) the deck is protected per Article 3.1.18.4.; b) the resulting concealed roof space is not more than 1 m in height; c) the roof space is compartmentalized per Article 3.1.11.5.[b]; and d) openings through the deck other than for Noncombustible roof drains and plumbing piping are protected per Subclause 3.1.18.5.(1)(iv). **NOTES:** [a] This assembly requires attention during construction to manage moisture, as gypsum materials and the concealed framed space may trap moisture if wetted during construction. Careful sequencing and protection from water is necessary. Preapplication of the top-side fire protection can be made in the factory, and consideration for making this part of a construction moisture protection plan should be made as part of the design. [b] The gypsum board is permitted to be either between or continuous below the sheathing supports.	 Cross Section
ROOFING MATERIALS	
1. Article 3.1.15.2. Roof Coverings: Sentence (4) requires that an EMTC building with a roof height greater than 25 m, measured from the floor of the first storey to the highest point of the roof, use roof coverings with a Class A fire rating per CAN/ULC-S107, Methods of Fire Tests of Roof Coverings. This is the highest fire rating intended to protect against severe fire test exposures. For flat roofs, this typically means a Noncombustible ballast is used, such as pavers or rock. For sloped roofs, it typically requires a Noncombustible shingle product, metal roofing, or a heavy-duty underlayment. Noncontiguous roof assemblies at different elevations can be evaluated separately.	 Cross Sections

Roof Assembly Examples

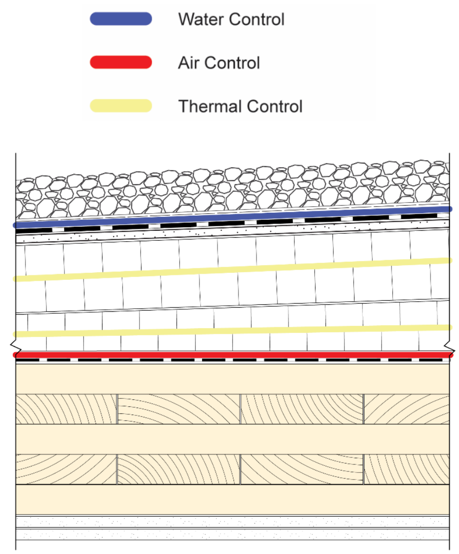
Two typical EMTC roof assemblies can be effectively used in EMTC, as presented in Table 5-10 below. The conventional and inverted roof assemblies are based on common roof assembly approaches and use many typical materials and components. In all cases, exterior insulation above the roof structure is used. Interior insulation in EMTC roof assemblies is not recommended in the BC climate, due to moisture and vapour control challenges. For more information on typical roof assembly design and construction, see Section 8 References and Related Documents.

The assembly cross sections in Table 5-10 show Mass Timber (with a thickness greater than 25 mm) as the vapour-control layer; however, dedicated vapour-control layers are also a viable strategy for EMTC. Three typical vapour control strategies for EMTC are discussed in Section 5.4.4.1 Control Layers and Critical Barriers, under the subsection Vapour Control.

Table 5-10: Overview of Typical Mass Timber Roof Assemblies Used in EMTC

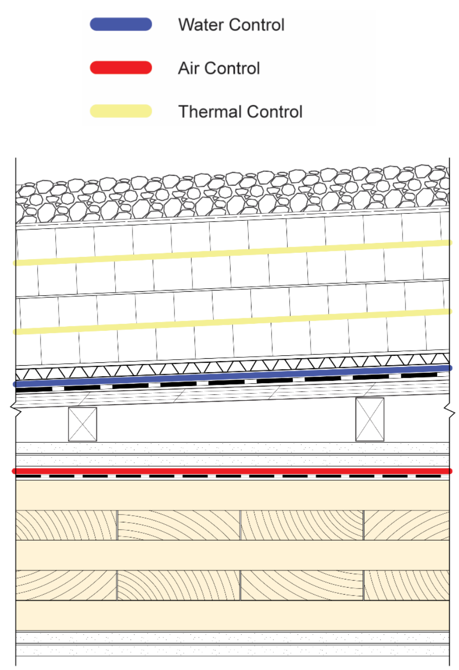
<table>
<tr><th>ASSEMBLY DESCRIPTION</th><th>ROOF ASSEMBLY CROSS SECTION</th></tr>
<tr><td colspan="2">CONVENTIONAL ROOF (“EXPOSED” MEMBRANE)</td></tr>
<tr><td>
Exterior:

Noncombustible roof ballast over filter fabric
Roof membrane over protection board
Rigid insulation with sloped insulation layer
Self-adhered air/vapour barrier applied directly to Mass Timber
Mass Timber panel (5-ply Cross-Laminated Timber [CLT] shown)
Interior encapsulation layer as required (two layers of 12.7 mm, Type X gypsum board), applied after roofing installed and watertight.

Interior:
This assembly is well-suited to British Columbia climates, since the air and vapour barrier membrane is located on the warm side of the insulation. The air and vapour barrier membrane in these assemblies may also serve as a moisture-management membrane to temporarily control moisture during the construction phase. As such, selection of the membrane and water tightness of the lap joints is critical. The vapour permeance of all assembly layers must be carefully considered relative to the Mass Timber panel and interior/exterior environmental conditions. Preapplication of the temporary roof membrane/vapour barrier prior to installation on site is strongly recommended to protect components from moisture during construction.
</td><td>


Cross Section
</td></tr>
<tr><td colspan="2">INVERTED ROOF (PROTECTED MEMBRANE)</td></tr>
<tr><td>
Exterior:

Noncombustible roof ballast over filter fabric
Moisture-tolerant rigid insulation (e.g., XPS)
Drain mat or grooved insulation
Roof membrane over protection board
Tapered framing and sheathing
Two layers of moisture-tolerant, 12.7 mm, Type X gypsum board
Mass Timber panel (5 ply CLT shown)
Two layers 12.7 mm, Type X gypsum board [a]

Interior:
This assembly is well-suited to British Columbia climates, since the air and vapour barrier membrane is located on the warm side of the insulation. The concealed space required to create a sloped roof, together with the associated fire protection, could be avoided if the Mass Timber panel structure itself were sloped or another monolithic sloping strategy was used, such as concrete topping. The roof membrane or air and vapour barrier membrane—whichever membrane is installed directly over the Mass Timber panel—may be considered to protect the Mass Timber from moisture exposure during construction. Care must be taken to prevent water from entering or being trapped within this concealed space during construction.
NOTES:
[a] The gypsum board is permitted to be either between or continuous below the sheathing supports.
</td><td>


Cross Section
</td></tr>
</table>

5.4.4.3 Wall Assemblies

Wall Assembly Structure Types

In EMTC, the exterior walls can be either Mass Timber or non-Mass Timber. For non-Mass Timber exterior walls in EMTC, refer to section D-6, Fire Performance of Exterior Wall Assemblies, in Appendix D, Division B of the Code. See also Section 5.5.1.3 Exterior Cladding Materials.

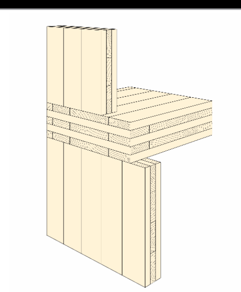
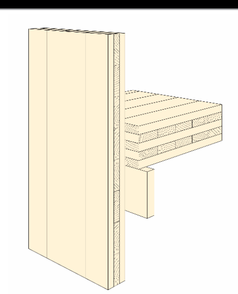
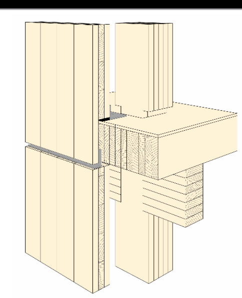
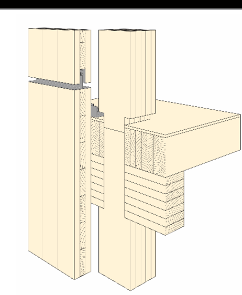
There are four typical Structural Mass Timber wall types; platform, balloon, bottom-bearing, and hung (curtain wall approach), see Table 5-11. Loadbearing Structural Mass Timber walls are part of either platform or balloon construction. Bottom-bearing and hung walls are both commonly used non-loadbearing Mass Timber wall options.

Design Considerations

Encapsulated Mass Timber exterior wall assemblies present many challenges with respect to concealed spaces, combustibility of cladding, and required separations, as well as the use of other permitted Combustible components (e.g., strapping, exterior insulation, water-resistive barrier membranes, claddings).

- Because of the solid nature of EMTC enclosure assemblies, additional service spaces may be needed to run building utilities.
- Generally, cladding materials should be Noncombustible due to the fire-sensitive nature of the assembly and given all the other encapsulation requirements. However, the Code does allow for portions of the cladding to be Combustible under certain conditions. Refer to Article 3.2.3.7. of the Code for the circumstances when Combustible cladding is permitted with respect to spatial separation, and Article 3.1.18.7. of the Code for further limitations with respect to EMTC. Both requirements must be met.
- Other Combustible components, such as membranes, insulation, and cladding attachments in exterior walls, or any component permitted in Noncombustible Construction, per Subsection 3.1.5. of the Code, can be used, provided the wall assembly satisfies the Code criteria for fire protection.
- While not specifically required by the Code, structural connections in the assembly must be adequately protected as part of the fire protection, including recessing them where no dedicated encapsulation layers are used. Structural connections must not prematurely fail and must have the same rating as the assemblies being supported. Refer to Section 5.7.5.5 Connections for structural requirements.

Table 5-11: Overview of Typical Mass Timber Wall Structure Types Used in EMTC

WALL STRUCTURE TYPE AND DESCRIPTION			
LOADBEARING		**NON-LOADBEARING**	
			
Platform: Mass Timber wall panels that rest on and/or support the building structure directly. Platform framing may not be suitable for tall buildings due to crushing.	**Balloon**: Mass Timber wall panels that run continuously past the floors, with each floor resting on a ledger or bracket that is connected to the exterior wall panels.	**Bottom-Bearing**: Mass Timber wall panels that are supported at their base by the building structure/floor.	**Hung ("Curtain Wall")**: Mass Timber wall panels that are set out beyond the building structure and run past its face, are hung and supported by the structure with clips or brackets.

Wall Assembly Diagrams

Table 5-12 outlines the basic design considerations for encapsulated Mass Timber wall assemblies based on the relevant Code requirements.

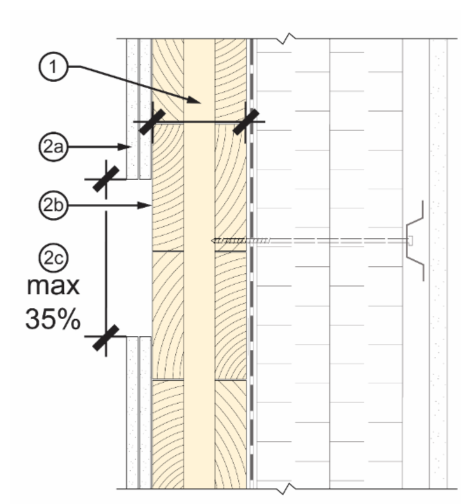
Wall Assembly Examples

Two typical opaque wall assemblies can be effectively used in EMTC, as presented in Table 5-13. The loadbearing and non-loadbearing assemblies are based on common exterior-insulated wall-assembly approaches and use many typical materials and components.

In all cases, insulation is placed on the exterior side of the structure and the air and water-resistive barrier. Interior insulation in encapsulated Mass Timber wall assemblies is not recommended in the BC climate, due to moisture and vapour control challenges. A non-opaque option such as a curtain wall, while a fenestration system, could also be used as part of the vertical enclosure assembly, provided the various fire protection and energy utilization requirements are met.

For more information on typical wall assembly and curtain wall design and construction, refer to Section 8 References and Related Documents.

Table 5-12: Overview of Mass Timber Wall Assembly Design Considerations for EMTC

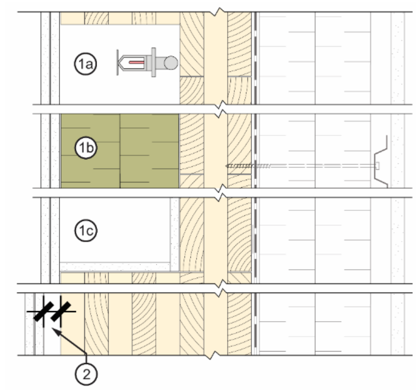
CODE REFERENCE AND DESCRIPTION	WALL ASSEMBLY PLAN SECTION
BASIC ASSEMBLY CONSTRUCTION	
1. Article 3.1.18.3. Structural Mass Timber Elements: Sentence (2) sets out the basic assembly requirements for typical Mass Timber elements, including walls that: a) are arranged in heavy solid masses containing no concealed spaces (except as permitted); b) have smooth flat surfaces, with no thin sections or sharp projections; and c) have the minimum dimensions, as listed in Table 3.1.18.3., which specifies i) 96 mm for walls that are fire separations or exterior walls (1-side exposure), and ii) 192 mm for walls that require Fire-Resistance Rating (FRR), but are not fire separations (2-sided exposure). 2. Article 3.1.18.4. Encapsulation of Mass Timber Elements: a) Sentences (1) and (2) require the protection of all exposed surfaces of Structural Mass Timber with a material that provides an Encapsulation Rating of at least 50 minutes. Materials include gypsum board, concrete, or other Noncombustible material per Article 3.1.19.2. Encapsulation Materials. b) Sentence (4)[a] allows for the exposed surface of Mass Timber walls within a suite to be unprotected provided that: i) All exposed surfaces face the same direction. ii) The Flame-Spread Rating on any exposed surface is not more than 150. c) Sentence (5) limits the total exposed surface area of Mass Timber elements within a suite to 35% of the suite's total perimeter wall area. This total surface area includes all exposed Mass Timber walls, beams, columns, and arches within the suite (refer to Sentence (3)[a] of the Code). **NOTES**: [a] Permissions for exposed Mass Timber within residential suites per Sentences 3.1.18.4.(3), (4), and (5) of the BCBC do not apply to residential suites in the VBBL.	 Plan Section

CODE REFERENCE AND DESCRIPTION	WALL ASSEMBLY PLAN SECTION

CONCEALED SPACES WITHIN THE WALL ASSEMBLY

1. Article 3.1.18.3. Structural Mass Timber Elements: Sentence (4) lists the options for the protection of (larger) concealed spaces. They must be:
   a) sprinklered and divided into compartments, per Subsection 3.1.11;
   b) completely filled with minimum 32 kg/m^2 mineral wool insulation [a]; or
   c) lined with 12.7 mm, Type X gypsum board or other material providing 25-minute encapsulation and vertically divided into compartments, per Subsection 3.1.11.
2. Per Article 3.1.18.14. Exposed Construction Materials and Components in Concealed Spaces, and Article 3.1.18.9. Nailing Elements, a 25 mm concealed space is permitted between the Mass Timber and the encapsulation material. A 50 mm space is permitted if its surfaces have a Flame-Spread Rating (FSR) of 25 or less, or if it is filled with Noncombustible insulation.
3. Article 3.1.18.15. Penetrations by Outlet Boxes:
   a) Per Sentence (1) the minimum dimension requirements for Structural Mass Timber elements (Clause 3.1.18.3.(2)(c)) do not apply at locations where outlet boxes are installed in accordance with Article 3.1.9.4.
   b) Additionally, per Sentence (2) exposed surfaces within the penetration do not require protection, per Sentence 3.1.18.4.(1).

NOTES:
[a] Mineral fibre for the purpose of filling concealed mass timber spaces must be rock or slag fibre insulation conforming to CAN/ULC-S702, Standard for Mineral Fibre Thermal Insulation for Buildings.



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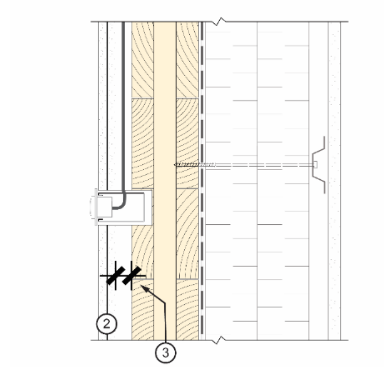
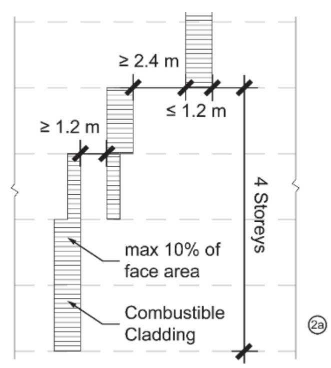


Plan Section

CLADDING MATERIALS

1. EMTC requires Noncombustible exterior wall assemblies with the following exceptions.
2. Sentence 3.1.18.7.(2) allows the cladding to consist of the following:
   a) Combustible cladding that
      i) is not touching/sharing a border over more than 4 storeys;
      ii) is <10% of the cladding on each exterior wall of each storey[a];
      iii) is ≤1.2 m wide;
      iv) has a Flame-Spread Rating (FSR) of ≤75 on any exposed surface or any surface that would be exposed by cutting through the material in any direction;
      v) is separated from other portions of Combustible cladding on adjacent storeys by a horizontal distance ≥2.4 m; and
      vi) is separated from other portions of Combustible cladding by a horizontal distance ≥1.2 m. Refer to Table 3.2.3.7. of the Code for exposing building faces.
   b) Combustible cladding that
      i) is not touching/sharing a border across adjacent storeys;
      ii) is ≤10% of the cladding on each exterior wall of each storey[a];
      iii) has a Flame-Spread Rating (FSR) of ≤75 on any exposed surface or any surface that would be exposed by cutting the material in any direction; and
      iv) is separated from other portions of Combustible cladding on adjacent storeys by a horizonal distance of ≥2.4 m.



Elevation

continued…

CODE REFERENCE AND DESCRIPTION	WALL ASSEMBLY PLAN SECTION

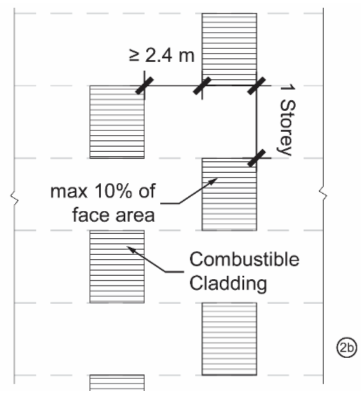
Cladding Materials, continued

c) Combustible cladding representing 100% of the first storey exterior wall, provided
   i) all portions can be directly accessed; and
   ii) the horizontal distance from building face to street or access route is ≤15 m.

d) The wall assembly satisfies the criteria of Clause 3.1.5.5 (1)(b) when subjected to testing in conformance with CAN/ULC-S134, Fire Testing of Exterior Wall Assemblies. Sentence (6) requires all assemblies containing Combustible fire-retardant-treated wood to be tested for fire exposure after the wood has been subjected to ASTM D2898, Standard Practice for Accelerated Weathering of Fire-Retardant-Treated Wood for Fire Testing. Per Sentence (4) of the Code, exterior wall assembles constructed per Section D-6, Fire Performance of Exterior Wall Assemblies, in Appendix D, Division B of the Code are deemed to satisfy this requirement.

3. Sentence (5) states that where the limiting distance in Table 3.2.3.1.-D or Table 3.2.3.1.-E permits an area of unprotected openings, ≤10% of exposing building face the construction requirements of Article 3.2.3.7. must be met, except as permitted in Article 3.2.3.10. (unlimited unprotected openings).
4. Sentence (7) sets minimum separations between portions of Combustible cladding. Where Combustible cladding, as described in items 2 a) or 2 b) above, is exposed to other Combustible cladding as described above, and the planes of the two exterior walls are parallel or the angle measured from the outside is <135°, the portions of cladding must:
   a) be separated by a horizontal distance of ≥3 m; and
   b) not be touching or sharing a border over more than 2 storeys.

NOTES:
[a] Except where the time from receipt of notification of a fire by the fire department until the arrival of the first fire department vehicle at the building exceeds 10 minutes in 10% or more of all fire department calls to the building, the area of combustible cladding shall not exceed 5% of the cladding on each exterior wall of each storey (refer to Sentence 3.1.18.7.(3) of the Code).



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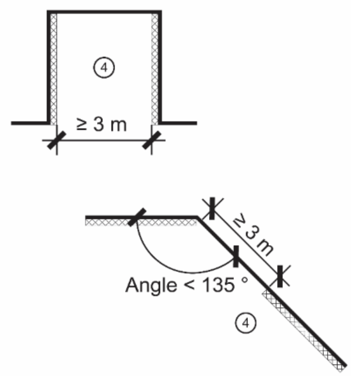
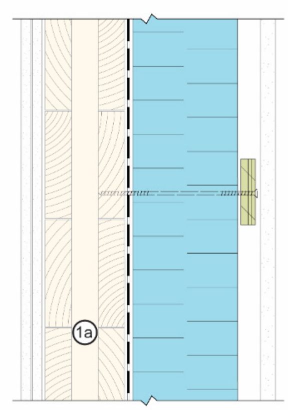


Plan Section

COMBUSTIBLE COMPONENTS IN EXTERIOR WALLS

1. Article 3.1.18.8. Combustible Components in Exterior Walls sets requirements for Combustible components in Encapsulated Mass Timber Construction (EMTC) exterior walls:
   a) Sentence (1) states that Combustible components other than Combustible cladding can be used in EMTC, provided the wall assembly satisfies the criteria of Clause 3.1.5.5 (1)(b) when subjected to testing in conformance with CAN/ULC-S134, Fire Testing of Exterior Wall Assemblies. Sentence 3.1.18.7.(6) of the Code requires all assemblies containing Combustible fire-retardant-treated wood to be tested for fire exposure after the wood has been subjected to ASTM D2898, Accelerated Weathering of Fire-retardant-Treated Wood for Fire Testing.
   b) Exterior wall assemblies constructed per Section D-6, Fire Performance of Exterior Wall Assemblies, in Appendix D, Division B of the Code are deemed to comply, per Sentence (2).



Plan Section

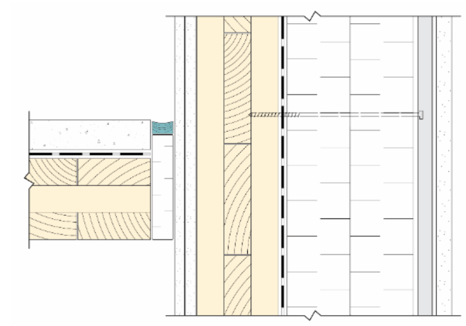
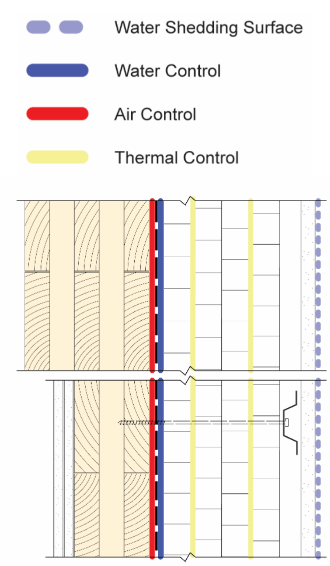
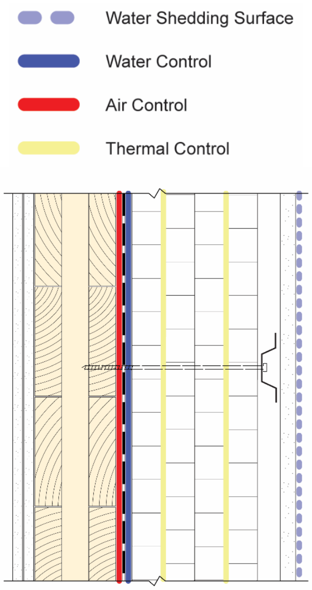
CODE REFERENCE AND DESCRIPTION	WALL ASSEMBLY PLAN SECTION
FIRESTOPS	
1. Per the various firestop requirements in Section 3.1. of the Code, all areas of a floor acting as a fire separation must include firestops at edges and penetrations. In particular, space between the edge of the floor and the interior face of the wall assembly, such as is created where hung exterior walls are set out from the structure (see Table 5-11), requires firestopping.	 Cross Section (at slab edge)
BUILDING FIRE SAFETY	
1. The cladding requirements under Article 3.1.18.7. do not supersede the provisions in Subsection 3.2.3. regarding spatial separation and exposure protection.	

Table 5-13: Overview of Typical Mass Timber Wall Assemblies Used in EMTC

ASSEMBLY DESCRIPTION	WALL ASSEMBLY PLAN SECTION
LOADBEARING EXTERIOR-INSULATED WALL	
Exterior: • Cladding (meeting combustibility requirements) • Strapping/airspace/cladding attachment system • Noncombustible exterior insulation • Self-adhered air/water barrier (meeting combustibility requirements) • Mass Timber panel (minimum thickness per combustibility requirements) • 5-ply Cross-Laminated Timber (CLT) or • 3-ply CLT with interior Type X gypsum board **Interior:** An exterior insulated wall assembly allows for flexibility at the interior for leaving the Mass Timber exposed, where permitted. Exterior insulation keeps the Mass Timber warm and dry to a near-indoor condition and can be a continuous thermally efficient layer, compared to interior insulation approaches. The Mass Timber panel allows flexibility in cladding attachment, since the structural connections can be made as needed to accommodate insulation and cladding installation without having to align with concealed framing.	 Plan Section

ASSEMBLY DESCRIPTION	WALL ASSEMBLY PLAN SECTION
NON-LOADBEARING EXTERIOR-INSULATED WALL	
Exterior: • Cladding (meeting combustibility requirements) • Strapping/airspace/cladding attachment system • Noncombustible exterior insulation • Self-adhered air/water barrier (meeting combustibility requirements) • Mass Timber panel (minimum thickness per combustibility requirements) • Interior Type X gypsum board **Interior:** While the Mass Timber and encapsulation requirements may differ for non-loadbearing walls, the basic design principles from an enclosure perspective are the same as those for loadbearing walls. However, there may be greater flexibility in the construction and installation approach, since the wall can mount onto the building as infill or be hung from the structure.	 Plan Section

5.4.4.4 Windows

Combustible Windows

Encapsulated Mass Timber exterior wall assemblies in EMTC are permitted to contain windows with Combustible sashes and frames, provided the windows are individual units, are separated by a minimum vertical distance, and the total area of openings in a wall face is below the Code maximum. Given the use of Mass Timber elsewhere, there is often a desire to also incorporate wood windows within these buildings. Typically, wood windows suitable for high-rise exposures are capped with aluminum for durability and referred to here as wood-hybrid frames.

Windows, doors, skylights, and their components must meet the requirements of Article 5.9.2.2. of the Code. The two acceptable compliance paths are following the prescriptive requirements of the Code or meeting the performance levels determined from the specific exposure conditions of each building, as required by the AAMA/WDMA/CSA 101/I.S.2/A440, "NAFS – North American Fenestration Standard/Specification for Windows, Doors, and Skylights". Note that commercial-grade windows (i.e., not "R" Performance Grade) are typically used in mid-rise and tall buildings, as rigid vinyl, fibreglass, and wood-hybrid framed windows are Combustible.

The use of Combustible windows beyond the restrictions of Article 3.1.18.6. of the Code would require an alternative solution. An alternative solution would include project- or assembly-specific CAN/ULC-S134, Standard Method of Fire Test of Exterior Wall Assemblies fire testing to prove that the alternative solution design would perform as well as a design that satisfies functional and objective statements of the acceptable solutions in the Code.

Design Considerations

Table 5-14 outlines the basic design considerations for windows in encapsulated Mass Timber wall assemblies, based on the current Code requirements.

Windows and Window Installation

The window installation approach for EMTC enclosure assemblies in EMTC uses similar detailing methods as traditional assemblies, with the typically non-flange window mounted at the Mass Timber panel, and the exterior insulation mounted up to or over the perimeter frame (see Table 5-15). As with any exterior-insulated assembly with the window aligned with the structure, unique closure or trim pieces may be needed around the window perimeter. For more details on window installation methodologies see Section 8 References and Related Documents.

Table 5-14: Overview of Combustible Window Design Considerations for EMTC

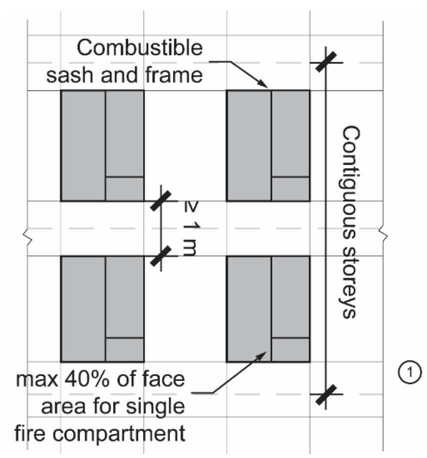
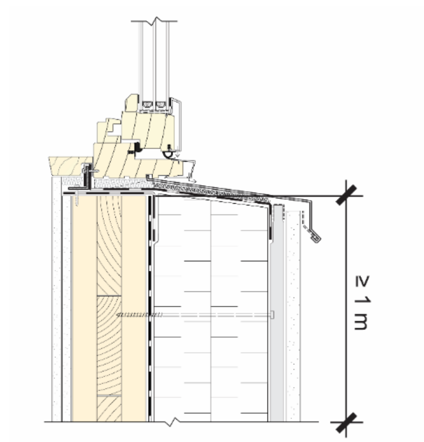
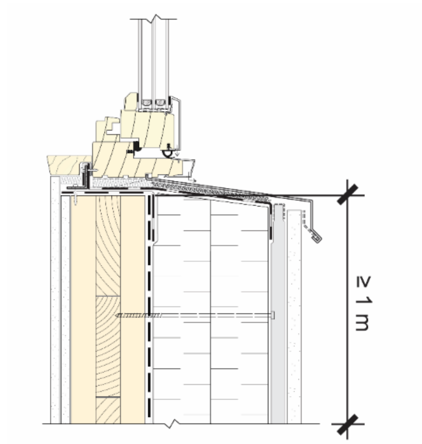
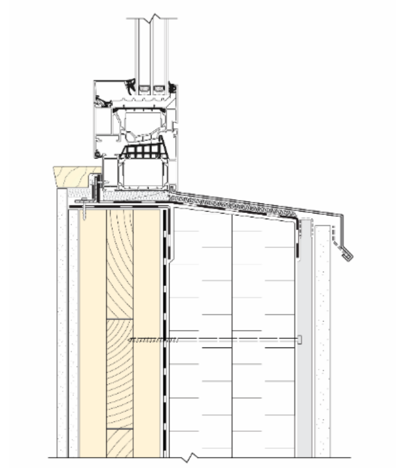
CODE REFERENCE AND DESCRIPTION	ASSEMBLY CROSS SECTION
WINDOW SASH AND FRAME CONSTRUCTION	
1. Article 3.1.18.6. Combustible Window Sashes and Frame: Sentence (1) allows for the use of Combustible window sashes and frames in EMTC provided: a) each window is an individual unit separated from other openings (windows) by Noncombustible wall construction or Mass Timber wall construction, per the minimum dimensions in Table 3.1.18.3.; b) windows in exterior walls that are touching/sharing a border with other storeys are separated by ≥1 m of Noncombustible wall construction or Mass Timber wall construction, per the minimum dimensions in Table 3.1.18.3.; and c) the total area of openings in the exterior wall face of a fire compartment is ≤40% of the total area of the wall face.	 Elevation  Cross Section

Table 5-15: Overview of Window Assemblies Used in EMTC

ASSEMBLY DESCRIPTION	ASSEMBLY CROSS SECTION
COMBUSTIBLE FRAME WINDOW	
1. As noted, the vertical offset distance between the window openings must be maintained under current Code requirements. The best practice window installation approach uses a drained secondary sill membrane that drains to the outside surface of the wall or, where appropriate, the outside surface of the exterior insulation. Over-insulation is also advisable where high-performance thermal and energy targets are sought. As with the wall assembly, the solid Mass Timber "substrate" allows flexibility in mounting options for the window, as well as the installation of insulation, cladding, and closures.	 Cross Section
NONCOMBUSTIBLE FRAME WINDOW	
1. Thermally broken aluminum window frame windows typically qualify as Noncombustible, so no vertical separation or maximum areas restrictions apply. The same installation approach as with Combustible windows is used.	 Cross Section

5.4.4.5 Balconies

Like roofs, balconies in EMTC also present many potential challenges with respect to concealed spaces, roof coverings, the use of wood roof sheathing for slope, and other Combustible materials.

Balcony Designs and Structural Connection Types

Two typical balcony design types on EMTC buildings are addressed in these guidelines: recessed and projecting. While these types are not necessarily unique to EMTC, the unconventional balcony construction approaches that may be used in EMTC prompt an evaluation from a broad enclosure-design perspective, as outlined in Table 5-16.

Furthermore, two typical balcony construction types may be used in EMTC: integrated and face-mounted. The EMTC enclosure assemblies, combined with the Structural Mass Timber, may allow for less-conventional balcony structural approaches and, therefore, building enclosure detailing considerations. As with all building enclosure design items, the balcony detailing approach should be coordinated with the work of other members of the design team, particularly the structural engineer of record (SER). Table 5-17 compares the two balcony construction approaches in EMTC.

Table 5-16: Comparison of Design Considerations for Recessed versus Projecting Balconies in EMTC

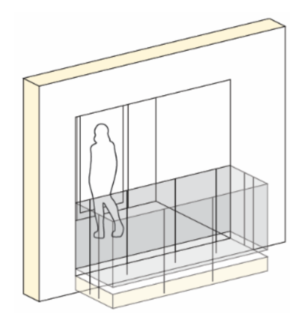
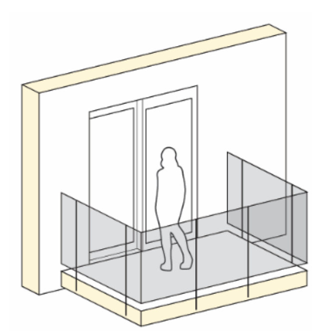
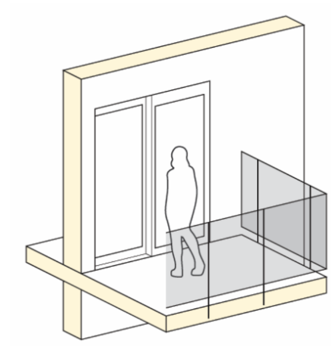
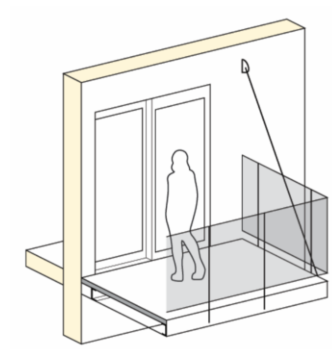
BALCONY DESIGN	ILLUSTRATION
RECESSED	
Recessed balconies are partially or fully inset into the building façade. A recessed balcony (among other considerations): • has potentially lower exposure of the balcony-to-wall detail compared to a projecting balcony; • allows for potentially simplified connections to the building, since it interfaces with the building at two or more exterior walls; • presents design challenges with respect to drainage from the balcony surface, especially when fully recessed, and may require a dedicated drain system; and • is a roof assembly (i.e., a roof deck) at portions, where there is interior space directly below (see Section 5.4.4.2 Roof Assemblies).	
PROJECTING	
Projecting balconies extend from the building façade with no recessed (i.e., inset) portions. A projecting balcony (among other considerations): • has the highest exposure of the balcony-to-wall interface; • is often a cantilevered Mass Timber structure or may require an additional exterior support structure, since it is generally only connected to the building at one side; and • may allow for more straightforward drainage design, because all edges can potentially be used for water drainage.	

Table 5-17: Comparison of Continuous versus Face-Mounted Balconies in EMTC

BALCONY CONSTRUCTION	ILLUSTRATION
INTEGRATED	
Integrated balconies are made from the Structural Mass Timber floor panel (in EMTC) or intermittent Structural Mass Timber beams that project through the enclosure (cantilevered members). An integrated balcony (among other considerations): • requires careful detailing at the balcony-to-wall interface, since the wood structure projects directly through the wall, disrupting the various enclosure control layers, most importantly the air barrier; • requires consideration for the thermal bridging effects of the balcony; • allows for the floor structure to be fully cantilevered (and projecting) and may not require additional exterior structural support (and therefore penetrations); and • requires careful consideration for long-term moisture protection around its entire surface, since the Mass Timber balcony connects through to the building's floor assembly.	
FACE-MOUNTED	
Face-mounted balconies are fastened directly to the building façade with intermittent connections, rather than using a continuous Structural Mass Timber floor structure or Structural Mass Timber beams (see above). A face-mounted balcony (among other considerations): • can be either Noncombustible, such as steel/concrete, or be made of Structural Mass Timber; • uses intermittent connections that may reduce the complexity and quantity of the components that penetrate through/interface with the building enclosure control layers, potentially reducing thermal bridging, air leakage, and the risk of water ingress; • may require additional exterior structural support, compared to an integrated (cantilevered) Structural Mass Timber balcony; • requires careful consideration for long-term moisture protection around its entire surface; and • requires consideration of differential movement between the balcony and the interior structure with respect to the membrane performance, for both similar and dissimilar materials.	

Design Considerations

Balcony assemblies in EMTC present several new design challenges, with respect to structural and building enclosure detailing, concealed spaces, durable balcony waterproofing, and the use of additional wood sheathing for slope.

- Exterior Mass Timber balcony components must be carefully designed to have durable water protection, as they are much more sensitive to moisture than concrete assemblies.
- Where soffit screening is used, ember-resistant soffit screening is recommended. See Section 5.4.9 Wildfires and Embers.
- Where bolt-on balconies are used, the EMTC enclosure assemblies, whether loadbearing or non-loadbearing, must be designed to accommodate them.
- Because of the solid nature of Mass Timber panels, additional service spaces may be needed to run building utilities that might otherwise have been run inside a concrete slab (e.g., in-slab dryer and kitchen exhaust ducts that terminate at the balcony soffit).
- Secondary sloped wood sheathing may be used to achieve the desired balcony

slope required for surface water management. With this approach, the Structural Mass Timber elements can be installed flat, and sloped blocking used to position the sheathing for drainage, as needed.

- For integrated balconies requiring additional sloping at the top surface, the increased height may result in a step up from the interior floor level. This condition would not be acceptable for accessible balconies, and is likely to cause moisture-ingress issues. To avoid this condition, the balcony Structural Mass Timber thickness could be reduced locally to accommodate the framing/sloping, or a face-mounted approach could be used.
- Guard attachment, while not specific to EMTC, should be carefully considered. Penetrations through the balcony roofing membrane on the top surface should be avoided, and attachment to the vertical face of the balcony must be designed to avoid potentially weak connections in the end grain of Structural Mass Timber elements. All guards and their attachment must meet the lateral load requirements in Part 3 and Part 4 of the Code.

Table 5-18 outlines the basic design considerations for encapsulated Mass Timber balcony assemblies based on the relevant Code requirements.

Balcony Examples

As indicated above, in the context of the Code, two basic balcony types are used in EMTC, each with unique design considerations. Table 5-19 presents these two assembly types, along with the different structural approaches.

Table 5-18: Overview of Balcony Design Considerations for EMTC

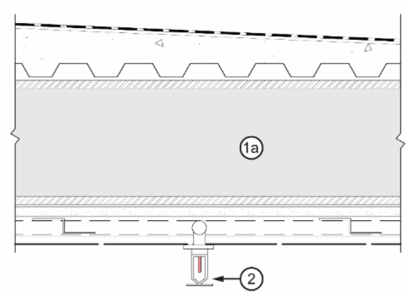
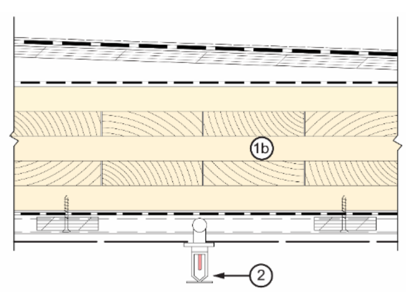
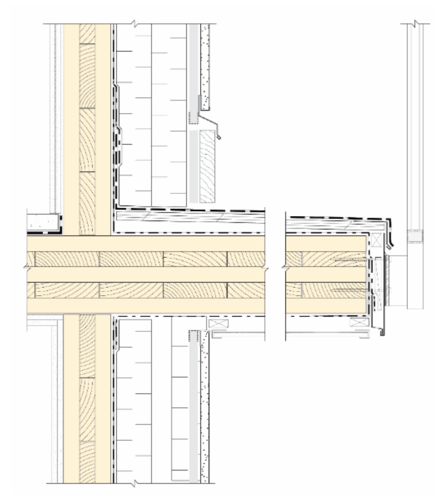
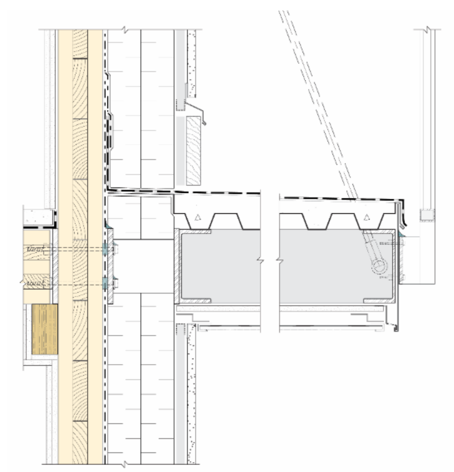
CODE REFERENCE AND DESCRIPTION	ASSEMBLY CROSS SECTION
EXTERIOR BALCONY CONSTRUCTION	
1. Article 3.2.2.11. Exterior Balconies: Sentence (2) sets out exterior balcony construction requirements for EMTC. They must be: a) of Noncombustible Construction; or b) be constructed according to the basic assembly requirements of Article 3.1.18.3., but are not required to be encapsulated per Sentence 3.1.18.4.(1). 2. Per Sentence 3.2.5.12.(8), balconies and decks projecting more than 610 mm require sprinklers.	 Cross Section  Cross Section

Table 5-19: Overview of Balcony Assemblies Used in EMTC

ASSEMBLY DESCRIPTION	ASSEMBLY CROSS SECTION
STRUCTURAL MASS TIMBER INTEGRATED BALCONY	
The Mass Timber floor assembly is extended to the exterior to form a balcony structure, which is fully protected with a robust waterproofing system. A dedicated robust roofing membrane is recommended, and a durable walking surface, such as pavers, should be placed on top for traffic protection. Note the Structural Mass Timber projecting to the exterior must be completely wrapped with the air barrier membrane to maintain the air barrier continuity; attempting to maintain the wall air barrier through the floor structure is challenging; therefore, redundancy is recommended. See also Section 5.4.4.1 Control Layers and Critical Barriers, under the subsection Water-Resistive Barrier/Waterproof Membrane.	 Cross Section
NONCOMBUSTIBLE FACE-MOUNTED BALCONY	
The Noncombustible balcony is, by nature, face mounted (unless a floor structure other than Mass Timber is used), and is commonly referred to as a “bolt-on” balcony. This configuration allows for potentially simpler detailing of the primary air and moisture barrier at the wall. However, the connection and support of the bolt-on balcony must be carefully designed to accommodate floor-to-floor building movement (especially if a balcony cable is used) and optimize the thermal performance by using thermal breaks. The bolt-on balcony (whether steel, concrete or other material) must still be protected with a robust waterproofing system.	 Cross Section

5.4.5 PREFABRICATED FACADES

Prefabricated facades are generally panelized exterior walls that are fabricated with most or all of their enclosure components installed off site. They are transported to site for installation, and require reduced on-site construction effort compared to site-built assemblies. These panelized facades are often built in dedicated manufacturing facilities or other controlled environments. Prefabricated facades may be necessary for encapsulated Mass Timber tall buildings, due to the fire protection requirements under the Code and Fire Code, and to protect the Mass Timber from extended exposure during construction.

Note that the guidance presented in this section may also apply to other prefabricated enclosure assemblies, such as roofs and floors, where appropriate, but these assemblies generally make up a smaller proportion of the enclosure in EMTC up to 12 storeys.

5.4.5.1 Panelization

For EMTC up to 12 storeys with typical floor layouts, the repetitious vertical enclosure can be designed as standardized panels with typical wall and glazing configurations. This panelization approach is not a new concept, but it may be an important consideration for EMTC enclosure assemblies, and for all enclosure types in EMTC (Figure 5-14).

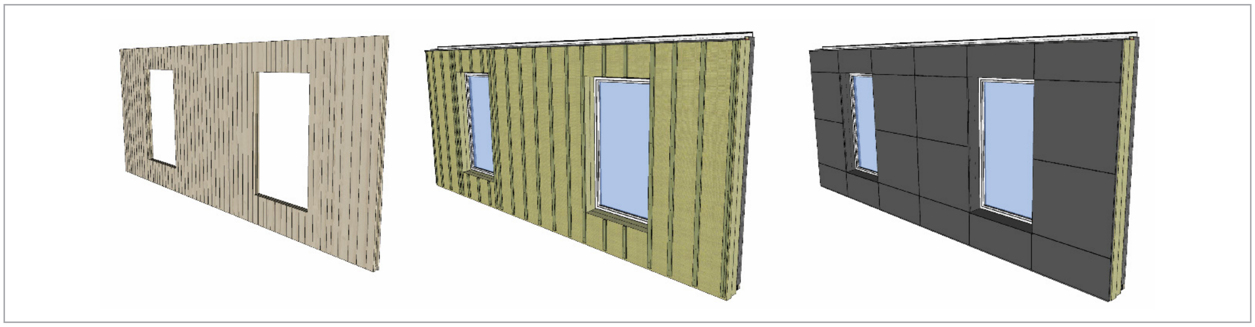
This panelization approach may involve more prefabrication of the opaque wall portions, including installation of windows and doors and interior finish components. It may also include planning for balcony installation, including attachment of structural bracket standoffs (see Section 5.4.4.5 Balconies).

The maximum size of prefabricated panels depends on the method used to ship panels to site, the weight of the panel, and the method of installation (i.e., the size of crane). Panel size can also be dictated by the panel-to-panel connections and the glazing layout.

Prefabricated panelized systems offer the following several potential benefits, compared to the conventional site-built enclosure construction approach:

- **Quality Assurance/Quality Control**: Prefabrication in a controlled manufacturing setting may allow for enhanced quality assurance and quality control, reducing the risk of deficiencies typically encountered on site-built components (see also Section 5.3.5.2 Advantages of Factory Prefabrication). Pre-site installation testing or performance mock-up testing is done to test the prefabricated system before installing it on site.
- **Accessibility**: Prefabrication allows for the ease of installation of components in a weather-controlled environment, and reduces challenges related to accessing high sections of a building on site.
- **Constructability**: With thicker wall and insulation depths required for energy-efficient buildings, constructability is an important factor, and direct oversight in a controlled environment makes potentially relatively complex detailing work easier to accomplish.
- **Reduced Waste**: Shop fabrication of panels with a standardized and optimized design can allow for reduced material waste and fabrication time.

Figure 5-14: Illustrations of prefabricated Mass Timber panel build sequence concept, showing installation of exterior control layers including insulation, glazing, and cladding

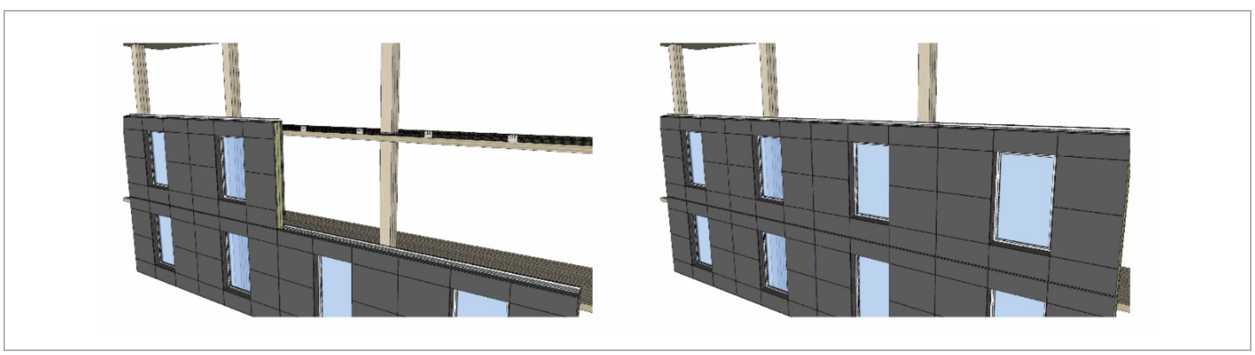


5.4.5.2 Site Installation

Once on site, prefabricated systems (Figure 5-15) offer the following further benefits over conventional approaches:

- **Protection**: Prefabricated Mass Timber panels, containing all or most control layers at the time of site installation, are better protected from incidental construction moisture exposure than fully exposed panels. The control layers also act as partial protection for the panels during storage and installation, and reduce the need for temporary protection. Note that the moisture/air control layers must either be folded or lapped *in-situ* or be installed as field lap pieces. Temporary protection of panel edges and end grains, including openings for windows and doors, may still be critical. The protection requirements and quality assurance/quality control protocols for installation should be specified by the design team and implemented by the constructor.
- **Speed**: Installation of prefabricated Mass Timber panels can be much faster than site-built assemblies. While the fabrication time is still part of the construction timeline, the installation on site can be rapid and efficient.
- **Access**: Prefabricated Mass Timber panels can be designed such that upon installation they require little to no further access from the exterior, reducing the need for elevated access equipment like scaffolding, stages, and lifts.

Figure 5-15: Illustrations of prefabricated Mass Timber panel installation sequence concept, with large areas completed in few steps



5.4.5.3 Prefabricated Volumetric Modules

Another factory-built option is prefabricated volumetric modules, which include structural systems, building systems, and built-in interior components. It is not a new concept, and prefabricated modular construction offers many of the same benefits as prefabricated panelized construction.

However, modules generally require specialty design and development compared to panelized approaches, since the large prefabricated components often include many interfacing components and present unique shipping and installation challenges.

Note that volumetric modular EMTC would likely result in concealed spaces between modules. These concealed spaces would need to comply with Sentence 3.1.18.3.(4) of the Code.

5.4.5.4 Prefabrication Review and Verification

As defined by the Code, field reviews are conducted "at a building site [and] at locations where building components are fabricated for use at the building site."

Like on-site field reviews, factory review work includes testing and verification that the components conform to the design drawings.

For further guidance on field reviews, see Section 7.2.5 Documented Field Reviews During Implementation or Construction, Section 7.4 Prefabricated and Factory-Built Components, and Section 8 References and Related Documents.

5.4.6 MOISTURE EXPOSURE AND PROTECTION OF MASS TIMBER

For moisture-sensitive products like Mass Timber, the most critical enclosure load is often liquid water. When Mass Timber absorbs water, it can shrink and swell, causing dimensional changes and creating an increased risk for microbial growth, decay, and corrosion of metal fasteners or connectors. Mass Timber sections can retain large amounts of water for extended periods of time if sufficient drying is not available, further increasing these risks. The recommended practice for EMTC is to keep the Mass Timber components warm and dry throughout the construction and occupancy of the building.

Managing moisture risks associated with EMTC and enclosure assemblies requires attention to moisture management during design, manufacturing, shipping, construction, and occupancy. Sources of moisture include but are not limited to:

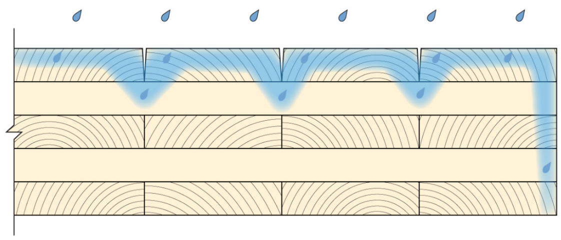
- wetting from rain of unprotected elements during transport or storage;
- rainfall and snowmelt, condensation, and plumbing leaks during construction; and
- plumbing failures, appliance leaks, spills, and the activation of the sprinkler system during occupancy.

When EMTC enclosure assemblies are subjected to long-term exposure or standing water, moisture can penetrate into the Mass Timber. This moisture can become trapped within the pore structure of the wood at locations such as prefabricated panel interfaces, lamination interfaces, splices, and exposed end grain, and between laminations and sheathing layers (Figure 5-16).

Successful moisture management of the EMTC enclosure assembly begins early in the design phase and continues throughout the construction phase of the project. A recommended approach to moisture management for EMTC buildings is to prepare a moisture management plan. This plan can be prepared by the design team, or it can be a requirement that the constructor provide it before commencing construction.

A moisture management plan will anticipate sources of moisture that the building might experience during construction, incorporate features in the design to prevent moisture exposure where possible, and outline how to address moisture exposure when it occurs during construction. For further guidance on Mass Timber moisture protection see Section 8 References and Related Documents.

Figure 5-16: Illustration of moisture penetration into a Mass Timber panel due to persistent wetting



5.4.6.1 Moisture Protection of Mass Timber

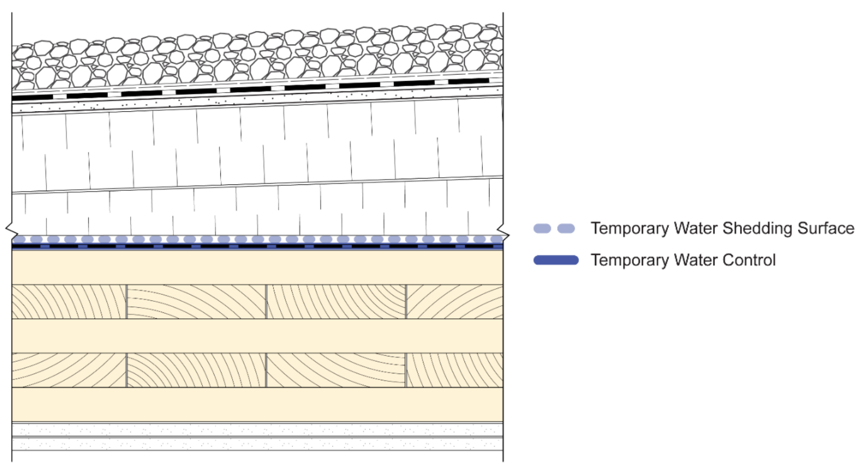
Exposure of the Mass Timber to moisture can be avoided through the careful selection and design of temporary membranes, slope, venting, and long-term water-resistive barrier and waterproofing membranes.

Assembly design planning offers opportunities to consider dual-purpose materials, such as acoustic underlayments or temporary roof membranes, which later function as the air barrier and/or vapour control membrane. These protective components can be installed both during fabrication, before there is a risk of exposure during transportation, or on site. Once on site, further moisture protection will likely be needed.

Factory-installed components include the enclosure elements that make up the final assembly, but may also include dedicated permanent moisture-protection layers, such as water-resistant wood sealer for any exposed wood protection, as well as temporary membranes and covers. Moisture protection installed prior to transportation and storage that does not trap moisture and facilitates drying, if needed, is another effective moisture-protection strategy. Site-installed moisture protection may include temporary membranes, covers/tarps, and sealant once the enclosure is assembled.

As noted previously, compared to conventional site-based construction approaches, prefabrication of assemblies allows more of the enclosure components to be installed in the factory, prior to delivery to site, and used as moisture protection. Once on site, this approach also facilitates faster close-in and reduces the moisture exposure of the EMTC enclosure assemblies.

Figure 5-17: Illustration showing how the membrane directly on the surface of the Mass Timber roof can be used as the temporary moisture protection during construction, and then serves as the roof air barrier membrane once the assembly is complete



5.4.6.2 Active Water Management Strategies

Exposure to construction moisture can be actively managed on site using additional methods and equipment beyond passive protection measures, including but not limited to the following:

- Using portable canopies, small tarps, squeegees, mops, and vacuums to limit standing water on Mass Timber elements, both in exposed areas and where water may travel further into the building.
- Using moisture-detection technology during the construction phase to confirm the moisture content (MC) of Mass Timber elements, before installing impermeable components and encapsulation layers. Testing of MC in Mass Timber prior to encapsulation is required.
- Employing real-time monitoring and logging of the MC levels in the Mass Timber elements, both near the surface and at greater depths within components, to help track at-risk areas (Figure 5-18). Note that end grains at panel edges, spline joints, and cut holes can absorb more moisture than wood faces, and will remain wet for a prolonged period after wetting has occurred.
- Including mechanical drying with blowers and electric heaters during construction, as part of the moisture management plan, if needed, to dry out Mass Timber elements once wet (see below).
- During construction, installing temporary floor drains on the uppermost exposed floor, to collect and drain water off the slab.
- Considering providing whole-building tarping and protection systems for buildings, when long periods of exposure to moisture are anticipated.

Drying of Mass Timber

Drying of exposed Mass Timber components can occur with prolonged exposure to sun and wind and as a result of active drying methods (Figure 5-19).

The ambient conditions in the interior of a completed (i.e., conditioned) building generally support the drying of wet materials where they are exposed to the conditioned air, but the use of active drying methods such as blower fans and electric heaters may be needed to accelerate drying to the required MC, prior to covering or encapsulating the Mass Timber components.

Figure 5-18: Illustration of moisture monitoring of the Mass Timber portions of a wall assembly

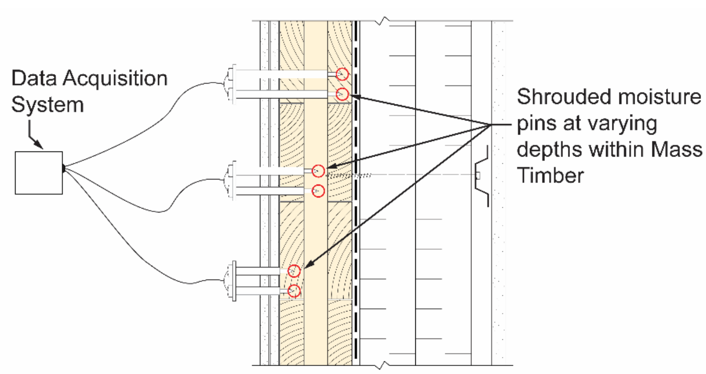
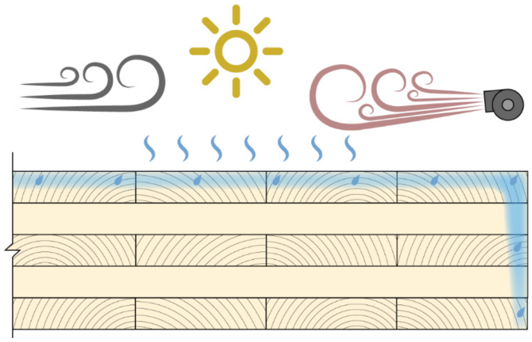


Figure 5-19: *Illustration of potential Mass Timber drying mechanisms for exposed components during construction*



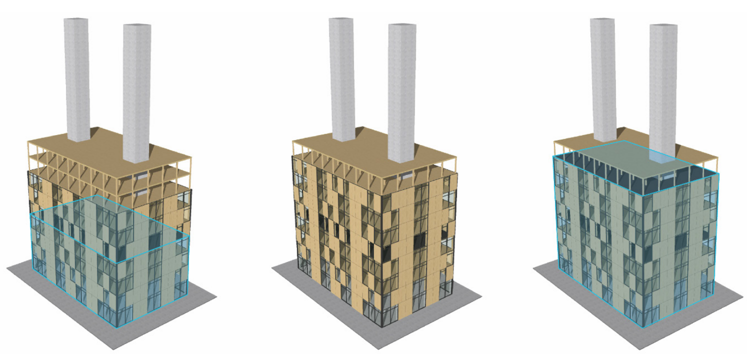
5.4.6.3 Scheduling and Sequencing

Limiting the duration of potential moisture exposure is an effective way to manage moisture risk on site. Scheduling material delivery as close as possible to installation to limit storage/staging time is best. Promptly installing permanent enclosure components will also help manage moisture, but where this is not possible, temporary protection can be used.

During the construction of EMTC buildings, a maximum of four floors of Structural Mass Timber can be without fire protection, per Article 5.6.4.3. of the Fire Code, meaning the lower floors must be encapsulated as the upper floors are added. This encapsulation may include the installation of gypsum board, which requires the lower floors to be dry and possibly conditioned; otherwise, the gypsum board may sustain damage from moisture and consequently need to be removed and replaced prior to closing in the building. One solution would be to complete the exterior walls floor-by-floor and temporarily waterproof every fourth floor level to act as the "roof" for the levels below. This waterproofed floor, tied into the completed exterior walls, would form a temporary enclosure, enabling interior finishing work to be completed on the lower floors.

In this regard, prefabrication of the enclosure can accelerate the completion of the temporary (and permanent) closure of the building, to ensure protection from moisture and enable the interior encapsulation to proceed. Care should be taken to avoid discontinuities through the floor plate (e.g., mechanical penetrations, elevator shafts), to ensure precipitation does not bypass the water-resistance layers.

Figure 5-20: *Illustration of a temporary enclosure sequence on every fourth floor of Mass Timber construction.*



NOTE: Temporary enclosures are highlighted in blue

5.4.6.4 Exposure to Moisture from Concrete

Concrete releases moisture as it cures, and also can act as a vapour-retarder that restricts drying. Concrete floor surfaces (and any non-porous horizontal surface) exposed to construction moisture can lead to ponding, which can wet nearby Mass Timber components. Moisture exposure of Mass Timber from concrete can be managed by:

- on Structural Mass Timber floors and/or roofs receiving concrete topping, using a dedicated moisture-protection membrane or coating that is highly water-resistant and has a low-to-moderate permeability (e.g., acoustic underlayment products or self-adhered membrane); and
- placing Structural Mass Timber wall panels and columns on curbs, and using structural connections that provide separation from direct contact with concrete (e.g., steel anchors that elevate the wood and separate it from wet materials).

As with all EMTC enclosure assemblies, the MC of the Mass Timber components must be measured and brought to safe levels—usually below 16%—prior to the application of impermeable components or finishes that may trap moisture. Once installed, further wetting of the Mass Timber can lead to trapped moisture, if not carefully managed.

5.4.7 MAINTENANCE AND RENEWAL

Many typical building enclosure maintenance considerations for High Buildings apply to EMTC buildings. However, several items may be unique to EMTC enclosure assemblies.

5.4.7.1 Control of Relative Humidity in Service

In-service building mechanical humidification or dehumidification may be required, to maintain the Mass Timber elements at appropriate MC levels. Interior air with prolonged periods of low relative humidity (RH) can result in Mass Timber with low MC, causing excessive shrinkage or surface checking. RH that is too high may result in fungal growth or condensation on cold surfaces. See Section 5.8.5.3 HVAC Systems for specific guidance on the control of RH within EMTC.

Specifying post-occupancy, continuous, moisture monitoring of the building is highly recommended, to mitigate the risk of moisture from any source accumulating and causing deterioration of the Mass Timber.

5.4.7.2 Wood Damage

Incidental water damage from ingress, plumbing, and appliance leaks can be difficult to repair in encapsulated Mass Timber assemblies, since the solid wood components cannot be easily replaced. Instead, Mass Timber needs to be dried out to safe moisture levels, sometimes requiring mechanical drying equipment.

It is important that access to the Mass Timber elements is possible from the interior, and that interior finishes are not permanently affixed with adhesive. The same applies to Mass Timber floors that must be accessed, usually from the bottom side. Gypsum board encapsulation could be installed with fasteners such that they can be removed if needed, and other specialty finishes could be installed as segments that can be partially removed, if needed.

Other than potential incidental moisture damage, Mass Timber components that are kept dry should not require maintenance throughout their service life.

If moisture-detection equipment has been used during construction, clear documentation regarding maintenance and long-term use must be provided to building operators by the equipment supplier.

As with other aspects of maintenance, the reading of moisture-detection equipment should be included as part of regular inspections performed by property management staff.

5.4.7.3 Exterior Access

EMTC up to 12 storeys may require roof anchors for suspended access equipment. These anchors may require specialty design for connection to Structural Mass Timber roof or wall assemblies, and often require additional support structure or bracing to meet the load requirements for fall arrest.

See also Section 5.7 Structural Considerations for further information on design and construction considerations for long-term maintenance and protection of Mass Timber elements in EMTC.

5.4.7.4 Pests

EMTC can be subject to damage by carpenter ants, termites, and other pests, in particular for wood components that are located at or near grade. While keeping wood elements of EMTC buildings dry by the building enclosure design fundamentals covered in this section is the first step to pest control, additional measures may be necessary.

For many construction types, an effective first step to mitigate against subterranean pests is to implement a pest-impermeable boundary around the structure that deters them from crossing into and coming in contact with the building. Another measure that has proved effective is to provide vertical distance between the grade and the wood structure, including exterior wood elements such as columns. This is often done by using a concrete structure at the first level and elevated concrete pedestals at column supports. Some wood treatments may also be effective at deterring some types of pests; they should be considered if the EMTC component can be treated.

5.4.8 ACOUSTIC CONTROL OF BUILDING ENCLOSURES

Providing adequate levels of noise and sound control in multi-unit residential buildings are mandatory requirements of Section 5.8. of the Code. Much effort has been spent on evaluating both sound transmission class (STC) and impact sound insulation class (IIC) of interior floor and wall assemblies, and on studies of flanking transmission in multi-unit residential buildings in Canada. However, other than consideration for flanking transmission between adjacent occupied indoor spaces, the Code does not have prescriptive requirements for the acoustic performance of encapsulated Mass Timber exterior walls and roof assemblies.

Based on what is known, the use of certain exterior insulation types in roof and exterior wall assemblies could significantly improve the acoustic performance of the assembly. However, further assessment and review of the sound characteristics of Mass Timber enclosure assemblies is recommended. See Section 5.6.6 Exterior to Interior Noise Control for further guidance.

5.4.9 WILDFIRES AND EMBERS

Various requirements in the Code for encapsulation of Mass Timber using gypsum board and the restricted use of Combustible exterior coverings do provide a good degree of fire protection of Mass Timber from direct flame and heat. Nevertheless, other enclosure components should be carefully considered in terms of fire risk from burning embers.

Wildfires or other burning materials that produce embers can lead to damage of minor Combustible materials on or in the enclosure, even with no nearby heat or flame. Sometimes overlooked, minor potentially Combustible exposed materials like synthetic bug screen mesh or fastener washers may be at risk of damage. Therefore, ember-resistant metal products like perforated sheet or steel mesh should be used wherever possible.

5.5 FIRE PROTECTION CONSIDERATIONS

5.5.1 FIRE RATINGS AND SEPARATIONS

5.5.1.1 Construction-Related Articles from the Code for EMTC

The Code incorporates the following construction-related Articles for EMTC under Subsection 3.2.2.:

- Article 3.2.2.48EMTC. Group C, Up to 12 Storeys, Maximum Area: 6,000 m^2, Sprinklered
- Article 3.2.2.57EMTC. Group D, Up to 12 Storeys, Maximum Area: 7,200 m^2, Sprinklered

The discussion in this section relates to these construction-related Articles. Structural Mass Timber may also be used in any building permitted to be of Combustible Construction.

5.5.1.2 Fire Separations

The construction materials used for fire separations in EMTC may or may not be of Structural Mass Timber. Fire separations that are not Structural Mass Timber, or Mass Timber fire separations that are non-structural, should be selected in the same manner as fire separations in any building; that is, based on fire-rated assemblies tested in accordance with CAN/ULC-S101, Standard Methods of Fire Endurance Tests of Building Construction and Materials, or on assemblies with Fire-Resistance Ratings (FRR) determined in accordance with Article 3.1.7.1. of the Code.

Article 3.1.7.1. of the Code permits the use of the methods found in Appendix D, Division B of the Code for determining the FRR of framed fire separations, including the methods in Section D-2.11, Mass Timber Elements. For Structural Mass Timber elements, Section D-2.11 provides additional considerations necessary to maintain continuity of fire separations, where Structural Mass Timber elements are designed in accordance with Annex B of CSA O86-19, Engineering Design in Wood. In addition, the Code requires the majority of Mass Timber to be encapsulated. Minor Combustible components are permitted, as for Noncombustible Construction per Subsection 3.1.5. of the Code, and specifically for EMTC per Subsection 3.1.18. of the Code.

The Code permits fire ratings to be obtained from testing or calculated, per CSA O86-19. While use of assemblies listed by accredited agencies such as ULC, UL, QAI, or Intertek is not required by the Code, tested assemblies provide an alternative to calculation. Where tested assemblies or components are not listed by an accredited agency, a fire protection engineer or other qualified Engineering Professional is responsible for assessing the applicability of the components, including the chain of responsibility.

If the test is not performed in an accredited laboratory or to a test standard, the fire protection engineer of record should witness the test or obtain a Schedule S-B and Schedule S-C from an Engineering Professional, serving as an SRP, providing assurance that the assembly conforms to the provisions of the Code. For further information, see the *Practice Advisory – Engineering Modifications to Fire-Tested and Listed Assemblies* (Engineers and Geoscientists BC 2020a). Additionally, if the test is not conducted in conformance with CAN/ULC-S101, an alternative solution under the Code is required for the assembly.

5.5.1.3 Exterior Cladding Materials

With some exceptions, the Code prescriptively requires Noncombustible exterior cladding in buildings permitted to be of EMTC. Most of the exceptions described in Article 3.1.18.7. of the Code do not allow extensive Combustible cladding other than on the first storey, where up to 100% of the cladding can be

Combustible if the cladding can be directly accessed (i.e., without intervening barriers such as fencing or inaccessible landscaping) and is located within 15 m from a street or acceptable fire department vehicle access route. Refer to Section 5.4.4.3 Wall Assemblies and Table 5-7: Overview of Insulation Options Used in EMTC Enclosure Assemblies for more information on Combustible cladding.

One exemption of Article 3.1.18.7. of the Code permitting Combustible cladding is through full-scale fire testing under CAN/ULC-S134, Standard Method of Fire Test of Exterior Wall Assemblies, as per Clause 3.1.5.5.(1)(b) of the Code. Section D-6, Fire Performance of Exterior Wall Assemblies (in Appendix D, Division B of the Code) includes five new exterior wall assemblies that are deemed to satisfy the criteria of Clause 3.1.5.5.(1)(b) of the Code, which allows them to be used in EMTC. Four of the five assemblies include wood studs in the exterior walls, while the fifth assembly includes Cross-Laminated Timber (CLT) panels without studs. One of the assemblies, EXTW-1, includes wood cladding but only as 12.7 mm fire-retardant-treated plywood siding. Full-scale fire testing under CAN/ULC-S134 is not mandatory for Combustible wall assemblies, which fall under the other exemptions of Article 3.1.18.7. of the Code.

The use of Combustible cladding in EMTC buildings is quite limited, per Table 3.2.3.7. of the Code, such that Combustible cladding can only be used where the maximum area of unprotected openings of an exposing building face is greater than 50%.

When considering the use of Combustible cladding for EMTC, the Architect or Engineering Professional should consider the durability of the material and the effect of weather on the cladding, as well as the risk of exterior fire spread.

Further, if the wall contains foamed plastic insulation, the provisions for protection of foamed plastic in Article 3.2.3.8. of the Code apply.

5.5.1.4 EMTC or Noncombustible Roof Assembly Requirements

Combustible components permitted for a roof assembly are essentially the same as for Noncombustible Construction, with specific permission for wood nailing elements, such as Combustible cant strips, roof curbs, nailing strips, and similar components found in Subsection 3.1.18. of the Code.

Foamed plastic insulation requirements are the same as for Noncombustible Construction as addressed in Articles 3.1.5.14. and 3.1.5.15. of the Code. See further discussion and examples in Section 5.4.4.2 Roof Assemblies.

5.5.1.5 Firewalls

As defined by the Code, a firewall is a type of fire separation of Noncombustible Construction that subdivides a building or separates adjoining buildings to resist the spread of fire; has an FRR as prescribed in the Code; and has structural stability to remain intact under fire conditions for the required fire-rated time.

Design and construction of firewalls used in EMTC are required to comply with Subsection 3.1.10. of the Code. The Code prescriptively requires that firewalls must be of Noncombustible Construction.

Where Mass Timber is proposed to be used as a firewall in an EMTC, the Mass Timber will be required to be provided as an alternative solution under the Code, which demonstrates compliance with the fire safety objectives and the functional and intent statements of the Code.

5.5.1.6 Elevator Shaft Walls

Elevator shaft walls may be of Mass Timber; however, coordination of required encapsulation on both faces and the attachment of elevator structural members is important, so the encapsulation is maintained for the life of the building.

Care should be taken that elevator structural elements are not attached through gypsum wallboard, where deterioration of gypsum wallboard may permit unacceptable movement.

5.5.1.7 Fire Rated Assemblies Calculated per CSA O86

A calculation procedure, as prescribed in Annex B of CSA O86-19, Engineering Design in Wood, may be used to determine the FRR of fire-rated assemblies. For more information, refer to Section 5.7 Structural Considerations.

5.5.1.8 Historic Methods

Appendix D, Division B of the Code includes some historic methods for calculation of fire ratings for nail-laminated timber floors and solid wood walls. The technical origins of these are unknown and difficult to assess for acceptability, as no loading criteria are provided. Appendix D also includes formulae for calculation of fire ratings of glulam beams and columns, which may be used as an alternate to Annex B of CSA O86-19.

5.5.2 ENCAPSULATION AND FIRE-RESISTANCE RATING

5.5.2.1 Exposed and Encapsulated Structural Mass Timber Members

To understand Encapsulation Ratings and Fire-Resistance Ratings (FRR) of Mass Timber elements, it is necessary to understand char. Annex B of CSA O86-19 Engineering Design in Wood provides char rates and calculation methodology for different types of Mass Timber elements.

When exposed to elevated temperatures, wood undergoes thermal degradation, called pyrolysis, resulting in development of a layer of char. Significant charring occurs at temperatures ranging from 280°C to 300°C, and is represented by a specified char rate in Annex B of CSA O86-19. Charring is influenced by various factors, such as density, moisture content (MC), wood contraction, and exposure conditions (fire severity). Between 100°C to 280°C, wood will lose some structural properties but is not fully charred; this is represented by a 7 mm ”zero-strength layer” and added to the calculated char depth.

Annex B of CSA O86-19 provides both a one-dimensional char rate (βo) and a notional char rate (βn), which represent shape factors and the effects of glue failure during charring for Cross-Laminated Timber (CLT). The char depth of a Mass Timber assembly is obtained from the product of a charring rate of a wood species, as prescribed in CSA O86-19, and the duration of fire exposure (that is, the desired FRR).

When Mass Timber elements are encapsulated with a single or multiple layer of 12.7 mm, Type X gypsum board, the heat transfer at the wood and gypsum board interface is effectively delayed, so the wood elements do not reach their critical heat flux or ignition temperature for a certain period of time. If the gypsum board protection remains in place when the critical heat flux or ignition temperature is reached, charring will occur at a slower pace until the protective layers fail.

The Encapsulation Rating is effectively the time that charring of a Structural Mass Timber element is delayed by the encapsulation membrane, and thus is limited from contributing to the growth and spread of fire. The FRR is the time over which the Structural Mass Timber element withstands the passage of flame and the transmission of heat, and retains sufficient uncharred wood such that it is able to sustain the prescribed design loads under fire conditions.

The Encapsulation Rating must be determined in accordance with the CAN/ULC-S146, Standard Method of Test for the Evaluation of Encapsulation Materials and Assemblies of Materials for the Protection of Structural Timber Elements. The Code permits a portion of Structural Mass Timber wall and/or ceiling surfaces to be exposed in EMTC. In areas exceeding the maximum Code provisions for exposed surfaces, an Encapsulation Rating of 50 minutes is required.

The Code prescribes that a 50-minute Encapsulation Rating is deemed to be achieved if the following are provided:

- two layers of 12.7 mm, Type X gypsum board (walls, beams, columns, and ceilings); and
- a 38 mm thick topping of gypsum-concrete or concrete (encapsulation from the top).

Note that the Encapsulation Rating is not the same as the contribution to the FRR.

In Appendix D, Division B of the Code, the Encapsulation Rating and the contribution of the encapsulation is the same: 25 minutes for a single layer of 12.7 mm gypsum board. CSA O86-19 recognizes that the gypsum wallboard, even when over 300°C, will stay in place on CLT and continue to slow the rate of char, even though char has begun. Annex B of CSA O86-19 therefore assigns a contribution of 60 minutes to the FRR for two layers of 12.7 mm gypsum board, provided the screw-spacing criteria of Annex B of CSA O86-19 are followed.

Figure 5-21 and Figure 5-22 show how the FRR is calculated between an exposed CLT assembly and an encapsulated CLT assembly, including the calculated char rate and the zero-strength layer, per Annex B of CSA O86-19. For an exposed CLT assembly (Figure 5-21), after 2 hours of fire exposure, a char depth of 103 mm is achieved (120 x 0.8 + 7 mm). For an encapsulated CLT assembly (Figure 5-22), after 2 hours of fire exposure, a char depth of 55 mm is achieved with minimum encapsulation prescribed in the Code. The design charring rate depends on the mode of heat transfer. For Mass Timber floors and walls, the mode of heat transfer is typically one-dimensional, whereas a corner rounding is explicitly considered for large rectangular cross sections.

Common practice is to have an acoustic membrane between the concrete topping and the CLT floor. Electrical raceways, hydronic heating, and other services may be laid in the concrete topping. This is acceptable practice, provided the topping has an equivalent thickness of 38 mm. As with any concrete topping, care should be taken to avoid cracking.

It is possible to increase the Encapsulation Rating such that a full 120 minutes of encapsulation is provided, and no char is anticipated. This could be provided by 4 layers of 12.7 mm, Type X gypsum board as shown in Figure 5-23.

The discussion above relates to CLT and solid timber members. Annex B of CSA O86-19 provides criteria for other types of Structural Mass Timber. Some suppliers may also have specific fire-test data for their proprietary products. There is currently very limited data for Nail-Laminated Timber; however, some archaic information is provided in Appendix D, Division B of the Code.

Figure 5-21: Diagram of an exposed Cross-Laminated Timber (CLT) assembly without encapsulation

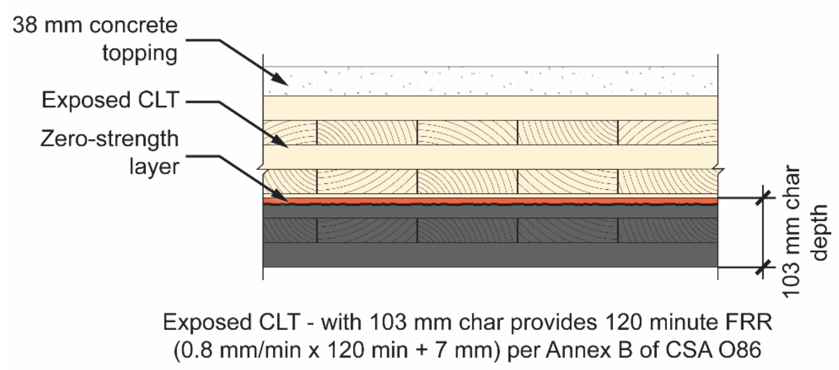


Figure 5-22: Diagram of an encapsulated Cross-Laminated Timber (CLT) assembly with the minimum prescribed 50-minute encapsulation

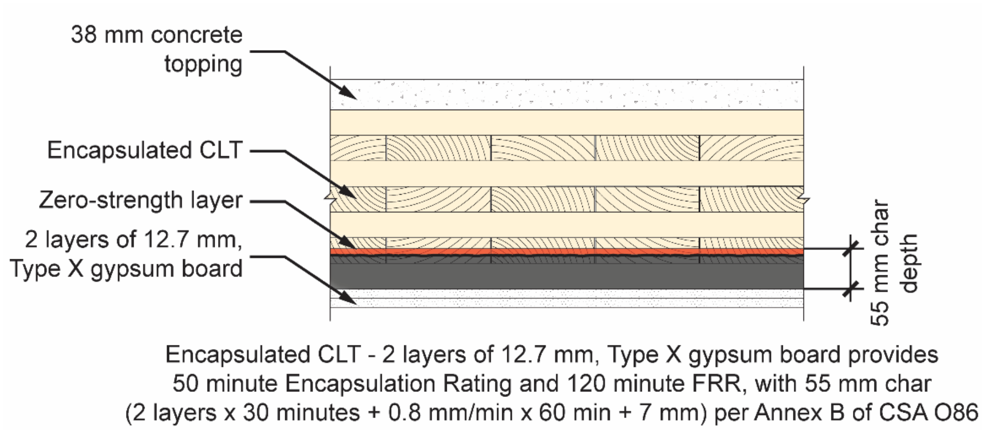
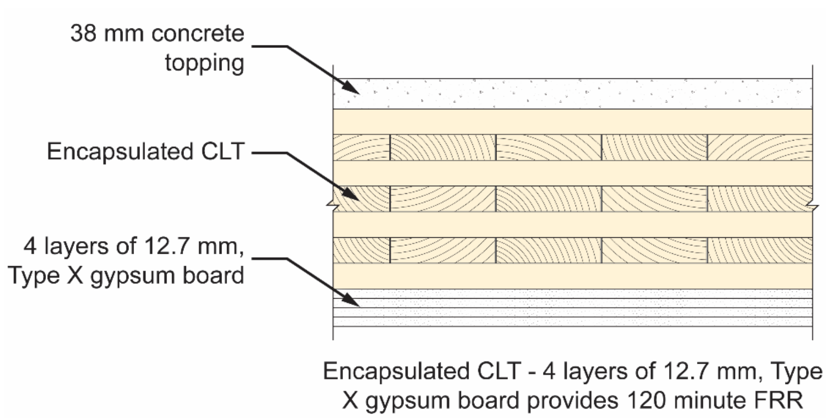


Figure 5-23: Diagram of an encapsulated Cross-Laminated Timber (CLT) assembly, with four layers of 12.7 mm, Type X gypsum board



5.5.3 CONNECTIONS

5.5.3.1 Types of Connections

Connections of loadbearing elements or assemblies must provide at least the same FRR as the required rating of the element itself or of the assembly they support as per Annex B of CSA O86-19.

An example of a connection fully protected by encapsulation is shown in Figure 5-24. An example of a historical wood-steel-wood connection, fully protected by the encapsulation and Structural Mass Timber elements, is shown in Figure 5-25.

See also Section 5.7.2.4 Protecting Connections for additional structural considerations.

5.5.3.2 Protection of Connections: Failure Mechanisms Under Fire

Protection of connections is required by completely burying the connection (Figure 5-24), encapsulation in gypsum board, protection by Structural Mass Timber charring, or through design of connections to be "fail safe" under gravity load—a technique commonly used in historic heavy timber buildings (Figure 5-25). Use of this last approach requires careful coordination with the structural engineer of record (SER), and requires consideration of the implication of crushing. Protection of connections requires review and coordination between the fire protection engineer (FPE) and the SER.

Lateral resisting elements do not need to meet the same FRR as gravity resisting elements. However, a degree of lateral resistance should be maintained. Refer to Section 5.7.3.1 Fire Protection Considerations for Lateral Systems for more information.

Gravity connection design is a critical component of any fire-rated timber building. Connection designs must be coordinated with the SER, to ensure fire ratings are met. Refer to Section 5.7.2.4 Protecting Connections for more information.

Figure 5-24: Diagram of a connection from the Brock Commons Tallwood House at UBC, fully protected by encapsulation and designed to be "fail safe" under gravity loads

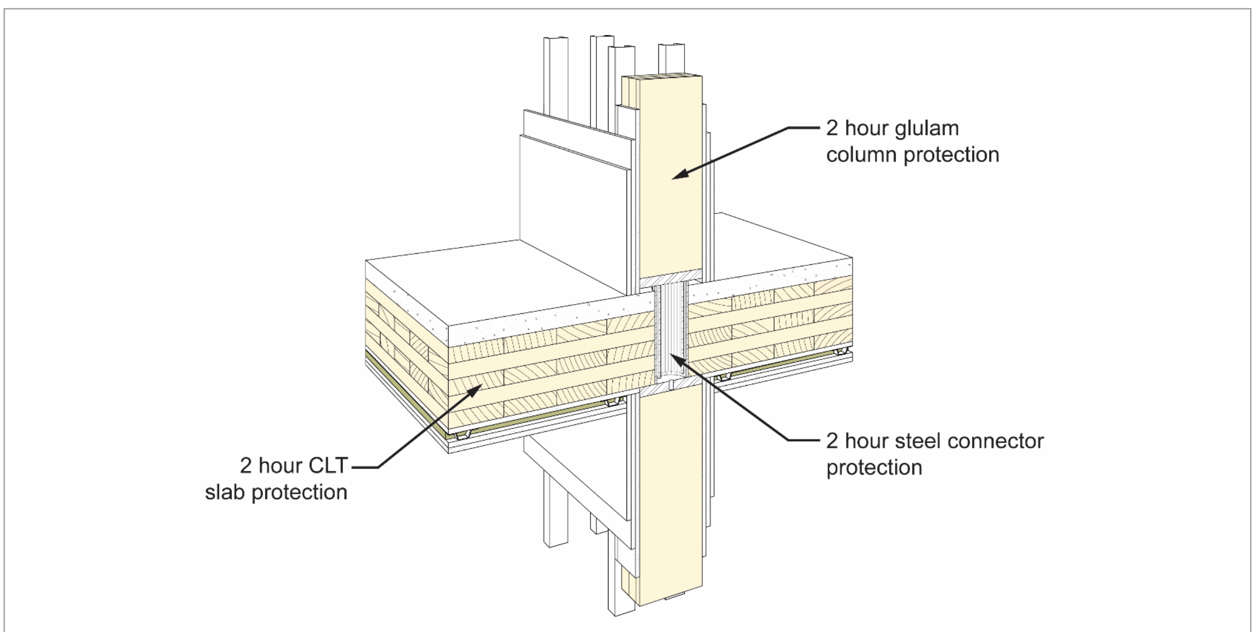


Figure 5-25: Photograph of a 1908 column connection designed to be "fail safe" under gravity loads. Failure would result in wood crushing but not structural collapse

5.5.3.3 Protection of Connections – Recommended Materials

Connections in buildings can be protected with gypsum board, concrete topping, or Structural Mass Timber. The Code provides minimum thicknesses for such applications, depending on the FRR of the structural member. In addition, listed materials for the protection of connections can be used, where applicable.

Refer to Appendix D, Division B of the Code for encapsulation requirements for steel connections. Steel connections in EMTC buildings are particularly important, compared to those used in steel or concrete buildings, as the Mass Timber does not act as a heat sink. Further, Mass Timber chars at 270°C, which is much lower than the generally accepted steel failure temperature of 540°C. The appropriate protection for steel connections should be considered at an early stage in the design, because it may affect some design parameters. For example, if surface-mounted connections are intended to be protected with gypsum board, the required board thickness may be greater than the encapsulation on the adjacent Structural Mass Timber surfaces, resulting in a "bump-out" that may be undesirable. For this reason, designers may consider using recessed concealed connections flush to the face of the Structural Mass Timber elements.

Where connections are protected, consideration should be given to the possibility that protection material (e.g., Structural Mass Timber or gypsum board) may fall off early, due to hot fasteners charring the surrounding wood. It is recommended that gypsum board providing protection be both nailed or screwed and glued with construction adhesive.

Intumescent paint should be used with caution on connections, unless test results are available appropriate to the specific connection. There are few successful test results of intumescent paint on timber connections. One condition where the use of paint might be appropriate is on steel ledgers on concrete. However, use of paint on hangers, ties, and other connections must consider the impacts of steel that will be exposed due to charring. No test results are currently available that show that intumescent paint can be effectively used to protect bolts or pins.

To maintain protection of gaps in connections, or gaps that may occur with shrinkage, firestop caulking may be required to be installed below the char line and during erection of the structure. Careful coordination between the FPE, SER, and Architect is required.

5.5.3.4 Panel Joints

Structural Mass Timber panel joints need to maintain the integrity of a fire separation. Panels that are encapsulated top and bottom, and glued or otherwise fastened together such that they cannot move relative to each other, generally do not require treatment.

Exposed panels with narrow gaps (less than 1 mm) and continuous concrete topping generally do not require treatment. Narrow gaps can be sealed with glue or acoustic topping. Current guidance indicates that larger gaps in exposed panels (e.g., exceeding 1 mm) should be sealed with firestop caulking installed above the char line; gaps larger than 2 mm should have a listed firestop system.

The research report *Evaluating Fire Performance of Nail-Laminated Timber* (FPInnovations 2019a) provides testing results and guidance on the influence of gaps.

Note that fire caulking must be coordinated with the design team. Fire caulking should be installed above the char line, and may need to be installed during erection, rather than later in construction. Fire caulking may also need to be called up on the structural drawings, and must be coordinated with the SER, as necessary.

If Mass Timber exceeds 19% MC during construction, the impact of shrinkage on joints as the Mass Timber is brought to in-service MC levels requires consideration in the design.

5.5.3.5 Firestopping

Currently, there are no listed firestopping systems for Structural Mass Timber, although the Canadian Wood Council and FPInnovations have performed multiple tests of Noncombustible penetrations. The tests to date show that appropriately designed firestopping for Noncombustible penetrations works. It should be noted that firestop systems must be tested to CAN/ULC-S115 in order to meet the acceptable solution requirements of Division B of the Code.

Caution must be taken with engineering judgments published by manufacturers. As engineering judgements contain engineering content, they must be designed, signed, and sealed by an Engineering Professional. Refer to the *Practice Advisory – Engineering Modifications to Fire-Tested and Listed Assemblies* (Engineers and Geoscientists BC 2020a).

Special attention should be paid to:

- hot pipes touching and charring wood, leading to failure;
- screws that may get hot, which may lead to the timber charring at the threads, leading to premature fallout of firestop devices;
- metal firestop devices touching timber, which may lead to char, allowing flames to bypass the firestop device; and
- reliance on wood to retain the firestop device or intumescent material, where the wood retaining the firestop device or intumescent material is within the char layer.

Note that a firestopping assembly listed for use with another substrate, such as concrete, cannot simply be transferred to Mass Timber, because of the different performance and characteristics of timber under fire conditions. Firestop systems with an annular space of zero between a metallic pipe and the substrate, which are common for concrete assemblies, are unlikely to be acceptable for encapsulated Mass Timber assemblies, because the wood may char through the entire depth of the penetration due to contact with the hot pipe, thereby allowing hot gases through. Also, firestopping in a thin layer at the exposed surface of an assembly, which is typical for concrete or gypsum board assemblies, is unlikely to be acceptable for encapsulated Mass Timber assemblies due to the deterioration of the adjoining wood surface as it chars.

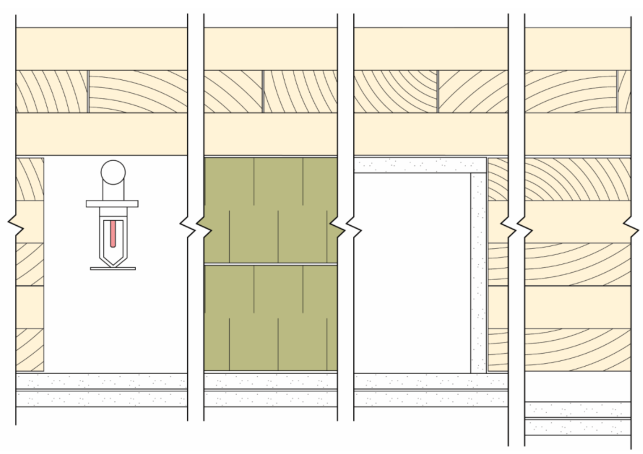
Firestopping of plastic pipes and conduit will require proprietary tested assemblies, as is required with all types of construction. It is important that these assemblies are tested specifically for Mass Timber. Designs for plastic pipe for concrete cannot be directly transferred to EMTC. Refer to Section 5.8.3.2 Penetrations and Firestopping for mechanical and electrical specific design considerations.

5.5.4 CONCEALED AND SERVICE SPACES

Service spaces and other concealed spaces within Mass Timber elements are required to be protected, as described in Sentence 3.1.18.3.(4) of the Code. Options include adding sprinklers in combination with fire blocks, filling with Noncombustible insulation, or lining with one layer of 12.7 mm, Type X gypsum board or other material that can provide a 25-minute Encapsulation Rating, as shown in Figure 5-26 (see Table 5-9: Overview of Mass Timber Roof Assembly Design Considerations for EMTC for detailed requirements). The option of including sprinklers intends that the sprinklers be installed in the cavity and the permissions to omit sprinklers of NFPA 13, Standard for the Installation of Sprinkler Systems do not apply.

Other concealed spaces outside of Mass Timber elements, such as vertical service spaces (shafts), like shafts in any other type of building, need to comply with the fire separation requirements of the Code. Subsections 3.6.3. and 3.6.4. of the Code may also require that some services in service spaces are Noncombustible. Where Structural Mass Timber members are located adjacent to a service space, requirements for encapsulation remain; encapsulate with two layers of 12.7 mm, Type X gypsum board or other material permitted for encapsulation.

Figure 5-26: Diagram of protection of concealed spaces



5.5.5 SHRINKAGE

Shrinkage of Mass Timber products varies significantly, depending on the product. Shrinkage of Nail-Laminated Timber (NLT) may be considerable and variable. Mass Timber products are generally manufactured with kiln-dried lumber and are surface planed, such that the change in MC from fabrication to in-service, and therefore shrinkage, is minimized, provided appropriate moisture-control measures are taken during construction. Manufacturers of Dowel-Laminated Timber (DLT) provide specific guidance to manage shrinkage, as do manufacturers of Cross-Laminated Timber (CLT). Shrinkage should be calculated by the SER and assessed in the design of other building components.

Design of firestopping of joints should consider potential changes due to shrinkage, and that shrinkage may open up joints, exposing steel elements to fire.

Refer to Section 5.7.4.1 Shrinkage Over Building Height for more information.

5.5.6 ALLOWABLE EXPOSED MASS TIMBER

The Code allows limited areas of exposed Mass Timber for walls and ceilings. Refer to Section 5.3.2.7 Encapsulation Criteria and Allowable Exposed Surfaces for more information.

Note that where exposed timber is desired, the additional char depth needs to be calculated and considered by the SER. See Section 5.5.2 Encapsulation and Fire-Resistance Rating.

5.5.7 CONSTRUCTION FIRE SAFETY PLANNING IN EMTC

Fire safety during the course of construction is prescribed in Part 8 of the Code, which refers to Section 5.6. of Division B of the Fire Code. A construction fire safety plan is required for all buildings. Compliance with these requirements is typically outside the responsibility of the Engineering Professionals involved with the design of a building project, and construction fire safety is not part of the items identified in Schedule B of the Code.

Due to the importance of fire safety during construction, and the potential complexity of EMTC, the involvement of an FPE in the construction fire safety planning process is recommended. Additionally, while not required by the Fire Code, some fire departments (the Authorities Having Jurisdiction to enforce the Fire Code) specifically require the involvement of an Engineering Professional.

The FPE retained for consultation on the fire safety plan may not be part of the design team. In that case, the FPE dealing with construction fire safety should contact the design team, including the design FPE, to confirm specific design aspects that may affect construction fire safety, such as the extent of wood elements that are not Mass Timber, or the extent of Mass Timber in exterior walls. The FPE is not responsible for the constructor's means and methods on site.

The Fire Code has specific provisions for fire safety during construction including:

- providing adequate water supply for firefighting;
- maintaining standpipes operational during construction;
- providing fire protection of stairs during construction, including 30-minute Fire-Resistance Rating (FRR) and 20-minute Fire-Protection Rating (FPR) doors; and

- providing encapsulation during construction, with one layer of 12.7 mm, Type X gypsum board or any other material that provides a 25-minute Encapsulation Rating. Refer to Article 5.6.4.3. of the Fire Code and Section 5.5.8 Encapsulation for Construction Fire Safety Plan.

The Fire Code requires that a construction fire safety plan be provided for every site, and that protection must be provided for adjacent buildings and facilities that would be exposed to fire from a construction site. Refer to Article 5.6.1.3. and Article 5.6.1.2. of the Fire Code, respectively, for these provisions. This may require investigation and analysis of potential fire exposure hazards to neighbouring buildings, including a survey of the neighbouring buildings to assess their susceptibility to hazards from the construction site. The exposure during construction is different from the exposure caused by the completed building, where fire separation and fire suppression systems will be complete.

Provision of standpipes has been required by the Fire Code for many years; however, they take on an added importance during construction of an EMTC building. An adequate water supply for firefighting is required, as soon as the Mass Timber material, or any other construction material, arrives at the site. Additional installation, maintenance, and testing procedures are applicable to standpipes in EMTC, as required by Article 5.6.4.2. of the Fire Code.

Exit stairs are required to be maintained, complete with a 30-minute FRR and 20-minute FPR doors. Options for doors during construction are provided, including 12.7 mm, Type X gypsum board on 12.7 mm plywood. Door closers and latches are required. It is expected and understood that stairs will be closed when work is occurring in a stair, but the expectation is that the duration of closure will be limited, and only one stair will be closed at any one time.

5.5.8 ENCAPSULATION FOR CONSTRUCTION FIRE SAFETY PLAN

Encapsulation during construction of at least 80% of the underside of each floor and at least 65% of Mass Timber walls is required.

For EMTC, the Fire Code permits a maximum of the four uppermost storeys to be unencapsulated during construction. The encapsulation required by Article 5.6.4.3. of the Fire Code must provide a minimum 25-minute Encapsulation Rating. One layer of 12.7 mm, Type X gypsum board is permitted to satisfy this requirement. Encapsulation during construction has proved problematic, as it is extremely difficult to maintain a building under construction sufficiently watertight to permit application of gypsum board. Use of water-resistant gypsum board is not generally practical, as it will prevent proper drying of Mass Timber elements if they do get wet, which may lead to shrinkage and moisture issues in the future. Mass Timber products typically cannot be relied upon to provide weather resistance without a top membrane in place.

Use of gypsum board as encapsulation during construction may require multiple installations, as well as ongoing monitoring of the MC of the Mass Timber that is covered by the gypsum board.

An engineered design solution may be appropriate, which would require submittal as an alternative solution under the Code. Alternative solution approaches would require acceptance by the Authority Having Jurisdiction (AHJ), which for the Fire Code is the local fire department.

An alternative solution may be a project-specific fire safety plan, as referenced in item A-5.6.4.3.(1) of the Notes in the Fire Code. Such a plan would have to be discussed with, and accepted by, the local fire rescue service. Such a plan may include:

- limiting Combustible debris in the buildings because, unlike a light wood frame construction site, there may be almost no small dimensional waste on site, since members and assemblies are typically prefabricated off site and not cut on site;
- on-site fire detection;
- inspection and debris removal from the site at the end of each working day;
- intrusion monitoring; and
- limiting Combustible sources.

Note that in cold climates, a specific problem exists with the need to heat EMTC during construction. Currently, most construction sites are heated with propane tanks and burners in the building. This heating solution creates an ignition hazard requiring management by the constructor. An alternative is to have heaters outside the building; however, these are reported as being difficult to maintain due to the extensive portable ducting. Electric heat is an option, if the final power supply for the building can be obtained early in the construction process, although standard construction power supplies are not sufficient for heating purposes. There are also concerns that electric heat is several times more expensive than propane heat.

5.6 BUILDING ACOUSTICAL CONSIDERATIONS

Sound interacts with nearly every building component in some way. Consideration of acoustic performance is often overlooked until late in the design, at which point trade-offs frequently have to be made with other interests (e.g., fire, structure, aesthetics, budget). The result is often less than optimal acoustic performance. This is unfortunate as, unlike fire or earthquake performance, the acoustic performance of a building is continuously tested and scrutinized by occupants. All of this combines to make acoustic issues one of the top complaints from building occupants.

While acoustic requirements can generally be integrated with those for fire design, there can be conflicts with those for natural ventilation, space planning, HVAC and other MEP (mechanical, electrical, plumbing) systems. For EMTC, it is even more important to consider acoustic requirements in the early stages of design, because Mass Timber does not perform well acoustically due to its low density and stiffness.

A particular concern in EMTC is the need to add layers to one or both sides of wall or floor/ceiling assemblies to meet even basic acoustic targets. This will have implications for floor-to-ceiling heights and, as a consequence, the project budget.

The main acoustic challenge in EMTC arises when the Mass Timber is used as a finish material (i.e., exposed wood). Although this can also be an issue when other building structure types are left exposed, the desire to leave wood exposed for aesthetic and biophilic reasons is generally greater than with steel or light wood frame construction.

Exposed wood may lead to several acoustical issues. Wood is a hard, sound-reflective surface, and when exposed as a ceiling in a commercial building will result in reverberant, noisy spaces that are not suitable for office use, due to poor speech privacy and intelligibility.

Mass Timber can also be problematic for sound isolation and impact noise control, as on its own, it has insufficient mass to meet typical design targets. This may still be true for Mass Timber partitions when acoustic treatment is added to one side only. Also, with exposed wood ceilings on both sides of a Mass Timber party wall, flanking sound becomes problematic. These issues are discussed in further detail below.

5.6.1 ROOM ACOUSTICS

The concept of room acoustics describes how sound travels, reflects, absorbs, and is perceived within a space, and is most commonly assessed by the reverberation time (RT_{60}), which is the amount of time it takes for a sound to decay by 60 dB within a space.

Room acoustic performance is often only considered to be a requirement in critical areas, such as theatres and other performance spaces; however, spaces that are occupied for long periods of time rely on good speech intelligibility, and those targeting comfort also require good room acoustics. Some of the common spaces that require good room acoustics are classrooms, offices, and conference rooms (especially those with teleconferencing), but any occupied space will benefit from good room acoustics.

Spaces may be finished with concrete, glass, gypsum board, or metal, all of which are understood to be highly sound-reflective materials with a noise-reduction coefficient of less than 0.10. Wood is often thought to be sound-absorptive and to create a “warm” space, but in fact it is highly sound-reflective, compared to concrete and gypsum board.

Materials selected specifically for their sound-absorptive properties are typically those with a noise-reduction coefficient of 0.70 or greater. These materials fall into two categories: cavity resonance absorbers and porous materials, such as fibreglass or mineral wool. The former is effective with careful design, while the latter is commonly used with fabric-wrapped panels, ceiling tiles, or perforated/slotted facings backed by fibrous materials. Most average spaces will perform well with sound-absorbent materials covering an area equal to 60% to 100% of the floor plan area of the space. The amount of required sound-absorbent material coverage increases as ceiling height increases and/or performance requirements increase.

Where Mass Timber is left exposed, especially as a ceiling finish in commercial or institutional spaces, reverberation times are likely to be high, resulting in reduced speech intelligibility (comprehension), increased sound build-up, and potential fatigue and discomfort for occupants. To control reverberation in these spaces, the addition of surface-mounted acoustic finishes or wall treatments should be considered and included in early budgets to ensure that performance is not compromised.

Figure 5-27 indicates the basic design strategies for various spaces, based on the acoustic performance requirements and room volume. For most commercial and institutional spaces, acoustic treatment with an area equal to the floor plan area of the space should be included in early budgets, so appropriate finishes can be carried through and included in the final build.

Figure 5-27: Comparison of basic room acoustic design strategies for various room sizes and acoustic requirements

ACOUSTIC PERFORMANCE REQUIREMENTS	SMALL VOLUME	MEDIUM VOLUME	LARGE VOLUME
	DETAILED DESIGN REQUIRED		
SPECIALTY	Audiology Booth Recording Room Music Practice Room	Teleconference Room Studio Music Room	Concert Hall Theatre
HIGH	Interview Room Project Room Quiet Room	Conference Room Tele-Learning	Auditorium Gymnasium Multi-Purpose Room
MEDIUM	Private Office	Classroom	Open Plan Office Library
LOW	WC/Storage	Corridor	Lobby Atrium

ACOUSTICAL CEILING TYPICALLY SUFFICIENT

5.6.2 SOUND ISOLATION

Sound isolation between dwelling units and neighbouring spaces in multi-unit residential buildings is the only acoustic requirement mandated by the Code, but sound isolation is important for all building occupancies.

In most spaces, occupants want privacy and do not want to hear sound from neighbouring spaces. Noise intrusion can vary from awareness to disruption, nuisance, or annoyance. The selection of a partition should be done with due consideration for the expectation of occupants, the type of noise sources and their sound levels, and/or the degree of privacy required.

5.6.2.1 Basic Sound Isolation

Sound isolation is best achieved with mass, separate layers and/or isolated layers with large acoustically damped air spaces (i.e., filled with fibrous insulation). Mass Timber is inherently weak as a sound-isolation material, because it has a density of about 500 kg/m^3, compared to concrete with a density of about 2,400 kg/m^3, and Type X gypsum board with a density of 750 kg/m^3. Mass Timber also does not have the benefit that framed walls provide; namely, a large insulated airspace and options for a structural break, surrounded by layers of dense gypsum board. These and other factors limit the sound-isolation performance of Mass Timber.

The sound-isolation performance of a wall or floor/ceiling assembly is rated using the sound transmission class (STC) rating scheme, which is a laboratory test rating based on the ability of an assembly to reduce airborne sound transmission and, specifically, its ability to provide speech privacy. The STC rating is a single number rating obtained by applying a standard sliding curve fit to the 1/3-octave band spectral transmission loss (TL) data obtained from laboratory tests. Although broadly used and convenient for comparing performance between different assemblies, the STC rating does not adequately address low frequency noise, and the oversimplification of a single number rating scheme can lead to significant performance differences between two similarly rated partitions. Another key limitation of STC ratings is that they represent ideal conditions without any leakage or flanking paths.

5.6.2.2 Code Requirements for Dwelling Unit Separations

Until recently, the STC rating of a partition separating adjacent dwelling units was the only requirement for residential buildings, per Article 5.8.1.1. of the Code. A partition with a minimum STC 50 rating (STC 55 for elevator shafts or refuse chutes) could be selected from Tables 9.10.3.1.-A and 9.10.3.1.-B of the Code and built without further concern. It was generally recommended to target a minimum partition rating of STC 55 to 60, with due consideration for flanking noise transmission (as recommended by the previous Code). The challenge with the STC-only requirement was that field performance was not clearly defined, and flanking sound path controls were not required, leaving actual sound isolation performance between dwelling units to potentially fall below that intended.

The Code (both previous and current) discusses sound leaks that may occur at connections with other walls, floors, ceilings, service penetrations, back-to-back electrical outlet boxes or medicine cabinets, and unsealed cracks or gaps. Article 9.11.1.4. of the Code describes several potential flanking paths, such as rigidly connected components, hollow cavities in floors/walls, or continuous layers that connect spaces. The solutions for leaks and flanking paths are to seal all potential gaps and seams, fill empty spaces with sound-absorbing materials, such as fibreglass or rock wool insulation, and introduce breaks and resilient connections in the construction. Article 5.8.1.1. of the Code addresses concerns for sound flanking by requiring a minimum apparent sound-transmission class (ASTC) rating of 47 (except for elevator shafts or refuse chutes).

The ASTC rating is a field-measured rating with conformance demonstrated by:

- measuring the performance of as-built construction;
- following the prescriptive design path outlined in Sentence 5.8.1.2.(2) of the Code (not applicable to EMTC); or
- performing calculations to estimate the ASTC-rated performance (simple or detailed method, per Articles 5.8.1.4. and 5.8.1.5. of the Code, respectively).

Each of the following methodologies has challenges, especially for EMTC, and significantly more so for exposed or partially exposed Mass Timber.

Field Measurement

The Code requires that measurements are taken in accordance with ASTM E336, Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Buildings, and classified using ASTM E413, Classification for Rating Sound Insulation. Measurement of the design is the best way to determine final performance; however, it can only be used during design if design details are being re-used from an existing project that has been measured. If a design is to be re-used, care should be taken to repeat the combination of connections on all sides of each partition, because even a small change can make a significant difference in final performance.

Another option is to use measurements where a detail is desired but cannot be accurately estimated or is expected to be marginal, and a pre-planned option is available to achieve the minimum performance requirement if the tested system does not meet the Code requirements.

Prescriptive Path

Unfortunately, there is no prescriptive path for EMTC in the current Code. The prescriptive path is only applicable to concrete, steel, and light wood frame construction, and is used only for STC ratings. Establishing an ASTC rating for EMTC requires the calculation method.

Calculation Method

The calculation method is outlined in the National Research Council Canada (NRC) research report, *RR-331 – Guide to Calculating Airborne Sound Transmission in Buildings* (NRC 2019), which is based on the ISO 15712-1 standard (revised by ISO 12354-1) but uses ASTM metrics for input to match North American industry practice. As well, *RR-335, Apparent Sound Insulation in Cross-Laminated Timber Buildings* (NRC 2017) provides additional data and methods specific for the analysis of EMTC. The simple calculation method uses single-number inputs (such as STC). The detailed calculation method uses 1/3-octave band data (such as TL) to give spectral results that provide more detail.

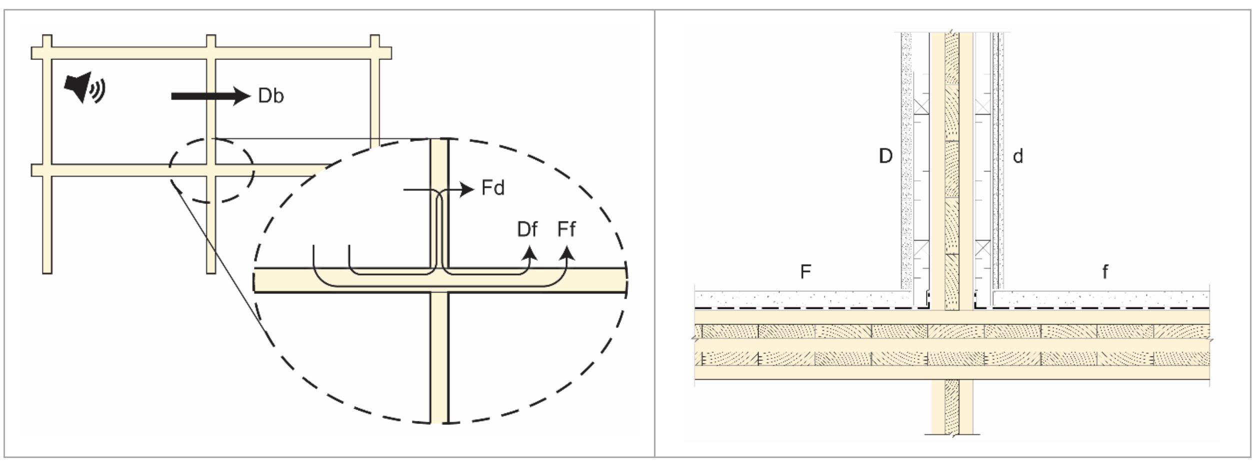
The calculation methodology involves evaluation of the primary sound-transfer path directly through the partition being evaluated, plus 12 sound-flanking paths (3 for each of the 4 junctions/adjoining assemblies), to determine the resultant ASTC rating.

See Figure 5-28 for an illustration of the three transfer paths at each junction.

The calculation method is relatively straightforward to implement as a spreadsheet, but the challenge is availability of the relevant input data for use in the calculations. There are currently limited options for input data (although NRC is growing this database), and the interpretation or extrapolation of the data for a particular design condition should be reserved for an acoustical engineer.

NRC released the soundPATHS Calculator, an online tool for calculating the ASTC (NRC 2020). While useful for evaluating some basic Structural Mass Timber systems, there are limitations in the assemblies that can be assessed, and at the time of writing, EMTC assessments only include Structural Mass Timber walls, floors, and ceilings (i.e., point support Structural Mass Timber panels or Structural Mass Timber panels supported on stud walls cannot be analyzed).

Figure 5-28: Illustration of the flanking sound transfer paths (3) to be analyzed at each of the 4 junctions/adjoining assemblies as part of the method for calculating ASTC ratings



Adapted from: *Acoustics Summary: Sound Insulation in Mid-Rise Wood Building: Report to Research Consortium for Wood and Wood-Hybrid Mid-Rise Buildings* (NRC 2014).

5.6.2.3 Flanking

Flanking sound paths are defined as all sound paths other than the direct transmission of sound through a given partition. These flanking sound paths include transfer:

- through the surrounding structure (e.g., floor, ceiling, side walls);
- via leaks or gaps (e.g., top and bottom of walls, openings around pipes and ducts);
- via cutouts (e.g., openings for electrical outlet boxes); or
- via structural bridging within the partition (e.g., structure, pipes, braces, or other solid materials that connect the two faces of a partition).

The ASTC method described by Articles 5.8.1.4. and 5.8.1.5. of the Code addresses control of flanking sound transferred via the structure surrounding the separating assembly, but final performance requires that all paths are addressed through proper detailing in design and careful construction.

Exposed Mass Timber has significant challenges in meeting Code requirements or sound-control targets. As a lightweight, continuous, exposed material, Mass Timber panels will easily transfer sound between adjacent spaces. Good sound isolation is best achieved when Mass Timber has sound-control assemblies covering both sides, addressing both direct sound transmission and flanking sound transmission.

Depending on the performance of all the components in the assembly, Mass Timber panels may require structural breaks, or reduced contact with other Structural Mass Timber panels. The structural break or discontinuity can be achieved when two panels butted together are connected by a single surface spline, or other similar detail. Alternatively, the joint between panels can be filled with a proprietary isolating material.

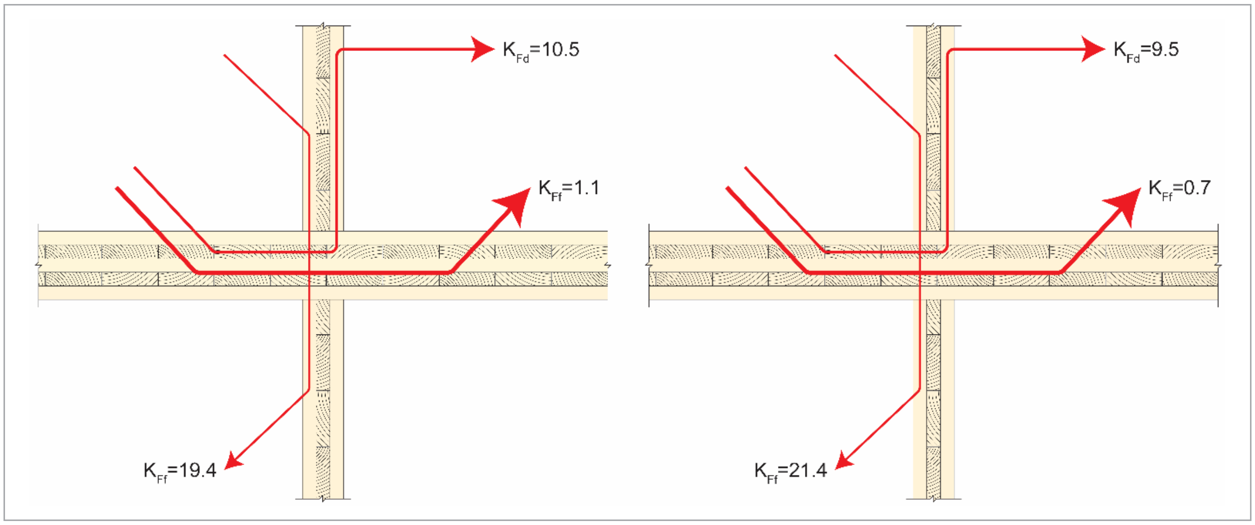
Even the use of fully threaded screws (rather than partially threaded screws) increases the flanking transmission between Mass Timber panels. The partially threaded screw pulls the pieces together to create a firm connection, whereas the fully threaded screw tends to leave a small gap, meaning that the connection is only through the screw itself. While this is not a detail to be relied upon for final performance, it is indicative of the level of detail that needs to be considered in the flanking analysis. The development of all joint details should be coordinated between the Architect, the structural engineer of record (SER), and the acoustical engineer, if retained.

The junction between Structural Mass Timber panels is a critical component to the calculation of the ASTC performance of the separation between two spaces and the one with the least-available information. The structural sound-transfer property of the junction is called the vibration reduction index (K_{ij}), where a low number indicates more efficient transfer of structure-borne sound and a higher number indicates better sound isolation.

Figure 5-29 illustrates how the greater the number of junctions the sound must pass through, or the fewer structural connections holding the joint together, the greater the sound reduction. There are several proprietary resilient materials that can be placed between Structural Mass Timber panels to further increase the K_{ij}, but use of these products must be coordinated with the SER.

It is also critical to consider the potential for flanking noise transmission along the exterior wall when evaluating the ASTC performance of interior partitions, particularly in residential construction where the Code requirements must be met.

Figure 5-29: Illustration of the vibration reduction index (K_{ij}) values for various structural sound transfer paths



Adapted from: Table 3.1.01 and 3.1.02: Transmission Paths, in *RR-335, Apparent Sound Insulation in Cross-Laminated Timber Buildings* (NRC 2017).

5.6.2.4 Wall Assemblies

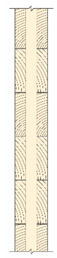
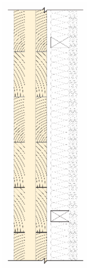
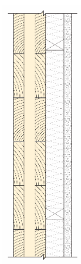
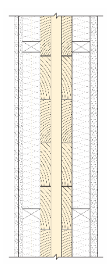
STC ratings for EMTC walls are available from many sources, including the Code, NRC publications, and many other industry publications from manufacturers and industry groups. Only tests performed by accredited labs should be relied upon, and field tests should be used as reference only and with great care.

Many different factors affect acoustic test results; it is important to understand exactly what has been tested and to compare the results from several tests for similar configurations, to recognize which components are driving the performance. For example, marketing materials might quote acoustic performance ratings without sufficient detail on the tested assembly (e.g., one floor isolation material may have been tested with a gypsum board ceiling, while another similar product may have been tested without). At first glance, it could appear that one isolation product has substantially better performance while, in reality, the tested assemblies had significantly different configurations. It is important to compare products that were tested with similar assemblies under similar test conditions.

The summary in Table 5-20: Overview of Sound Transmission Class Ratings of Various Cross-Laminated Timber (CLT) Wall Build-ups are sourced from *Acoustics Summary: Sound Insulation in Mid-Rise Wood Buildings – Report to Research Consortium for Wood and Wood-Hybrid Mid-Rise Buildings* (NRC 2014).

It can be seen from Table 5-20 that, when compared with a solid wall, there is significant improvement in acoustical performance when layers are added and structural breaks are provided (e.g., a 12.7 mm air gap). Structurally separated furring walls are one of the best options for making significant improvements in acoustic performance, much as double-stud construction provides significant improvement over single-stud construction.

Table 5-20: Overview of Sound Transmission Class Ratings of Various Cross-Laminated Timber (CLT) Wall Build-ups

LEFT-SIDE FINISH	ILLUSTRATION (SHOWING 3-PLY)	RIGHT-SIDE FINISH	5-PLY, 175 mm		3-PLY, 78 mm	
			TOTAL THICKNESS	STC	TOTAL THICKNESS	STC
• None		• None	175 mm	38	78 mm	33
• None		• Two layers, 12.7 mm, Type X gypsum board • 38 mm x 64 mm studs with batt insulation • 12.7 mm air gap	277 mm	59	Not tested	Not tested
• None		• Two layers, 12.7 mm, Type X gypsum board • 38 mm x 64 mm studs @ 600 mm o.c. with batt insulation	264 mm	50	167 mm	45
• two layers, 12.7 mm, Type X gypsum board • 38 mm x 64 mm studs @ 600 mm o.c. with batt insulation		• Two layers, 12.7 mm, Type X gypsum board • 38 mm x 64 mm studs @ 600 mm o.c. with batt insulation	353 mm	56	256 mm	51

NOTES:

Abbreviations: o.c. = on-center; STC = sound transmission class

Adapted from: Acoustics Summary: Sound Insulation in Mid-Rise Wood Buildings – Report to Research Consortium for Wood and Wood-Hybrid Mid-Rise Buildings (NRC 2014).

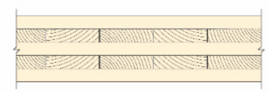
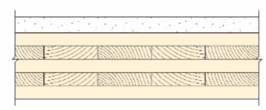
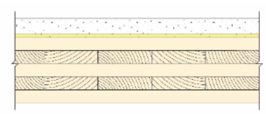
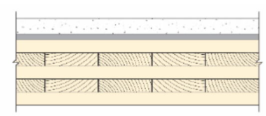
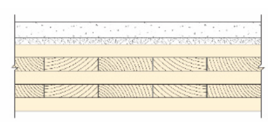
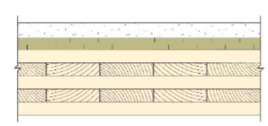
These wall assemblies are intended to demonstrate acoustic performance and do not necessarily represent Code compliant wall assemblies with respect to fire protection, fire-resistance, or the building enclosure. See the Code as well as Section 5.3 Architectural Considerations, Section 5.4 Building Enclosure Considerations, and Section 5.5 Fire Protection Considerations for other discipline-specific requirements and considerations for wall assemblies.

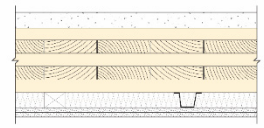
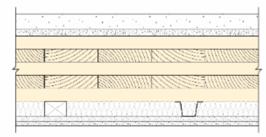
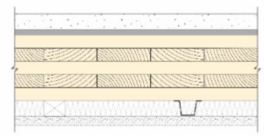
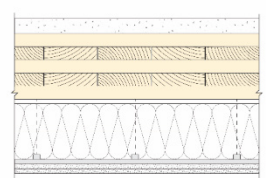
5.6.2.5 Floor/Ceiling Assemblies

Sound isolation through floors/ceiling assemblies (and their flanking paths for ASTC assessments) should also be considered. As with walls, additional layers can be added on both sides of the Structural Mass Timber. Floor toppings and ceilings can provide significant performance improvements and should be considered to achieve basic design targets.

As with Structural Mass Timber walls, the sound-isolation performance of Structural Mass Timber floors is increased significantly when structural breaks are incorporated. Unlike walls, where complete air gaps are not normally an option, best performance is achieved by supporting a gypsum board ceiling with flexible connectors that include springs, rubber isolation elements, suspension wires, or light-gauge steel supports. Air spaces should always be filled with sound-absorbing materials, such as fibreglass or mineral wool batts. This aligns well with the encapsulation requirements of dropped ceilings, but will be more challenging when the Mass Timber surfaces are exposed to the extent permitted for EMTC in the Code.

Table 5-21: STC (and IIC) Ratings for Various Cross-Laminated Timber (CLT) Floor Assemblies [a]

LAYERS (TOP TO BOTTOM) [b]	175 mm STC (IIC)	245 mm STC (IIC)	ILLUSTRATION
• Mass Timber (175 mm or 245 mm)	41 (25)	44 (30)	
• Concrete topping (normal weight), 38 mm thick • Mass Timber (175 mm or 245 mm)	49 (28)	51 (35)	
• Concrete topping (normal weight), 38 mm thick • Closed-cell foam, 9.5 mm thick • Mass Timber (175 mm or 245 mm)	53 (36)	56 (44)	
• Concrete topping (normal weight), 38 mm thick • Rubber membrane, 17 mm thick • Mass Timber (175 mm or 245 mm)	54 (44)	56 (48)	
• Concrete topping (normal weight), 38 mm thick • Recycled fabric felt, 19 mm thick • Mass Timber (175 mm or 245 mm)	59 (42)	61 (49)	
• Concrete topping (normal weight), 70 mm thick • Rigid mineral wool insulation, 32 mm thick • Mass Timber (175 mm or 245 mm)	57 (45)	59 (49)	

LAYERS (TOP TO BOTTOM) [b]	175 mm STC (IIC)	245 mm STC (IIC)	ILLUSTRATION
• Concrete topping (normal weight), 38 mm thick • Mass Timber (175 mm or 245 mm) • Wood or metal furring, 38 mm thick, batt insulation[c] • two layers, 12.7 mm, Type X gypsum board	56 (41)	59 (46)	
• Concrete topping (normal weight), 38 mm thick • Recycled fabric felt, 19 mm thick • Mass Timber (175 mm or 245 mm) • Wood or metal furring, 38 mm thick, batt insulation[c] • two layers, 12.7 mm, Type X gypsum board	63 (45)	65 (48)	
• Concrete topping (normal weight) 38 mm thick • Rubber Membrane 17 mm thick • Mass Timber (175 mm or 245 mm) • Wood or metal furring, 38 mm thick, batt insulation[c] • two layers, 12.7 mm, Type X gypsum board	60 (51)	62 (53)	
• Concrete topping (normal weight) 38 mm thick • Mass Timber (175 mm or 245 mm) • Light steel grid suspended ceiling (150 mm airspace)[c] • 140 mm batt Insulation • two layers, 12.7 mm, Type X gypsum board	75 (60)	78 (66)	

NOTES:

Abbreviations: DLT = Dowel-Laminated Timber; IIC = impact sound insulation class; NLT = Nail-Laminated Timber; STC = sound transmission class

These floor assemblies are intended to demonstrate acoustic performance and do not necessarily represent Code compliant floor assemblies with respect to fire protection, fire-resistance, or concealed spaces. See the Code as well as Section 5.3 Architectural Considerations, Section 5.4 Building Enclosure Considerations, and Section 5.5 Fire Protection Considerations for other discipline-specific requirements and considerations for floor assemblies.

[a] Table adapted from: *Acoustics Summary: Sound Insulation in Mid-Rise Wood Buildings – Report to Research Consortium for Wood and Wood-Hybrid Mid-Rise Buildings* (NRC 2014)

[b] Mass Timber elements assume no leakage (i.e., leakage between individual boards in NLT or DLT Mass Timber will diminish the performance from that described)

[c] The Code requires that concealed spaces are sprinklered and divided into compartments, completely filled with mineral wool insulation, or lined with gypsum board (see Table 5-5 of these guidelines for more detail)

5.6.3 IMPACT/FOOTFALL SOUND INSULATION

Impact/footfall noise is the most common cause of complaints in residential buildings. Similar to sound isolation, the low density of wood and the continuous structure make it challenging to control impact/footfall noise.

Impact noise is measured and reported as the impact insulation class (IIC), measured in a laboratory setting, or the apparent impact insulation class (AIIC), measured in the field. The Code recommends a minimum IIC rating of 55 for unfinished floors in residential buildings. Note that only the last assembly presented in Table 5-21 above achieves a rating above IIC 55.

Common practice is to target higher ratings, such as 65 or even 75, to reduce the risk of complaints in multi-unit residential buildings. As shown in Table 5-21, only the last floor/ceiling assembly, which includes a concrete topping and a suspended gypsum board ceiling with batt insulation in the air cavity, achieves a performance of IIC 60 or greater.

A bare Structural Mass Timber floor panel without a ceiling below will achieve an IIC rating of approximately 25 to 30; as with sound isolation, adding various layers both above and below the wood floor structure will help to increase this performance.

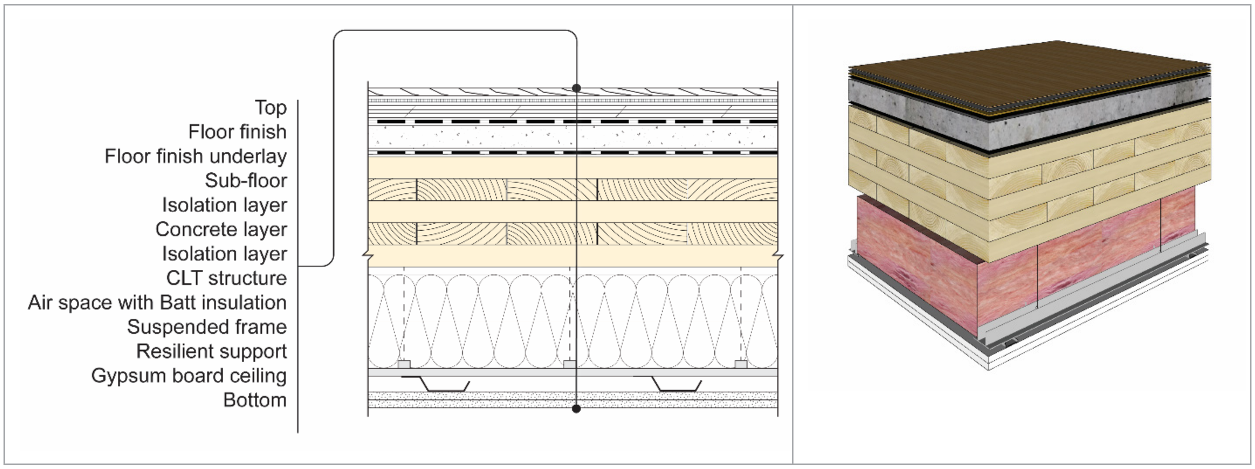
Often the most effective way to prevent noise problems is to reduce or eliminate the source itself or address the problems as close to the source as possible. The source of impact/footfall noise is significantly reduced by the presence of carpet, although carpet alone on Structural Mass Timber panels is insufficient for sound and impact control. Improvements of between 5 and 15 points can be expected, depending upon the carpet, underlay, thickness and span of wood, and other factors.

When hard-surface floor finishes, such as concrete, wood, or tile, are used, the inclusion of isolating layers is required to control impact noise (and sound transfer). Twelve or more different layers could be used to provide impact (and noise) control, and each has numerous options from many manufacturers. Figure 5-30 illustrates a potential build-up.

The number of layers and options results in unlimited iterations, making it difficult to find test data for any specific design. Manufacturers of various isolation materials provide test data, but each manufacturer includes or excludes variations of layers above and below, and varying structural options and thicknesses, making comparisons of even two basic underlays difficult. For example, two underlay manufacturers may have tested with different thicknesses of Cross-Laminated Timber (CLT); one manufacturer may have tested with a ceiling below and the other without; or the finished floor for each test may have been of different thickness or material.

The complexity of interactions between layers makes impact noise performance difficult to model or predict, and research indicates that even in-situ tests for 1.2 m x 1.2 m samples can have varying results. Ultimately, the best judgment of those with experience in acoustics should be relied upon to provide estimates of performance based on comparing test data from assemblies with similar construction to the desired design; where possible, mock-up floor testing should be done to assess AIIC ratings at the earliest opportunity during construction.

Figure 5-30: Illustration of potential build-up of floor and ceiling layers to manage impact/footfall noise



5.6.3.1 Gym, Fitness, Exercise, and Activity Spaces

Impact noise from weights being dropped, heavy footfalls from running on a treadmill, and other exercise activities and equipment use extend well beyond the typical occupancy requirements and IIC testing methods. Regardless of the structure (e.g., concrete, Mass Timber, steel), caution is needed when designing for activity spaces. Good design practice places these spaces well away from noise-sensitive spaces, buffered by less-sensitive spaces, but when impacts get into the structure, the noise can still travel efficiently through the structure and radiate in spaces that are seemingly remote.

Experience with Structural Mass Timber supporting high-impact activities is limited, and extra caution should be taken. Sample testing with weight drops can inform and guide the selection of materials for the floor/ceiling buildup. Preliminary guidance from those experienced in acoustical design should be considered, followed by coordination with fitness flooring and impact-control suppliers, to develop and test desired floor/ceiling systems. Structural changes to accommodate additional weight, and to avoid variations in floor height, should also be considered.

Early consideration (concept design) and planning to discuss the minimum required (or desired) acoustic performance of the floor system, and the associated structure, cost, and space requirements for meeting those targets, should be done. A final commitment to the specific design and material selection is not required, but having space and budget to accommodate a general concept will avoid surprises related to costs, space requirements, or poor acoustic performance. Once the building structure is in place, or by using mock-ups, tests of various floor/ceiling build-ups can be performed to help select the most appropriate system that balances all design requirements.

5.6.4 BUILDING SERVICES NOISE AND VIBRATION CONTROL

Building services, such as mechanical systems, plumbing systems, electrical systems, emergency generators, and elevator systems, create both noise and vibration that require acoustic treatments to prevent noise transmission to nearby occupied spaces.

The main transmission paths from these sources are duct-borne noise, airborne noise, and structure-borne noise (or vibration-induced noise). Each of these noise transmission paths is discussed below.

5.6.4.1 Duct-Borne Noise

It is expected that the strategies for controlling duct-borne noise will be no different for EMTC than for other types of construction.

5.6.4.2 Airborne Noise

Airborne noise is that which radiates from building services equipment. For EMTC, the same considerations that are given to sound isolation partitions for privacy should be given to sound isolation solutions for MEP (mechanical, electrical, and plumbing) equipment. However, noise produced in MEP equipment spaces is more low-frequency and generally higher sound intensity than noise experienced in most other spaces. This requires greater care in the selection of partitions, while also considering that Mass Timber partitions are not as effective for noise control as are concrete or stud construction. As such, Mass Timber partitions around MEP spaces should have sufficient thickness to provide the required sound isolation.

For MEP spaces adjacent to occupied spaces, it is generally good practice to start with walls that have a minimum STC rating of 60. For walls, refer to Section 5.6.2.4 Wall Assemblies; and for floor/ceilings, refer to Section 5.6.2.5 Floor/Ceiling Assemblies. For floors, consideration of structure-borne noise and vibration-isolation control should also be given (see Section 5.6.4.3 Structure-Borne Noise).

Once MEP equipment is selected, detailed calculation of the airborne sound transfer from MEP spaces into adjacent occupied spaces is recommended, to confirm that noise levels, especially at low frequencies, will be adequately controlled.

5.6.4.3 Structure-Borne Noise

Controlling structure-borne noise is done primarily by using isolation materials, such as springs or rubber isolators or pads. The performance of vibration-isolation systems is highly dependent upon the supporting structure being very stiff and heavy, so that the structure has limited movement. If the structure is softer and lighter in weight, then there is a risk that the supporting structure will move (vibrate) and will reduce the effectiveness of the vibration-isolation system.

Wood is lightweight but relatively stiff, and therefore has the potential to radiate noise efficiently (much like a musical instrument). The continuity of Structural Mass Timber panels is also problematic, because once vibration gets into the structure it can propagate efficiently. There may be some minor benefit from the inherent damping properties of wood, which could help to dissipate the vibration and structure-borne noise, but this should not be relied upon for vibration and structure-borne noise control.

Available guidance for vibration control from ASHRAE—such as the A*SHRAE Handbook – HVAC Applications (ASHRAE 2019)*—and other sources is largely empirical and based upon experience with concrete and steel construction over many decades. At this time, the research is ongoing on how Mass Timber responds to vibration input from MEP systems and how to adapt vibration-isolation systems for EMTC.

Current recommended design guidance for controlling vibration in EMTC is to follow the vibration-control guidance from ASHRAE, with due consideration for maximum floor deflections (due to equipment weight) and to add mass and stiffness to the structure supporting the vibrating equipment. Some options to consider are thicker, normal-weight concrete toppings (e.g., 75 mm to 150 mm thick) and/or 100 mm thick housekeeping pads, to distribute point loads from isolators and add localized mass and stiffness to the structure. Inclusion of these mass elements requires that the overall building structure is suitably designed to support this additional mass, which can also affect wind and earthquake response and loading, depending upon the level on which the mechanical and electrical room(s) are located. For these reasons, it is critical for the acoustical engineer, SER, mechanical engineer of record (MER), electrical engineer of record (EER), and Architect to coordinate options for mechanical and electrical room placement, and to ensure that appropriate acoustic controls are included.

5.6.5 FLOOR VIBRATION

Floor vibration is generally caused by environmental sources (e.g., road, rail), mechanical sources (e.g., fans, pumps), or human activity (e.g., walking, exercising). Mechanical vibration is best dealt with at the source, with good vibration isolation and the addition of localized mass and stiffness. Control of vibration from environmental and human activity sources requires similar consideration and analysis to what is done for other structures, but needs to consider the unique properties of Mass Timber.

Vibration criteria will remain the same as for any other structure, as the criteria are based on human comfort or operation limits for vibration-sensitive equipment.

For environmental vibration sources, EMTC has a disadvantage when compared to concrete because of the lighter weight construction. One of the benefits of heavier construction is that the transfer of vibration from the soil into the foundation is better mitigated; however, propagation of vibration through Mass Timber is not currently as well understood, and would be influenced by the types of connections and joints, the overlay materials and finishes, and many other construction details that would influence the rigidity/isolation and damping properties of the structure. These differences should be considered when assessing a site for EMTC. For example, where a concrete building may not have any issues near a rail line, there may be issues within EMTC buildings at the same location.

Human activities are typically the most significant vibration source within a building, with walking being one of the largest inputs (outside of gyms and fitness spaces). Mass Timber is more susceptible to walking inputs, because it is much lighter than concrete and steel building structures. Refer to Section 5.7.5.7 Floor Vibration for more information on assessing floor vibration from footfalls.

The same consideration for vibration should be given to EMTC as is done with other types of buildings, but the threshold for initiating more detailed study should be lower, as there are more unknowns with Structural Mass Timber and it is better to identify issues before the design and construction are too advanced.

5.6.6 EXTERIOR TO INTERIOR NOISE CONTROL

The control of noise intrusion from external sources is not a mandated Code requirement, but to meet ASTC performance of an interior separation, the building exterior wall should be designed to limit flanking transmission between adjacent occupied indoor spaces that share a common section of the building enclosure. A continuous Structural Mass Timber panel that connects adjacent interior spaces could be a significant source of flanking transmission. As discussed in Section 5.6.2.3 Flanking, flanking sound transmission is best addressed by using separated layers and/or structural breaks.

Many jurisdictions in British Columbia (BC) also require that external noise intrusion is controlled via the building enclosure, to meet interior sound-level limits for residential occupancies. In most buildings, it is the windows that limit the sound isolation performance, but if Mass Timber is used for the building enclosure, it too may reduce the overall sound isolation of the assembly.

Common sound limits for residential occupancies are those based on recommendations published by the Canada Mortgage and Housing Corporation (CMHC) and are based on a 24-hour equivalent sound level ($L_{eq,24hr}$) with the following limits:

- 35 dBA in bedrooms;
- 40 dBA in living, dining, and recreation rooms; and
- 45 dBA in kitchens, bathrooms, hallways, and utility rooms.

While not a requirement, the design of commercial buildings should also consider the control of noise ingress from the exterior, to ensure desirable conditions for tenants. Typical upper limits for acceptable background noise levels in offices are 30 dBA for teleconference rooms, 35 dBA for conference rooms and private offices, and 45 dBA for open offices. Although these values are based on steady-state noise levels, it would be undesirable to have peak levels exceed these targets regularly and become disruptive to conversations. Accordingly, maximum traffic noise levels should be part of the overall evaluation.

Although STC is the commonly known sound-isolation rating for interior partitions, when dealing with control of transportation noise, it is better to use the outdoor-indoor transmission class (OITC) rating to ensure that the performance matches the requirements. The reason for using the OITC rating is that it represents the performance for blocking transportation noise (e.g., air, rail, road), which has greater low-frequency content than normal speech (which is what the STC rating evaluates).

According to CMHC, where outdoor noise levels are between 55 and 75 dBA, detailed analysis is necessary to determine the appropriate form of construction. Typical window options available from most manufacturers reach a maximum performance of an OITC rating of approximately 32, before specialty windows and framing systems are needed. This may limit window sizes, but the light weight of EMTC assemblies may also make it more difficult to meet local requirements without additional care and attention being given to the design.

If the building is going to be located next to a high-traffic roadway or at the intersection of two busy roads, early consideration for the cost of glazing and building enclosure design will be required, to ensure that the project will meet site-specific performance requirements, and that the required design strategies will be included in the project budget.

The requirements will be dependent on:

- sound levels outside the building facade (varies with distance from the noise source);
- sound-isolation performance of each building enclosure component;
- dimensions/area of each building enclosure component;
- interior room dimensions; and
- interior room finishes.

Where the solid portions of the wall are designed to have good acoustic isolation, reducing the size of windows will, in most cases, further improve performance. Conversely, if the performance of the wall components has not been carefully considered, then more expensive, higher performance windows will be required.

Acoustic data for building enclosures is generally difficult to obtain, because of the significant variability in options for materials, structure, layers, and proprietary products. Estimates for sound isolation of building enclosure construction are most often based on theoretical calculations that are compared with certified laboratory-tested assemblies of a similar nature, to ensure that reasonable estimates are obtained.

5.6.6.1 Exterior Walls

For discussion purposes, the following typical EMTC enclosure assembly has been evaluated to provide general indicators of how various changes may improve the acoustical performance of the building enclosure. Note that there are many variables to consider, and specific guidance from an acoustical engineer should be sought for project-specific details. In critical applications, laboratory testing of the intended building enclosure assembly should be considered.

Figure 5-31 shows a typical exterior wall construction consisting of:

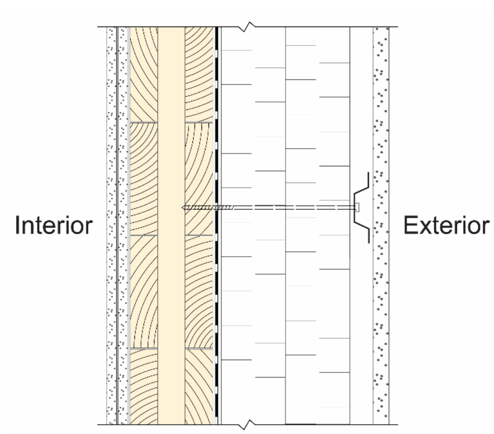
- 2 layers of 12.7 mm, Type X gypsum board;
- 100 mm CLT;
- 150 mm rigid mineral wool;
- 22 mm airspace with metal hat tracks; and
- fibre cement panel cladding.

Performance of the assembly described above is estimated to provide an OITC rating of approximately 41 (STC 43), based on modelling and comparisons with similar laboratory-tested assemblies. This is possibly a conservative value, but variation could be as much as plus-or-minus 5 to 10 points. Some of the variables that can change the result include:

- the density of the wood;
- how the wood is glued;
- the type and spacing of pin connections;
- connection details for the hat track;
- the density and thickness of the fibre cement panels;
- the presence of any gaps or openings in the system; and
- the thickness/spacing of each of the elements.

The estimated rating will provide reasonably good sound isolation, mostly due to the large airspace filled with mineral wool, the limited point connections between the interior and exterior Mass Timber layers, and the overall mass of these layers.

Figure 5-31: Diagram of a typical exterior wall assembly



The following estimates are for expected changes in performance, based on various individual modifications in construction:

- Excluding interior gypsum board (exposed CLT): Reduction of approximately 4 points
- Placing interior gypsum board on 25-gauge steel studs with batt insulation in the cavities: Increase of approximately 15 points
- Placing interior gypsum board on studs with batt insulation in the cavities, spaced 25 mm away from the CLT panel: Increase of approximately 20 points
- Increasing the thickness of CLT by 50 mm: Increase of approximately 1 to 2 points
- Replacing rigid mineral wool with similar thickness of rigid foam products, such as XPS, EPS, or polyisocyanurate: Reduction of approximately 5 to 10 points
- Replacing exterior fibre cement panel with 89 mm brick: Increase of approximately 5 points

Note that these changes cannot be simply added together when combined, because acoustic ratings are dependent upon the combined performance of the system. The above are only intended to illustrate which changes have the most impact on improving the sound isolation of the building enclosure.

Modifications that are expected to have minor effects are:

- changing the depth of the rigid mineral wool by plus-or-minus 50 mm; and
- replacing exterior fibre cement panel with 22-gauge metal cladding.

The acoustical performance of various types of Mass Timber (e.g., CLT, mass plywood panels [MPP], Nail-Laminated Timber [NLT], Dowel-Laminated Timber [DLT]) can vary, but the variation is reduced significantly when gypsum board is applied directly to both sides of the Mass Timber material.

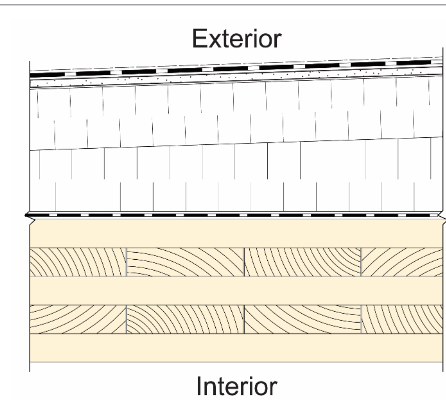
5.6.6.2 Roofs

Factors affecting the acoustic performance of a Structural Mass Timber roof are similar to those for exterior walls. Again, for discussion purposes only, the following typical Structural Mass Timber roof assembly was evaluated.

Figure 5-32 shows a typical roof assembly consisting of:

- 2-ply SBS modified bitumen roofing systems (approximately 6 mm thick and 7 kg/m^2);
- 12.7 mm roof board;
- 150 mm thick polyisocyanurate insulation;
- waterproof membrane; and
- 175 mm thick 5-ply CLT (exposed underneath).

Figure 5-32: Diagram of a typical roof assembly



Performance of the assembly described above is estimated to provide an OITC rating of approximately 35 (STC 42), based on modelling and comparisons with results from similar laboratory-tested assemblies.

The estimated performance is limited by use of polyisocyanurate insulation and the continuous structure (i.e., no structural breaks).

The following estimates are for expected changes in performance, based on various individual modifications in construction:

- Replacing polyisocyanurate with rigid mineral wool: Increase of approximately 5 to 10 points
- Adding 50 mm smooth gravel ballast or concrete paver on top of the SBS as finish (and fire protection): Increase of approximately 5 points
- Adding 25 mm to 100 mm plywood over the framing layer between the polyisocyanurate and CLT, to provide slope: Decrease of >5 points (models indicate significant resonance; testing is suggested)
- Adding 2 layers of 12.7 mm gypsum board to the underside of CLT: Increase of approximately 2 points
- Adding 2 layers of 12.7 mm gypsum board on 38 mm furring, with batt insulation in cavities, to the underside of CLT: Increase of approximately 4 points
- Adding 2 layers of 12.7 mm gypsum board on 92 mm, 25-gauge steel studs (or wood stud with resilient channel), with batt insulation in cavities, to the underside of CLT: Increase of approximately 6 points
- Adding 2 layers of 12.7 mm gypsum board on light steel grid, with batt insulation inside 250 mm cavity, to the underside of CLT: Increase of >15 points
  - Note that the Code requires that voids are sprinklered and divided into compartments, completely filled with mineral wool insulation, or lined with gypsum board; see Table 5-5: Overview of Water-Resistive Barriers (Walls and Sloped Roofs) Used in Encapsulated Mass Timber Enclosure Assemblies for more details.

Note that these changes cannot simply be added together when combined, because acoustic ratings are dependent upon the combined performance of the system. The above are only intended to illustrate which changes have the most impact on improving the sound isolation for the roof. Assessment by a person qualified in acoustics is recommended.

If the building enclosure will be Mass Timber, and the site is located along a busy transportation corridor (e.g., air, rail, road), then early evaluation for acoustic performance should be considered.

Acoustical performance is only one of many aspects for building enclosure design. Coordination of acoustical, fire protection, water management, energy efficiency, and aesthetic requirements is required, to ensure that all of the building enclosure requirements are met. See Section 5.4 Building Enclosure Considerations.

5.7 STRUCTURAL CONSIDERATIONS

The structural engineer of record (SER) should review all parts of these guidelines; this section provides a more focused view of the structural considerations for EMTC up to 12 storeys.

5.7.1 DESIGN CONSIDERATIONS

The SER should be involved early in an EMTC building project and work with the Architect to optimize the panel layouts and floor layout to meet span capabilities, architectural requirements, and fabricator optimization for panel layouts; this collaboration will assist in developing a practical, achievable, and economical design.

Grid spacings will vary with product types and system types; refer to Section 5.3.3 Structural System Considerations for descriptions of the different available systems. Where open floor plans are desired, post and beam framing is likely the preferred architectural approach, as described in Section 5.3.3.2 Post and Beam Frame Systems.

These systems can be provided with either thinner Structural Mass Timber floor panels supported on purlins on girders, or thicker Structural Mass Timber floor panels supported directly on girders, eliminating the need for purlins. Where more walls are available, the option of loadbearing panel systems that reduce or eliminate the need for beams supporting the panels, as described in Section 5.3.3.3 Post and Panel Systems, is available.

Grid spacings for any of the gravity systems will vary as well, depending on the architectural layout and the acceptable structural depth; i.e., combined beam and panel depth. These requirements should be coordinated with the Architect. Beam design should be completed per CSA O86-19, Engineering Design in Wood.

Suppliers will provide information about Structural Mass Timber panel availability and structural properties; for more information on panel products, refer to Section 5.3.2.3 Material Considerations, under the subsection Mass Timber Products.

Service routing and major duct runs need to be considered and coordinated with the mechanical engineer of record (MER) and the electrical engineer of record (EER); these systems may affect the framing approach. Point-supported systems do not currently have a design approach provided in CSA O86-19; these can be designed as a “new or special system,” per CSA O86-19 clause 4.3.2, but are outside the scope of this document.

It is also important to coordinate the lateral design and its intersection with architectural and fire protection requirements. Where Structural Mass Timber lateral systems are used, potentially including Structural Mass Timber stair or elevator cores, extensive coordination is required, to ensure all the architectural and fire requirements, such as smoke containment and fire separations, are met. Refer to Section 5.5.1 Fire Ratings and Separations for more information on fire requirements.

Hybrid systems are another approach to tall wood construction that has worked on past projects, such as using steel braces or concrete cores to provide the lateral force-resisting system, in combination with Structural Mass Timber floors and columns. Lateral systems are discussed in more detail in Section 5.7.3 Lateral Considerations.

5.7.2 FIRE CONSIDERATIONS

The behaviour of Structural Mass Timber systems under fire conditions is complex. The SER is responsible for determining the residual section properties after a fire event, based on char rates provided by the applicable codes (where specifically addressed), or those provided by the fire protection engineer (FPE), if retained, on the project. For items not specifically addressed in Annex B of CSA O86-19 or Appendix D, Division B of the Code, (e.g., Nail-Laminated Timber [NLT], proprietary connections), general guidance and review of char rates by an FPE is recommended.

Fire design can be completed for individual structural members by either fully encapsulating the timber, achieving the required rating through char alone, or by using a combination of thinner encapsulation and char. Refer to Section 5.5.2 Encapsulation and Fire-Resistance Rating for minimum encapsulation requirements, and Section 5.5.6 Allowable Exposed Mass Timber for extent of the encapsulation requirements for EMTC.

Structural design for fire is prescribed in CSA O86-19. Information and approaches to fire design are advancing rapidly, so retention of or consultation with an FPE on recent developments and strategies not yet found in the EMTC provisions in the Code may benefit a project. Refer to Section 5.5 Fire Protection Considerations for more detailed discussion of fire requirements.

5.7.2.1 Char

For detailed information about char, refer to Section 5.5 Fire Protection Considerations. Unless otherwise specified by the FPE, char should be calculated based on the provisions in Annex B of CSA O86-19 for all Structural Mass Timber elements. Annex B of CSA O86-19 provides an integrated approach to fire design, including char rates for Structural Mass Timber that specifically address Cross-Laminated Timber (CLT) and connections. The SER should review the applicable char rates being applied, and the associated load cases, with the FPE.

The provisions of Appendix D, Division B of the Code provide an acceptable approach to determining char. However, these calculations provide less clear guidance on design for cross-laminated panels, such as CLT, and should not be mixed with the char approach provided in CSA O86-19. The Appendix D calculation method also does not provide clear guidance for fire-rated connection design, as discussed in Section 5.7.3.6 Connections. Where this method is used, it is recommended that it be reviewed by an FPE.

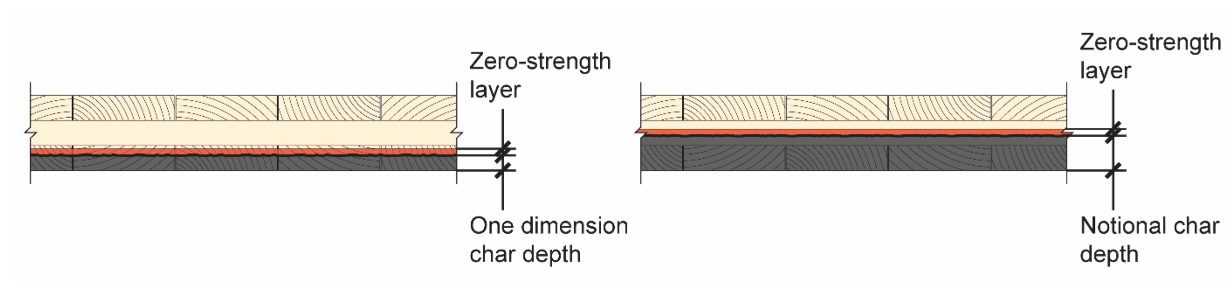
The char calculations from Annex B of CSA O86-19 provide different char rates, depending on the number of surfaces exposed to fire. One-dimensional char, which is commonly applied to Structural Mass Timber panels in floors or walls, has a lower char rate than that used for charring on multiple faces of a single member, such as beams and columns. In either case, a zero-strength layer must be accounted for, as described in Annex B of CSA O86-19.

5.7.2.2 Mass Timber Panel Elements

Structural Mass Timber panels with alternating layers, such as CLT, have a higher prescribed char rate whenever the char depth exceeds the depth of the first lamination, owing to the potential for delamination between layers. As the layers char and separate, the next layer is exposed to a higher initial charring rate. This is reflected in CSA O86-19 by requiring a higher “notional” char rate for CLT, where the char depth exceeds a single lamination (Figure 5-33). To accurately determine if the lower char rate is acceptable, it is important to know the specific lamination thickness, which will vary between suppliers.

CLT and other laminated products, such as mass plywood panels (MPP), are manufactured based on ANSI/APA PRG 320, Standard for Performance-Rated Cross-Laminated Timber. This standard also includes requirements for the glues used between layers to prevent delamination and flashover of the newly exposed uncharred wood; note that the ANSI/APA PRG 320 certification does not negate the need for higher notional char rates.

Figure 5-33: Illustration of a single-layer with one dimension char depth, and a multi-layer with notional char depth



Structural Mass Timber panels with all fibre in one direction, such as glue-laminated timber (GLT), laminated strand lumber (LSL) panels, NLT, and Dowel-Laminated Timber (DLT), can use a single char rate regardless of the char depth. It should be noted that for NLT and DLT panels, each space between individual panel elements (i.e., 38 x 140 members) may be considered a joint from a fire perspective, depending on the width of the space. As such, char rates for materials such as NLT and DLT are dependent on continuous topping, to prevent air and flame movement through joints.

Gaps between individual laminations can significantly affect the performance of the panel in fire conditions. Maximum gap size and wood moisture content (MC) during fabrication should be specified in the contract documents; these gap limits should be reviewed and coordinated with the FPE. Additionally, where significant wetting occurs during construction, the resultant swelling and subsequent shrinkage will result in gaps, even where panels are fabricated to meet the specified requirements; refer to Section 5.7.4 Moisture Considerations for more information on wood swelling and shrinkage.

The potential risk from construction wetting is greater for NLT and DLT than for glued products—if gap sizes exceed the limits provided by the FPE, it may result in the panel no longer having the required Fire-Resistance Rating (FRR). In this case, it could be necessary to either encapsulate, replace, or otherwise retrofit panels to eliminate the gaps (e.g., fire caulking between laminations).

Regardless of the Structural Mass Timber panel type, tolerance gaps between adjacent panels must be coordinated with the Architect and FPE. Firestopping and sealing of the joints are required, in addition to the consideration of char on the sides of the panel at the joint.

5.7.2.3 Beam and Column Elements

Beam and column elements experience char on all exposed faces (typically three or four sides) in a fire. The charring of these surfaces can be evaluated using one-dimensional char, provided corner rounding is explicitly included, as outlined in Annex B of CSA O86-19. Alternately, the charred section can be evaluated using the notional char rate, as described in Annex B of CSA O86-19, which implicitly accounts for the corner rounding.

Where elements are flush with a Structural Mass Timber panel (or other continuous surface), char can be considered on three faces only, as shown in Figure 5-34. For Structural Mass Timber, NLT, or DLT, the panel can only be treated as a solid panel when there are sufficiently strict fabrication and construction MC requirements to limit gaps in place, as discussed in Section 5.7.2.2 Mass Timber Panel Elements.

Figure 5-34: Illustrations of three-sided char

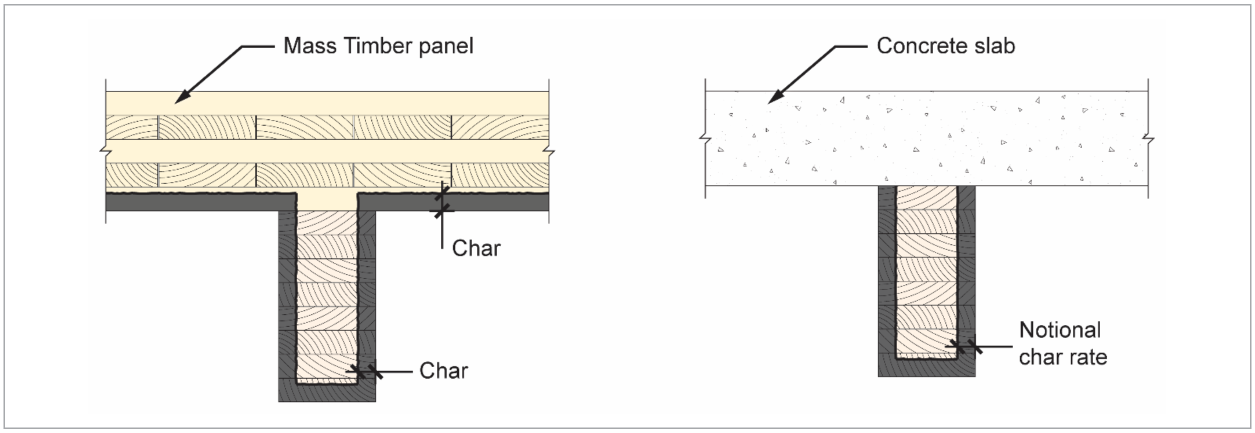
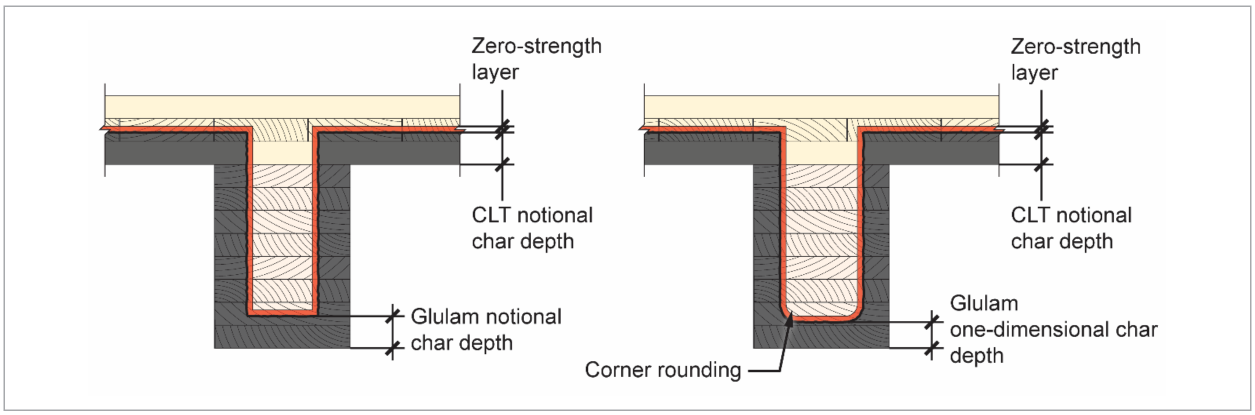


Figure 5-35: Illustrations of notional char on beam (left); one-dimensional char with corner rounding (right)



Note that where one element provides protection to an adjacent element, as shown in the 3-sided char images in Figure 5-34 and Figure 5-35, a tight connection is required (1 mm to 2 mm). If this is not provided, or it is possible for a larger gap to develop as a result of shrinkage, fire caulking may be required and should be discussed with the Architect and FPE.

Beams not tight to the face of a continuous panel cannot be considered protected on one face, and they should be taken as elements experiencing 4-sided char, like columns. Alternately, fire caulking could be provided at all gaps; this should be coordinated with the FPE.

5.7.2.4 Protecting Connections

Protection of connections is required through encapsulation in Type X gypsum board, with protection by timber, or through design of connections to “fail safe” under gravity load. Refer to Section 5.5.3.3 Protection of Connections – Recommended Materials for more information.

Protection of connections must meet the full FRR of the elements that are being supported, and must include evaluation not only of exposed steel, but also of steel that may become exposed due to char. Exposure of steel can draw heat into a connection, causing the interior of the otherwise-protected timber to experience char and potential failure. Connections require review with the

Architect and FPE. An FPE could also provide guidance and recommendations of listed and fire-tested connection assemblies.

The most robust connection provides fire protection by protecting the entirety of the connection with wood and/or gypsum board. For connectors without encapsulation, all connectors must be concealed within the unaffected zone of the timber (i.e., char depth + zero-strength layer) to prevent propagation of heat into the member; no steel should be exposed, nor should it protrude into the charred depth. It is important to note that when designing a connection, it is recommended to use the more precise one-dimensional char with explicit inclusion of corner rounding, as discussed in Annex B of CSA O86-19.

Form-fitted connectors (e.g., Megant®, Ricon®, Sherpa®) allow for fully concealed connections, but require relatively tight construction tolerances. Knife plate connections can also be considered fire-protected connections, provided that both the knife plate and the steel dowels do not protrude into the charred or heat-affected zone; the slots for the knife plate and the holes to accommodate the dowels must be plugged with timber to the calculated char depth or be fully encapsulated (Figure 5-36). Note that edge and end distances for connectors, as described in CSA O86-19, must be adhered to for the charred section. It may be necessary to note fire caulking on the structural drawings. Coordination with the Architect and FPE is required, to make sure fire caulking and firestop requirements are clearly documented.

For bearing connections, it is important to ensure that the bearing support has sufficient residual width and depth to support the bearing connection (Figure 5-37 and Figure 5-38). When evaluating a beam, whether supported on a column or otherwise, it is important to evaluate both the strength of the elements and the residual bearing area at the connection.

Figure 5-36: Illustration of a fire-protected knife plate connection

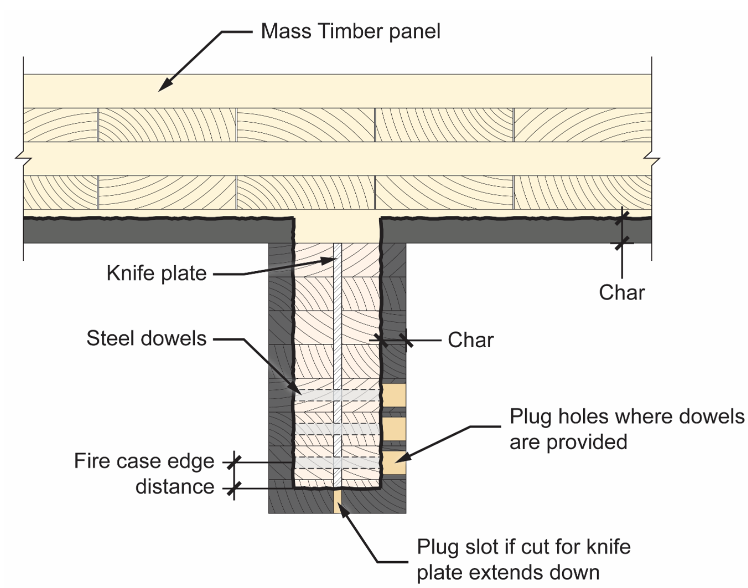


Figure 5-37: Illustration of char impact on bearing length: two beams bearing on interior column

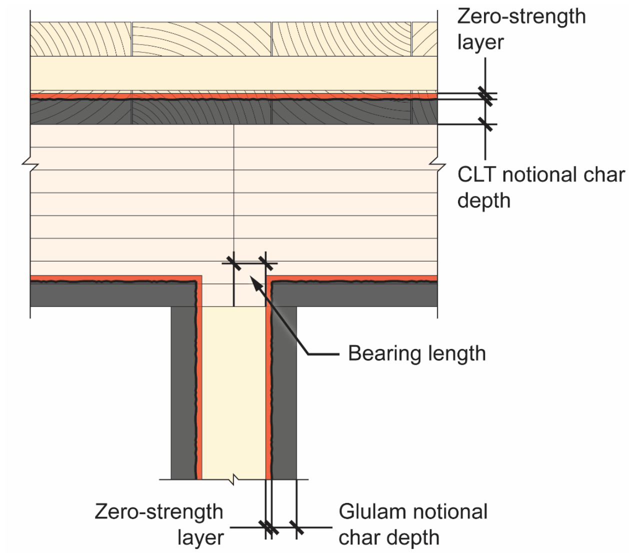
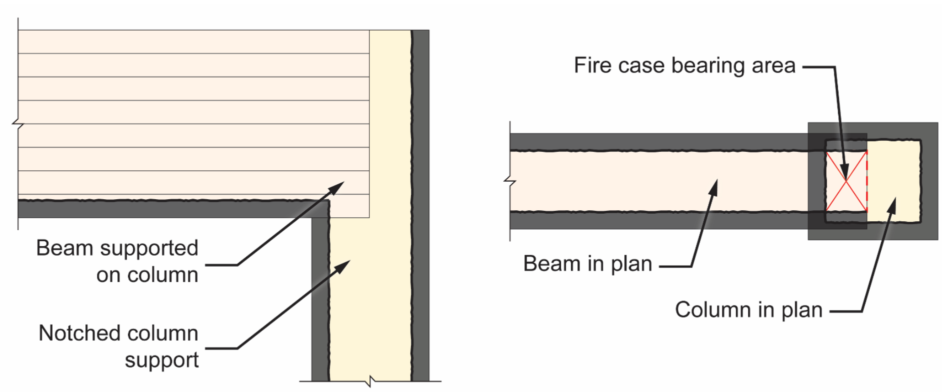


Figure 5-38: Illustration of char impact on bearing length: single beam bearing on exterior column



5.7.3 LATERAL CONSIDERATIONS

The lateral system of any building is a key element of the structural system. The lateral systems in EMTC can involve a hybrid system—marrying a Structural Mass Timber gravity system with either steel or concrete lateral elements—or an entirely Structural Mass Timber system using either CLT shearwalls or Structural Mass Timber braces.

Height limits prescribed in the Code must be met for any lateral system; it should be noted that the height limits associated with Structural Mass Timber lateral systems may prevent Code-compliant implementation for tall buildings. Consideration must be given to both the horizontal and vertical elements of the lateral force-resisting system. Systems that are outside the provisions and guidance provided in CSA O86-19 and the Code will require an alternative solution under the Code.

For discussion of horizontal elements of the lateral force-resisting system, refer to Section 5.7.3.4 Hybrid Systems, and for vertical elements, refer to Section 5.7.3.1 Fire Protection Considerations for Lateral Systems, Section 5.7.3.2 CLT Shearwalls, and Section 5.7.3.3 Timber Braces and Moment-Resisting Frames with Ductile Connections.

Structural Mass Timber floor systems are generally lighter than concrete or steel floor systems, and may result in lower overall lateral forces, depending on the ductility of the system used. For taller buildings, wind design will often govern the lateral design of the buildings, particularly in low seismic zones. The lightweight structure should be carefully evaluated, as it may have different dynamic properties than a heavier structure.

5.7.3.1 Fire Protection Considerations for Lateral Systems

There are no current Code provisions that require fire resistance for lateral elements that do not form part of the gravity load carrying system. However, it is recommended that vertical and horizontal elements of the lateral system retain sufficient capacity after a fire, to resist the factored effects of sway. Best practice suggests designing for the effects of a one-in-10 year wind loading using “Load Combination Case 4” from Table 4.1.3.2. of the Code. Properly detailed diaphragms and connections are critical to maintaining the integrity of the lateral system after a fire.

Special care should be taken where steel connections in the lateral system may affect or compromise the gravity loadbearing capacity of the structure. For example, a knife plate built into a timber column could compromise the entire timber column, even if the knife plate itself is only loaded in lateral cases. Refer to Section 5.7.2.4 Protecting Connections and Section 5.7.3.6 Connections for more information.

5.7.3.2 CLT Shearwalls

CLT shearwall systems are a lateral system found in the Code and outlined in CSA O86-19. CLT shearwall design should follow the requirements Chapter 11 of CSA O86-19.

The CSA O86-19 commentary also provides guidance on system behaviour, dissipative connection design, and other information, such as yielding and capacity designed elements. For seismic-governed connections, capacity design can be complicated, as it requires either test data availability or design to near elastic (i.e., bail-out) loads; refer to CSA O86-19 and associated commentary for guidance. Additionally, height limits and the limitations of applicability of CSA O86-19 (only platform framing is permitted) prevent the use of CLT shearwalls as a Code-compliant system in EMTC tall buildings.

Coordination of shearwalls with the Architect is necessary. It may be reasonable to assume fire is contained in one fire compartment such that other connections can be considered protected. Care should be taken for gravity walls acting as shearwalls, to ensure that the lateral system steel connections do not compromise the gravity system in a fire.

5.7.3.3 Timber Braces and Moment-Resisting Frames with Ductile Connections

Timber braces and moment frames are noted as acceptable lateral systems in the Code. Despite their inclusion, there is little guidance on the design approach to achieve the ductility noted.

Due to the absence of clear guidance in CSA O86-19, comprehensive analysis and/or testing may be required to demonstrate the ductility behaviour of a proposed brace system and its connections. In general, the connections (e.g., brace end connections or moment beam-column connections) are designed to be the dissipative element, whereas the timber members are capacity-protected.

Section 4.3.2 of CSA O86-19 states the following:

> "Elements not covered by this standard may be used where systems are based on analytical and engineering principles and reliable test data, that demonstrate the safety and serviceability of the resulting structure for the purpose intended."

Additionally, height limits described in the Code prevent the use of timber braces or moment resisting frames as a Code-compliant system in EMTC tall buildings, similar to the height restrictions for CLT shearwalls.

5.7.3.4 Hybrid Systems

For other non-wood lateral systems (e.g., concrete shearwalls, steel braces), it is important to ensure there is a clear and robust load path between the Structural Mass Timber and the lateral elements. It is also important to consider construction tolerances of the materials used, to make sure that the load path intended in the design can be achieved.

Careful consideration is also required for the potential differential movement between non-wood elements and the Structural Mass Timber framing.

For more information on shrinkage, refer to Section 5.7.4.1 Shrinkage Over Building Height.

5.7.3.5 Diaphragms

Diaphragm action is generally achieved using Structural Mass Timber floor systems. Structural Mass Timber panels with all fibre in one direction, such as NLT, DLT, and GLT, do not have significant in-plane lateral strength and are typically sheathed with plywood, similar to light wood frame floors. The design of these floor systems follows the requirements of a blocked plywood diaphragm, section 11.8.5 of CSA O86-19, including diaphragm deformations.

Careful detailing is required where the assembly calls for concealed spaces between the Structural Mass Timber panel and the plywood (see Figure 5-39). In addition to fire requirements for such concealed spaces (discussed in Section 5.5.4 Concealed and Service Spaces), these may result in an unblocked diaphragm condition.

For more information on the design and detailing of diaphragms on one-way spanning systems (e.g., DLT, NLT), refer to the *Nail-Laminated Timber: Canadian Design and Construction Guide* (Think Wood 2017).

Structural Mass Timber panels with alternating layers such as CLT have significant in-plane lateral strength and stiffness, so they often act as the primary diaphragm element. CLT diaphragms must remain elastic as per clause 11.9.3.7.1 of CSA O86-19. The individual Structural Mass Timber panels must then be stitched together; these panel-to-panel connections are generally the governing element within a diaphragm. These joint connections can be done with plywood splines, steel plate splines, or lapped splines, as outlined in the *Canadian CLT Handbook* (FPInnovations 2019b).

As discussed in the *Canadian CLT Handbook*, take care when implementing the half lap joint, as it can sometimes result in splitting in the cross section. Reinforcing screws on either side of the lap joint can prevent this type of cracking (see Figure 5-40), but their design and implementation is not currently included in CSA O86-19.

Figure 5-39: Illustration of concealed spaces between the Structural Mass Timber Panel and the plywood sheathing

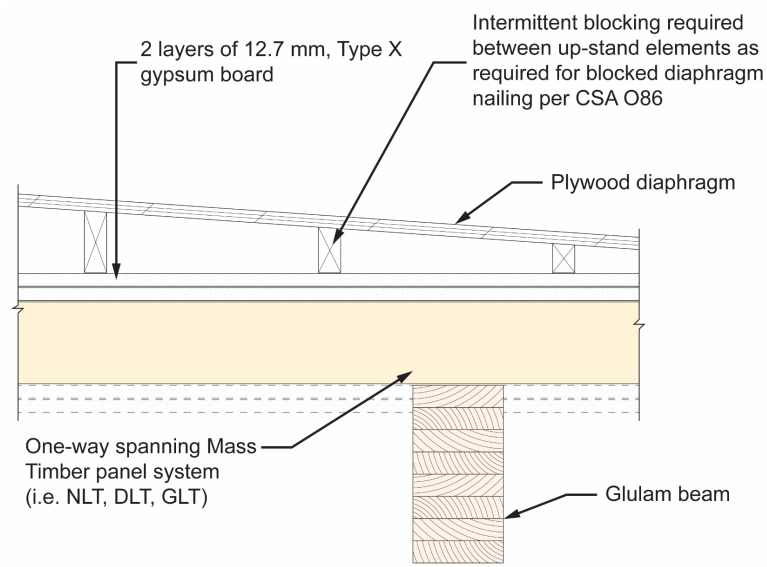
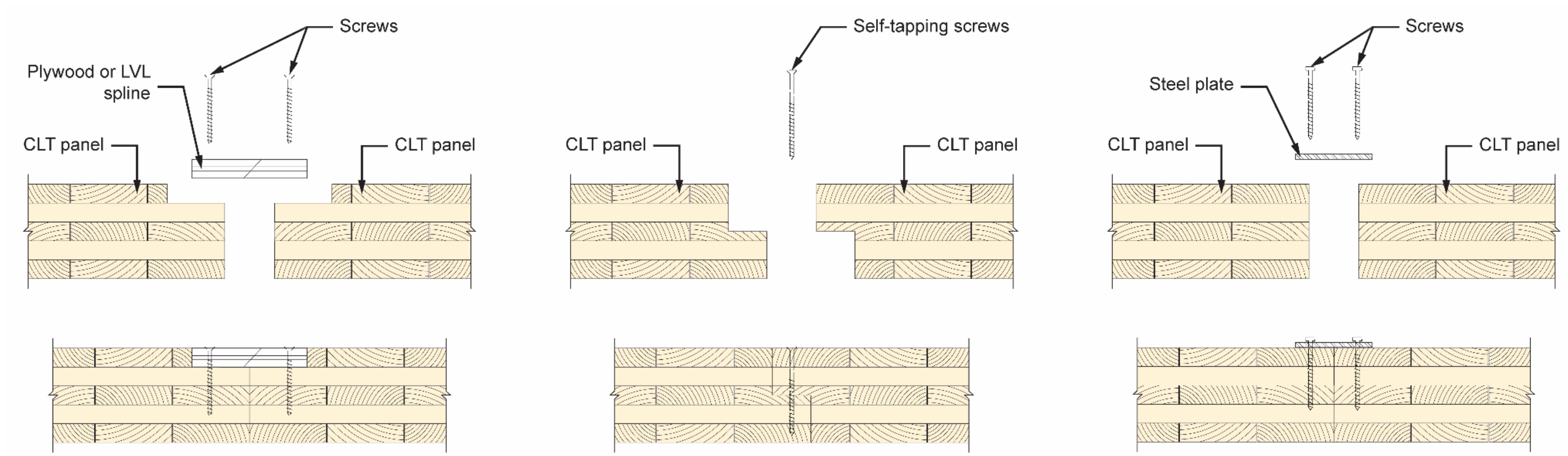


Figure 5-40: Diagram of various CLT splice joints



5.7.3.6 Connections

Connections between the vertical seismic force-resisting system and the diaphragm are critical items that should be capacity designed, per CSA O86-19.

These connections must have appropriate tolerances, particularly between different materials on hybrid buildings. The variation in fundamental material properties between material types should be accounted for. For example, steel elements change in length due to thermal expansion and contraction, whereas timber changes dimensions according to changes in MC (see Section 5.7.4 Moisture Considerations).

Connections between material types should allow for the relative movement of the different elements, and both the construction condition and in-service condition must be accommodated. For elements like drag straps, it is important to consider stiffness compatibility between the connectors and the often-long-thin steel straps, to ensure loads are distributed along the length of the drag element.

Additionally, as with any other type of construction, all primary gravity elements must be able to tolerate the deformations associated with the building's lateral drift, which is described in the Code as follows:

> "All structural framing elements not considered to be part of the SFRS [seismic force resisting system] must be investigated and shown to behave elastically or to have sufficient non-linear capacity to support their gravity loads while undergoing earthquake-induced deformations calculated from the deflections determined in Article 4.1.8.13."

Connections are a critical component of the structural system. Along with other structural elements, connections must be checked for tolerance of lateral deformation. For example, beam-column connections in elements not forming part of the lateral-resisting system must be able to tolerate the rotation associated with the expected storey drift.

5.7.4 MOISTURE CONSIDERATIONS

Wood is an orthotropic, hygroscopic material that expands or contracts with changes in MC. The dimensional change in wood varies, depending on the orientation to the grain of the wood. Radial and annular (perpendicular-to-grain) shrinkage can vary from 3% to 12%, or approximately 1% for every 5% change in MC. Shrinkage along the grain is typically much less, varying from 0.1% to 0.2%, and will contribute to overall axial shortening of the member. Annex A of CSA O86-19 provides guidance on calculating the expected shrinkage in a member.

North American fabrication requirements for glulam and CLT specify a maximum MC of 12% plus-or-minus 3% at fabrication. In comparison, in-service timber MC in an enclosed building can be as low as 6%. This change in MC will result in measurable perpendicular-to-grain shrinkage for any Mass Timber element. In cases where Mass Timber is significantly wetted during construction, or subject to high relative humidity (RH), the variation from the construction MC and the final *in-situ* MC could be even greater. For moisture-critical components, such as connections, the SER should stress the importance of protecting the connection and consider specifying construction conditions that must be met to maintain the capacity of the connection, both during construction and in service, once the MC normalizes.

Note that shrinkage may impact fire separation requirements and building enclosure requirements. It is recommended that the SER coordinate with the Architect, FPE, and building envelope consultant (BEC) on the effects of MC.

5.7.4.1 Shrinkage Over Building Height

For each additional storey in EMTC, particularly in tall buildings, the shrinkage associated with the MC can be a major concern. If construction allows for perpendicular-to-grain bearing, even if all design requirements are met, cumulative shrinkage can be difficult to manage. For example, if each floor experiences 12.7 mm of shrinkage, at the 12th floor, there will be over 150 mm of cumulative shrinkage, and without proper detailing, this may result in tripping hazards and other issues. Hybrid systems with either steel or concrete vertical elements (e.g., a concrete core) are particularly vulnerable to the negative consequences of shrinkage, due to the differential movement between materials.

One common approach to minimize shrinkage issues is to avoid perpendicular-to-grain conditions in the gravity load path between floors. In this case, only axial shortening (up to approximately 3 mm each floor) needs to be accommodated. Detailing for vertical load paths is discussed in Section 5.7.5.2 Vertical Load Path Detailing. The design of platform framed systems, such as Code-compliant CLT shearwalls, must also carefully consider the impact of shrinkage over the full building height, as perpendicular-to-grain bearing is effectively a requirement of the system.

Designers should indicate the expected building shrinkage and settlement overall and per storey on their drawings, and should coordinate with the Architect, MER, EER, and any other affected parties. This predicted shrinkage should include the shrinkage resulting from the change in MC (discussed elsewhere in Section 5.7.4 Moisture Considerations), as well as elastic deformation in the columns and any perpendicular-to-grain elements, and creep in the columns (discussed in Section 5.7.5.4 Creep).

5.7.4.2 Shrinkage and Swelling in Connections

It is also important to consider shrinkage in the connection detailing of individual elements (Figure 5-41). For large dimension cross sections, shrinkage in the member can result in checking or splitting of the wood, particularly if connections are acting to restrain this shrinkage (e.g., dowel connection distributed over full depth of glulam beam).

To avoid this, it is preferable to keep connectors grouped tightly together, using multiple rows if needed, as shown in Figure 5-42 and Figure 5-43. Alternately, if the dowels are only loaded parallel to grain, the holes in the steel plate can be slotted perpendicular-to-grain to avoid unintended restraint. Refer to CSA O86-19 for limits on distance between fasteners perpendicular to grain to prevent splitting.

Note that Chapter 12 of CSA O86-19 should be followed for the design of any non-proprietary connector. Both the dowel strength and the wood failure, including splitting, should be considered on any connection detail.

The design of connections must also consider swelling when exposed to moisture in either exterior conditions or when exposed during construction. See Figure 5-43 for the effects of shrinkage on improperly detailed connections.

Similar approaches used for shrinkage can be used for typical doweled connections. For less traditional connections, such as Structural Mass Timber members hung from supporting members above, particularly if the supporting members are steel elements, careful detailing is required. (See Figure 5-44.)

In cases where significant wetting occurs either during construction, or from a failed roofing membrane, the swelling will likely be larger than can be accommodated by the steel elongation of any steel connector (e.g., screw, bolt). The connection should be designed and detailed to either allow for the elastic deformation needed to accommodate swelling associated with significant wetting, or provided with some other form of redundancy. If not appropriately detailed, hanging connections subject to significant wetting could result in catastrophic failure of the connection.

Figure 5-41: Illustration of shrinkage considerations in Structural Mass Timber beam connections

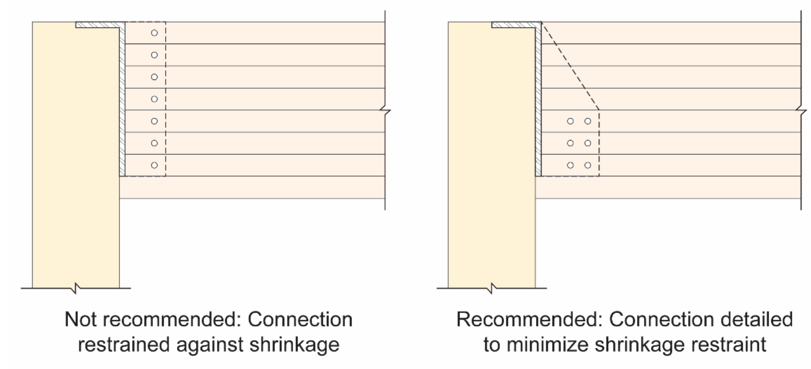


Figure 5-42: Illustrations of shrinkage considerations in Structural Mass Timber column and beam connections

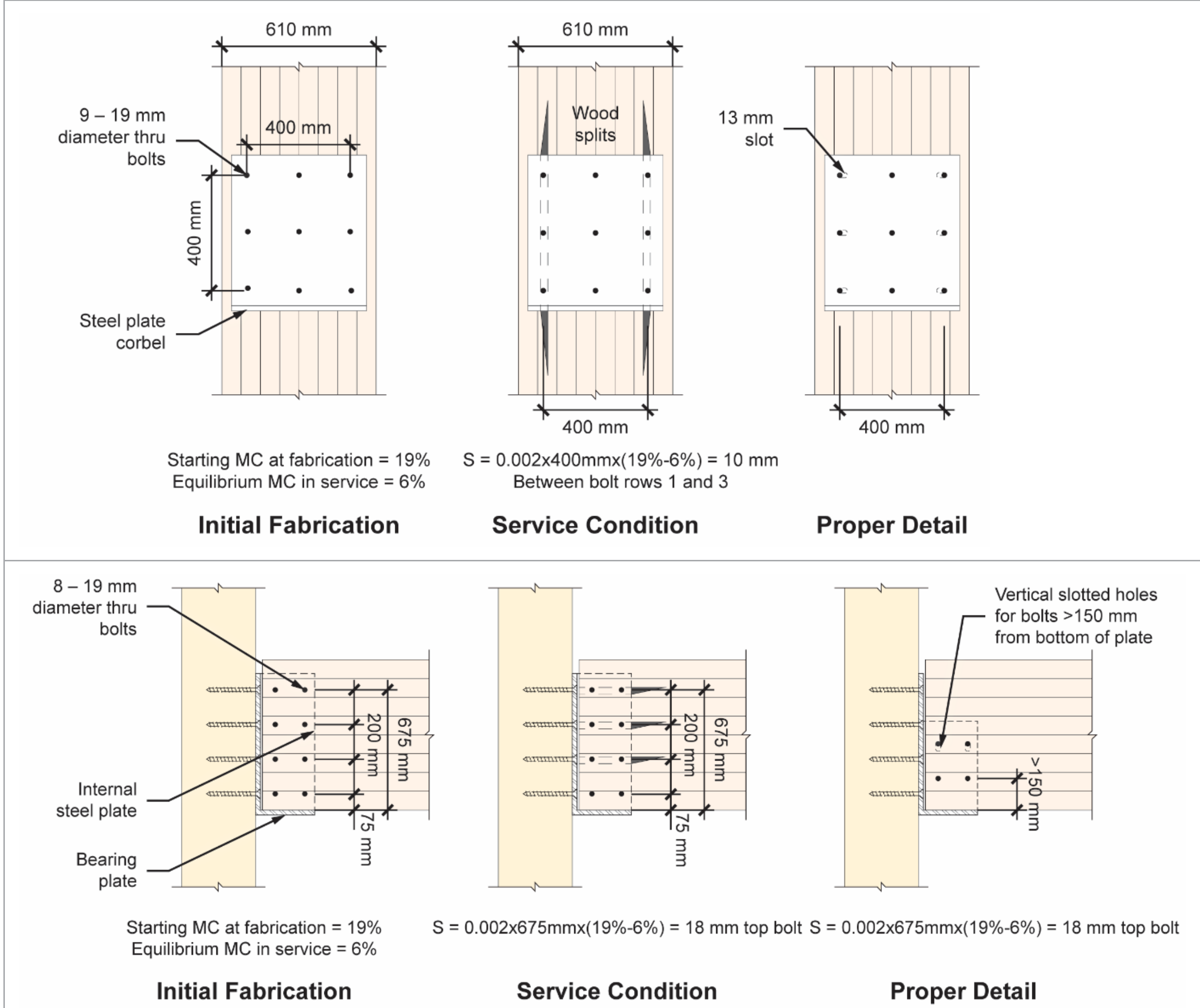


Figure 5-43: Illustrations of shrinkage considerations for Structural Mass Timber to concrete connections

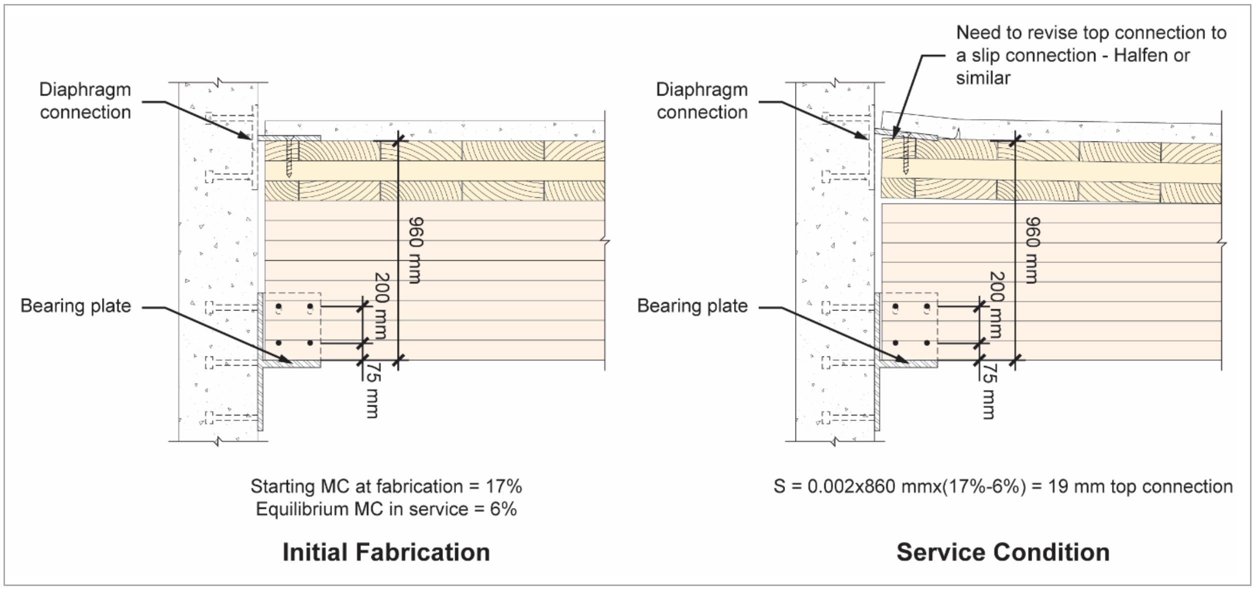
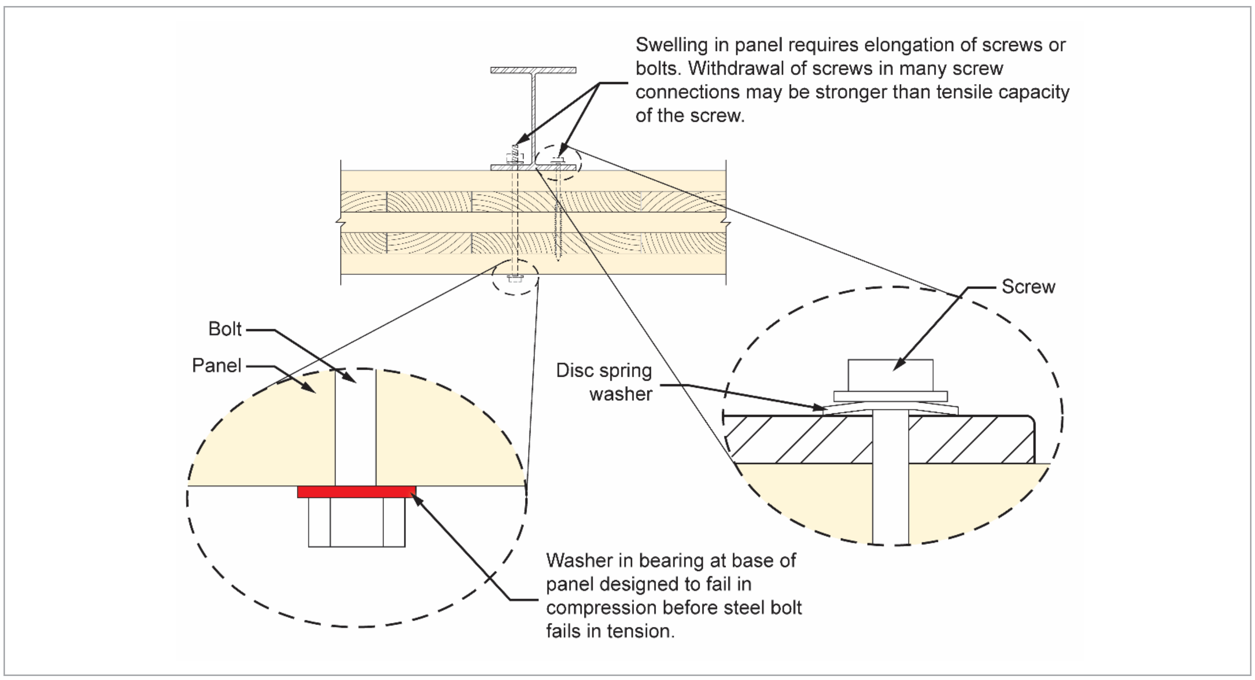


Figure 5-44: Illustration of swelling considerations for screws and bolts in Structural Mass Timber panels



5.7.4.3 Construction Moisture Considerations

Construction moisture is an important consideration in the detailing of Structural Mass Timber elements. In locations where significant wetting is expected during construction, it is important to design Structural Mass Timber connections to accommodate expected swelling in the Structural Mass Timber members. The swelling that occurs because of wetting should be considered an unstoppable force, similar to frost heave. Many of the above-noted details for connections will also limit impacts from swelling during construction.

Dimensional change due to changing MC must also be considered for Structural Mass Timber panels. Due to the cross laminations, CLT is dimensionally stable in plan, subject only to parallel-to-grain shrinkage due to the cross laminations; large dimensional changes in CLT will generally be restricted to the thickness of panel. Conversely, one-way spanning systems (e.g., DLT, NLT, GLT) are subject to perpendicular-to-grain shrinkage across their width and depth; it is critical to provide regular gaps between panels, to allow swelling to occur across the width of the panel. For more information refer to the *Nail-Laminated Timber: Canadian Design and Construction Guide* (Think Wood 2017).

It is recommended to provide the constructors with performance specifications for acceptable upper limits on MC during construction, and prior to placement of roofing, concrete topping, or other finishes.

5.7.5 GRAVITY CONSIDERATIONS

5.7.5.1 Column Design

Although not addressed in CSA O86-19, it is recommended to consider the moment that may result from any imposed or accidental eccentricity in column design. At a minimum, the moment associated with accidental eccentricities due to fabrication tolerances for connectors and flatness of column ends, and erection plumbness tolerances should be considered and coordinated with the suppliers' tolerances. It is also important to consider eccentricities associated with unbalanced live or snow loads.

Column sizes will increase to support the applied load associated with each additional floor, with those on the lower floors having a larger cross section than those on the upper floors. As the number of floors increases, the column size required may exceed the typical sizes outlined in the *Wood Design Manual* (CWC 2017). Where this occurs, it is recommended that the SER discuss availability of different materials, larger sizes, or block-glued columns with the local manufacturer(s). It is also important to discuss the size implications with the Architect, as larger column sizes may affect the functional space requirements.

5.7.5.2 Vertical Load Path Detailing

Special consideration for vertical load path detailing is required for EMTC, especially tall buildings, as the number of storeys increases. Horizontal Structural Mass Timber elements in floors are not largely affected by the number of storeys, but the size of columns and the associated connections between columns at floors are significantly impacted.

As the number of storeys increases, the loads on columns increase accordingly, often resulting in loads that exceed perpendicular-to-grain bearing strengths (Figure 5-45). This, compounded with the shrinkage issues discussed in Section 5.7.4.1 Shrinkage Over Building Height, can be largely eliminated by column-to-column connections with end-grain bearing only.

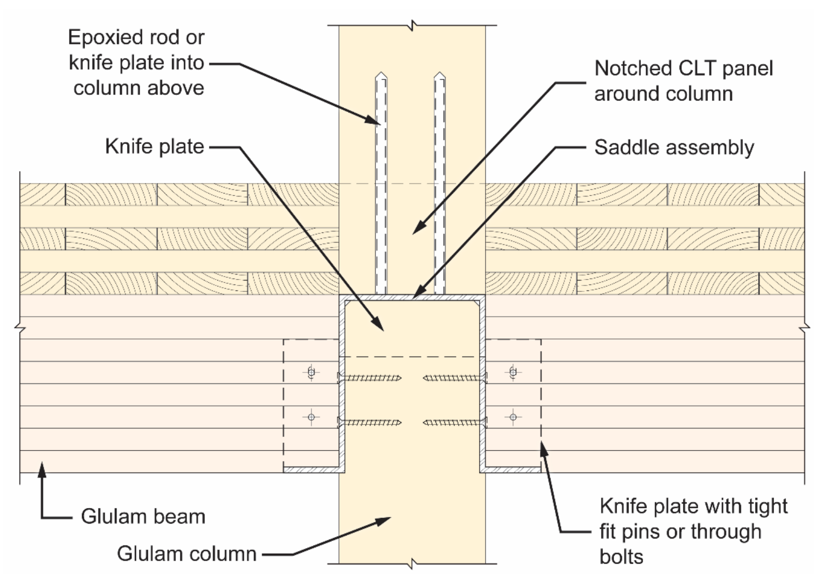
Like columns, CLT walls will be similarly impacted by strength and shrinkage, so the SER needs to consider alternate detailing requirements for CLT gravity walls.

Code-compliant CLT shearwalls are required to be platformed framed, as discussed in Section 5.7.3.2 CLT Shearwalls; the perpendicular-to-grain strength of the Structural Mass Timber floors can be a significant design constraint, particularly for tall buildings.

Where CLT gravity walls are used but are not considered part of the lateral system, they should be considered to be "stiff" elements and detailed in accordance with the Code. The Code states the following regarding stiff elements:

> "Stiff elements that are not considered part of the SFRS [seismic force resisting system], such as concrete, masonry, brick or precast walls or panels, shall be
>
> a) separated from all structural elements of the building such that no interaction takes place as the building undergoes deflections due to earthquake effects as calculated in this Subsection, or
>
> b) made part of the SFRS and satisfy the requirements of this Subsection."

Figure 5-45: Illustration of an example of structural beam-to-column connection without perpendicular-to-grain bearing



5.7.5.3 Balconies

Balcony systems in EMTC should be considered similar to the balcony systems in concrete or steel framed buildings. For balconies using continuous Structural Mass Timber panels from the interior to exterior, coordination is required with the Architect and BEC, to ensure that thermal bridges are designed and detailed appropriately (discussed in Section 5.4.4.5 Balconies).

This type of continuous structural framing will also typically require the finished surface to step up for the balcony, as the structure would not be stepped down. Balconies that step down to accommodate a flush walk-out surface typically require external framing and a bolt-on connection to the primary structure (see Section 5.4.4.5 Balconies, under the subsection Balcony Examples).

Often these bolt-on balconies are designed as steel framed systems. Where Structural Mass Timber is used, it would need to be designed similar to any other exterior wood structure, considering moisture and EMTC-specific FRR requirements, as outlined in these guidelines. The bolt-on connections and supporting Structural Mass Timber should be designed based on the CSA O86-19 connection and member design requirements, respectively.

5.7.5.4 Creep

Creep is also a concern that is not extensively addressed in the Code and referenced standards. CLT creep is defined in Annex A of CSA O86-19; however, there is no guidance for creep deformation of elements such as beams, one-way spanning panels, and columns. For guidance on creep in these elements, it may be appropriate to reference the United States standard, the National Design Specification for Wood Construction (NDS), or the European standard, Eurocode 5: Design of Timber Structures – Part 1-1.

Currently, only guidance on horizontal elements is given; it is generally deemed acceptable to use similar creep factors for the amplification of long-term deformations expected in columns. Both elastic and long-term column shortening should be considered on tall buildings.

5.7.5.5 Connections

Connections should be designed per CSA O86-19. Shrinkage requirements are to be considered per Section 5.7.4.2 Shrinkage and Swelling in Connections. Fire rating requirements are to be considered per Section 5.7.2.4 Protecting Connections.

Where proprietary connections or connectors are used, refer to the supplier's published documentation and associated Canadian Construction Materials Centre (CCMC) reports for design information. For products without a CCMC, it is at the designer's discretion to review testing documents or other certifications (e.g., ICC approvals, ETA approvals) to satisfy themselves that the product meets the requirements of Section 4.3.2 of CSA O86-19.

Construction tolerance for wood connections should also be considered and discussed with the constructor, when retained and available during the design process. This can be critical for hybrid systems involving concrete or steel lateral and gravity elements. Connections provided must meet the tolerance requirements of the elements with the least allowable tolerance. For proprietary connectors, refer to the supplier documentation for appropriate construction tolerances.

5.7.5.6 Mechanical and Electrical Penetrations

Mechanical, electrical, and plumbing (MEP) system routing must be carefully coordinated with the MER, EER, and Architect. It is often structurally preferable to run all mechanical and electrical services below or outside the structure, either left exposed or within dropped ceilings and furred out walls, rather than within or through Structural Mass Timber panels, beams, or columns. Dropped ceilings and concealed spaces create many other challenges, due to the encapsulation requirements of EMTC; exposing the services may be the preferred solution. Refer to Section 5.8.2 Design Considerations.

CLT floors with penetrations require special detailing. Finite element modelling analysis can help determine stresses around openings, but results must be carefully evaluated. The recommended simple, conservative approach for penetrations through CLT floors is to make sure the net width of the panel can support the loads applied over the gross width, for both strength and serviceability. This approach is anticipated to work well if the penetrations are small and their locations are distributed in such a way that the panels are well-preserved.

For one-way spanning systems, penetrations through floor systems need to be more carefully considered; refer to the *Nail-Laminated Timber: Canadian Design and Construction Guide* (Think Wood 2017) for more discussion on this. Consider including typical detail guidance on allowable penetrations through Structural Mass Timber floors, to more readily allow penetrations to be provided in future renovations or changes during construction.

A similar approach can be used for penetrations through CLT walls under gravity loads. It should be noted that for a fully Code-compliant design, CSA O86-19 requires that parts of walls with openings should not be considered part of the lateral force resisting system.

Mechanical and electrical services should not penetrate through glulam beams, wherever possible. Currently, CSA O86-19 does not provide any guidance on penetrations through glulam beams or columns, so allowing such penetrations would not constitute a fully Code-compliant approach, and would therefore require an alternative solution under the Code, if proposed. The APA – Engineered Wood Association (APA) has published a technical note with guidance on penetrations from the wood design standard in the United States, the NDS. The European standard, Eurocode 5: Design of Timber Structures, provides guidance on localized stresses around penetrations and methods for reinforcement.

5.7.5.7 Floor Vibration

Floor vibration will often govern the design of a Structural Mass Timber floor system, rather than ultimate limit state (ULS) strength or serviceability limit state deflection, due to the lightweight nature of these systems compared to other floor systems (such as concrete slabs). For more discussion on floor vibration, as well as discussion on other environmental or mechanical vibration, refer to Section 5.6.5 Floor Vibration. Coordination with the Architect will be required when other members of the design team, such as the acoustical engineer or the MER, are reviewing vibration from equipment or building services.

For footfall vibration on floors, Annex A of CSA O86-19 provides some simplified methods for calculating vibration performance of CLT floor panels supported on walls, but other conditions, such as point supported or post and beam, and other Structural Mass Timber panels are not directly discussed. The Canadian CLT Handbook (FPInnovations 2019b) provides some additional information on footfall vibration for CLT floors supported on beams.

The newly published *US Mass Timber Floor Vibration Design Guide* (Wood Works 2020) provides Structural Mass Timber specific vibration guidance for various systems, including guidance for implementation of finite element modelling, as well as a recommended analysis approach.

5.8 MECHANICAL AND ELECTRICAL CONSIDERATIONS

The mechanical engineer of record (MER) and the electrical engineer of record (EER) should review all parts of these guidelines; this section focuses on the specific mechanical and electrical requirements encountered in EMTC up to 12 storeys.

For a summary of important considerations for EMTC, and differences compared with other construction types, see Section 1 Foreword.

5.8.1 GENERAL CONSIDERATIONS

5.8.1.1 Collaboration Among Disciplines

Collaboration among mechanical, electrical, and plumbing (MEP) Engineering Professionals and other members of the design team during the design phase is of critical importance, as there is limited opportunity to make modifications in the field during construction.

The entire design team should collaborate early in the process, to allow for economies to be realized and for conflicts to be identified at the earliest point possible. The integrated, collaborative approach should continue throughout the entire project, from design through construction.

5.8.1.2 Implications of Systems Integration

Detailed coordination of wiring, piping, and ductwork services, including routing, sizes, locations, suspension details, and gradients (slopes), where applicable, is critical for EMTC buildings.

Due to the solid and prefabricated nature of Structural Mass Timber members and/or panels, mechanical and electrical services cannot typically be buried within the structure. Penetrations for services, piping, and ductwork should be thoroughly planned prior to member and/or panel fabrication, and should be coordinated with the other members of the design team, particularly the Architect and the structural engineer of record (SER).

The MER and EER may also encounter conflicts between their respective systems, as well as opportunities to share concealed spaces. Therefore, routing should be determined during the design process, so concealed spaces, structural penetrations, and firestopping of penetrations can be coordinated.

Importantly, unprotected concealed spaces are not permitted in EMTC; they must be either sprinklered, completely filled with fire-resistant insulation, or lined with gypsum board. It is generally preferable to run services in non-Structural Mass Timber walls and avoid structural penetrations wherever possible.

5.8.1.3 Moisture Control in Service: Penetrations

Service penetrations should be planned to run horizontally through vertical surfaces, rather than vertically through horizontal surfaces, wherever possible, as they are easier to protect from moisture ingress both during construction and in service.

Minimizing penetrations on the roof will reduce the opportunity for water penetration and moisture damage to the building, which could be difficult and/or expensive to remediate. Refer to Section 5.4.6 Moisture Control and Protection of Mass Timber for further details.

5.8.1.4 Implications of Moisture Build-up or Flooding After Occupancy

The implications of post-occupancy water damage should be considered at the design stage by all disciplines, to minimize the consequent need for repairs. Considerations include but are not limited to:

- optimizing plumbing fixture layouts, to minimize water spread, such as arranging washrooms back-to-back, minimizing remote fixtures where possible, and providing additional floor drains (more than that required by the Code);
- providing active water-detection systems that either sound an alarm or shut off water service when moisture is detected;
- providing more service shutoffs, to minimize the area affected by the service interruption should a leak occur; and
- providing waterproof membranes and floor drains in areas with plumbing fixtures, to allow water to be contained such that it would not affect the wood structure adversely, or to such an extent that a major repair would be required.

These design, monitoring, waterproofing, and water-management strategies should be coordinated with the Architect, the building envelope consultant (BEC), if retained, and the SER. The BEC can provide advice to the Architect and Engineering Professionals for ongoing moisture-management strategies.

As described in Section 5.3.4.1 Implications of Flooding After Occupancy and Section 5.4.7 Maintenance and Renewal, continuous post-occupancy monitoring of concealed spaces for the presence of moisture and water is good practice, and owners should be advised of this ongoing maintenance strategy. The MER and EER should discuss water-detection technology and post-occupancy moisture management strategies with the owner and/or the Architect, SER, and BEC.

Systems can be as simple as water sensors equipped with a built-in audible alarm located where water escape is most likely (e.g., washing machines, toilets, sinks). More sophisticated systems have sensors that can instruct shutoff valves to close when water is detected. Some systems have communication capability and send emails if water is detected. These systems are available either wired or battery-operated, and communication is generally wireless. These systems will require careful coordination between the MER and the EER, and in some cases, a Supporting Registered Professional (SRP) with expertise in telemetry may be advisable.

5.8.2 DESIGN CONSIDERATIONS

The MER and EER, in collaboration with the other disciplines, should clearly define routing, pipe and duct dimensions, raceway diameters, and suspension details, to allow for precise prefabrication in the factory where Structural Mass Timber components are being produced. Consolidation of horizontal and vertical runs and allocation of spaces for service shafts, junction boxes, and electrical panels during the design phase has a subsequent impact on the construction sequencing on site.

The MER and EER should have a good understanding and level of experience working with Mass Timber products, as they will have to consider the natural characteristics of Mass Timber during the design phase.

5.8.2.1 Shrinkage and Support

Mass Timber contains a certain percentage of moisture, which will vary between the fabrication, construction, and in-service stages. As the moisture content (MC) of Mass Timber varies, the members shrink and swell, causing dimensional changes. The most significant dimensional changes happen during construction and in the transition from the construction to in-service stages, but changes during service should also be considered.

The amount of shrinkage that a building will experience between the fabrication and/or construction and in-service stages varies, based on the Mass Timber material and member type, but it can generally be expected that each level may shrink up to 12.7 mm or more, which may impact the integrity of the building's mechanical and electrical systems. When carefully detailed, the shrinkage can be isolated on a floor-by-floor basis, making the effects of shrinkage, and its detailing considerations, uniform across the height. The MER and EER should coordinate the expected vertical shrinkage of the building with the Architect and SER early in the design process, to develop a strategy to accommodate the anticipated movement.

Examples of detailing to accommodate the effects of Mass Timber shrinkage include anchoring pipes strategically, to allow movement away from the anchor; using devices such as pipe braided hose loops; integrating multiple flexible mechanical couplings; and using in-line mechanical movement compensators. These details will allow the main pipe to move; branches from the main pipe should be dealt with in a similar manner. Horizontal drainage piping should be over-graded to maintain slope when the vertical pipe moves due to shrinkage. Similarly, pipe guides are required adjacent to movement compensators, to prevent lateral deflection of the pipe when it moves due to shrinkage.

Examples of strategic anchoring for mechanical systems include:

- installing a single anchor at the top or bottom of the pipe, allowing movement in only one direction;
- locating a single anchor in the middle of the pipe, reducing the amount of movement by half but requiring the movement above and below the anchor to be dealt with by a compensator; and
- employing multiple anchors, with compensators between anchors.

Similarly, the electrical systems should have flexibility to accommodate anticipated movement, and should include:

- installing junction boxes at every fourth floor for the cable and wiring slacks;
- integrating conduit expansion fittings and cable slacks at expansion joints; and
- adding flex cable bus extension parts within run or bus duct flexible braids (power shunts).

The types of support systems used with concrete or steel structures will likely not be suitable for Mass Timber. The connection requirements will depend on both the mechanical or electrical support system and the structural system; the connection requirements, including specific locations of the mechanical and electrical systems, need to be coordinated with the Architect and SER.

5.8.2.2 Routing Considerations

The size and location of penetrations should be coordinated with the Architect and SER, as there will be specific requirements and limitations based on the material and structural member type.

MEP services should not penetrate through Structural Mass Timber beams, unless no other routing is possible. However, if Structural Mass Timber beam penetrations are permitted by the Architect and SER, they will generally be permitted to be located at mid-span and mid-depth. Similarly, Structural Mass Timber floor and wall panel penetrations should be located as far away as possible from concentrated loads and support points and other penetrations. Permissible penetrations for panels will vary on a material and project basis; the SER should be consulted early in the design to establish the limitations.

Except as provided in Sentence 3.1.18.15.(2) of the Code regarding outlet boxes, all electrical devices recessed into the Structural Mass Timber should have an opening that is typically 25 mm larger than the size of the device for fire protection. Once installed, these openings must be sealed and fire rated to match the component in which they are installed. The most common devices requiring these penetrations are power and data outlet boxes, and junction boxes installed in vertical and horizontal assemblies. Wiring for electrical devices will generally not be recessed into the timber structure, especially not in beams and columns; this should be coordinated with the Architect and SER.

Early coordination of service routing facilitates prefabrication of Mass Timber products complete with cutouts for services, allowing for rapid installation and reduction of labour on site. Sections of the horizontal and vertical services should be designed, and spaces in the suspended ceilings or walls should be allocated in advance for easy installation of MEP services on site. Little or no on-site cutting or drilling for electrical or mechanical services should be anticipated.

Where Structural Mass Timber penetrations are not permitted and/or services are required to be outside the structure (i.e., dropped below or located in service cavities), special attention should be paid to minimize and coordinate concealed spaces. All concealed spaces must be encapsulated or otherwise fire protected. Refer to Section 5.7.5.6 Mechanical and Electrical Penetrations for structural penetration requirements and Section 5.5.4 Concealed and Service Spaces for fire protection requirements.

A 3D virtual model can be a valuable tool to locate MEP penetrations in the structure, to facilitate coordination and avoid conflicts.

5.8.2.3 Service Spaces and Vertical and Horizontal Runs

In EMTC buildings, horizontal service spaces, vertical service spaces, shafts, and any other spaces containing mechanical and electrical services are considered concealed spaces requiring fire protection measures.

It is important that the Architect and Engineering Professionals collaborate to identify spaces required for mechanical, electrical, and fire suppression. Concealed spaces in EMTC must be either fully encapsulated or otherwise fire protected by sprinklers or insulation, as per Subsection 3.1.18. of the Code. See Section 5.4.4 Building Enclosure Assemblies and Materials for additional information.

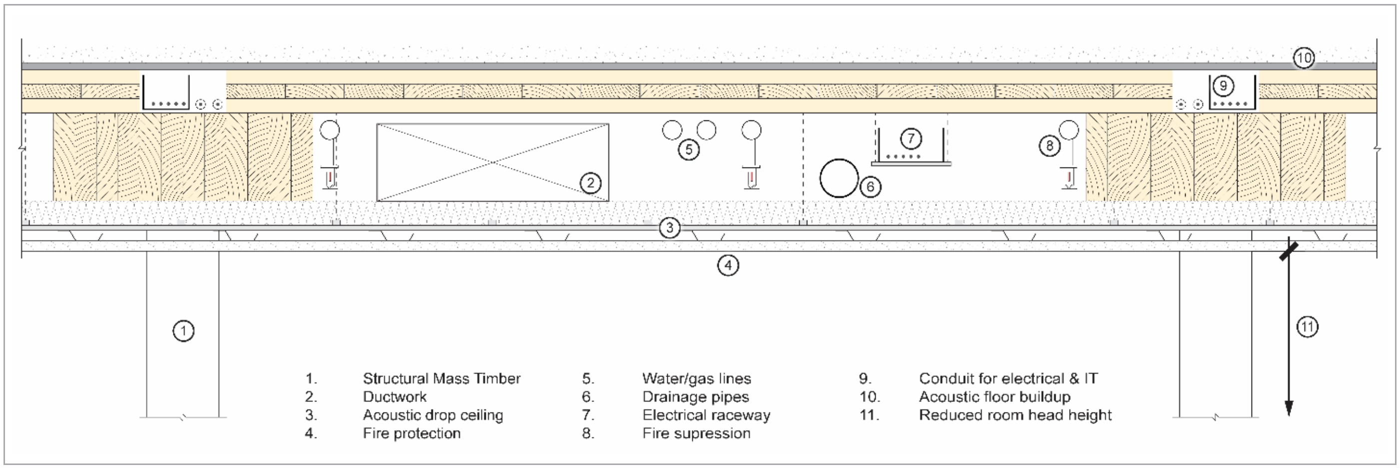
Running ductwork or piping in Structural Mass Timber floors, unless the floor assembly specifically allows it, should not be considered. Structural Mass Timber panel systems are not suitable for housing slab-type ducts or services with pressurized water. Caution should be taken when running services containing water in concealed spaces, as any leakage would be very difficult or even impossible to repair.

The fire rating of walls, ceilings, and floors for service rooms and closets will be provided, as per the Code requirements, subject to the chosen fire protection system for those particular service rooms.

The 2018 *Canadian Electrical Code* defines the types of raceways and spacing between various types of electrical services and spacing relative, in most cases, to mechanical and plumbing services. Both horizontal and vertical services in EMTC that run inside a concealed space will require fire protection, as per Subsection 3.2.7. of the Code. In rare cases, the services may be in chases or cutouts in the Structural Mass Timber. The prefabrication of the panels, beams, and columns with cutouts incorporated will allow for services to be installed easily, without a need for additional cutting of openings at the site. The MER and EER should consider every aspect of their design with respect to the routing and integration with the Structural Mass Timber, prior to prefabrication.

An example of MEP services inside a Structural Mass Timber floor assembly is shown in Figure 5-46. Note that the fire protection requirements of concealed spaces are not shown in this figure; refer to Section 5.4.4 Building Enclosure Assemblies and Materials for information on the encapsulation requirements.

Figure 5-46: Illustration of a mechanical, electrical, and plumbing (MEP) service ceiling arrangement



5.8.3 FIRE PROTECTION CONSIDERATIONS

5.8.3.1 Encapsulation and Char

The MER and EER need to be aware of the encapsulation requirements for EMTC. Encapsulation can be provided by using two layers of 12.7 mm, Type X gypsum board, through charring of the Mass Timber, or with a combination of the two strategies. The MER and EER should coordinate firestopping requirements with the Architect and fire protection engineer (FPE), if retained, for penetrations through fire separations.

Refer to Sections 5.3.2.3 Material Considerations, 5.5.2 Encapsulation and Fire-Resistance Rating, and 5.7.2 Fire Considerations for details of char and encapsulation, how they affect firestopping, and smoke and fire damper installations. It is important to understand these concepts in conjunction with the following.

5.8.3.2 Penetrations and Firestopping

Pipes, ducts, conduits, metal-armored cables, and other services penetrating Structural Mass Timber wall and floor panels must be separated from the Mass Timber by a minimum annular space of 12.7 mm, as per CAN/ULC-S115, Standard Method of Fire Tests of Firestop Systems. It is recommended a typical annular space of 25 mm be provided for all penetrations of Mass Timber elements to facilitate firestopping. Metal pipe or conduit penetrations up to 150 mm with an annular space of 12.7 to 38 mm can be firestopped as shown on Figure 5-47, Figure 5-48, and Figure 5-49.

The annular space should be packed with mineral wool insulation, to prevent a pipe heated by a fire causing charring on the surface of the annular space. This requirement applies to both fire separations and non-fire separations. If the firestop material is required because the wall or floor is a fire separation, the material needs to be located such that it will not be in the char layer after fire exposure. This may mean that there will be mineral wool protecting the pipe (or other device) on both sides of the firestop material.

Most piping carrying water in the building will require insulation for energy or condensation considerations. If the provided insulation around an insulated pipe is mineral wool, and the thickness is greater than 12.7 mm, the insulated pipe can be installed snug to the opening and will prevent char in the annular space. If the insulation is not mineral wool, an additional minimum 12.7 mm annular space must be provided around the insulation to protect the surface of the annular seal from charring. If the insulation through the opening is changed to mineral wool, no additional treatment is required to protect the exposed timber, provided the annular space is filled.

Similarly, as with pipe penetrations, duct penetrations must be separated from the wood inside the opening to prevent the development of char during fire exposure. However, duct penetrations also require a fire damper collar or sleeve to go into the Mass Timber opening, which includes the 12.7 mm annular space for the mineral wool insulation. Firestop material will be required for ducts penetrating fire separations, to close the annular space that is filled with mineral wool.

In all cases, the fire protection and firestopping requirements of services penetrations should be coordinated with the Architect and FPE; and the size, location, and effects of the penetrations on the structure should be coordinated with the Architect and SER.

It is recommended that all pipes and ducts in ETMC be insulated with fibreglass or mineral wool insulation, rather than Combustible insulation.

It is the responsibility of the MER and EER to specify the insulation requirements and firestop material for their service penetrations. Firestop material must be installed as indicated by the product manufacturer; however, a unique aspect of EMTC is that the firestopping needs to be located far enough into the material to avoid ending up in the char layer. The MER and EER should note that concrete firestop materials cannot be used for Mass Timber, unless they are explicitly approved or extensive testing is done to confirm adequate performance.

Currently, there are no tested firestopping methods for plastic piping penetrations through Mass Timber. Plastic pipe penetrations in EMTC will likely require an alternative solution under the Code. Generally, Combustible piping must meet the requirements for Combustible piping in Noncombustible Construction, as per Article 3.1.5.19. of the Code. See Figure 5-47 for an example of a proposed alternative solution for a plastic pipe penetration.

Fire rating at the place of penetration of electrical service is of prime importance. Penetrations should be carefully coordinated with the Architect, SER, and FPE for firestopping at fire separations. Steel conduits are currently the only approved and certified method in Canada for larger openings used for running the mechanical and electrical services through Mass Timber fire separations. Figure 5-50 and Figure 5-51 show test setups for fire testing of mechanical and electrical penetrations in Structural Mass Timber panels; the quantity and clearance between penetrations in this test is likely to be structurally unacceptable.

Currently there are no listed firestopping systems for Structural Mass Timber. Refer to Section 5.5.3.5 Firestopping for more information on firestopping for EMTC.

Figure 5-47: Illustration of a proposed plastic conduit/pipe firestop detail for CLT panel with recommended bore

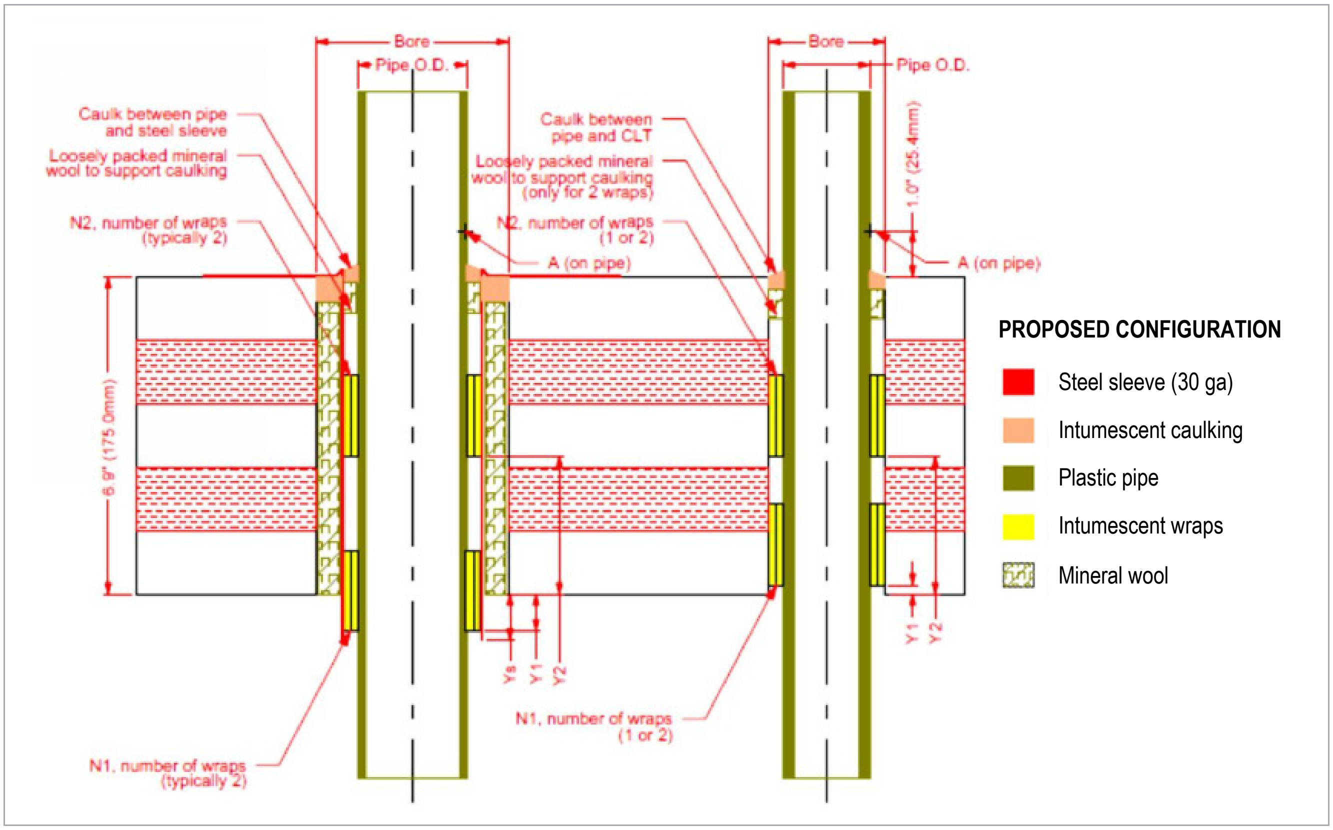


Figure 5-48: Photograph of an upper 12.7 mm annular space filled with mineral wool and caulking, and steel sleeve filled with intumescent caulking

Figure 5-49: Photograph of an annular space between CLT (plywood)

Figure 5-50: Photograph of a test assembly prior to testing with steel conduits (exposed side to the fire is below and unexposed side is above CLT structure)	Figure 5-51: Photograph of a firestopping assembly of various electrical systems prior to testing
	

5.8.4 ACOUSTICAL CONSIDERATIONS

Due to the light weight and stiffness of Structural Mass Timber panels, special considerations should be taken to mitigate the effects of noise generated by building services, such as mechanical systems, plumbing systems, electrical systems, emergency generators, and elevator systems. These services create both noise and vibration that require acoustics treatments to prevent noise transmission to nearby occupied spaces.

The main transmission paths from these sources are duct-borne noise, airborne noise, and structure-borne noise (or vibration-induced noise). Each of these noise transmission paths is discussed in Section 5.6.4 Building Services Noise and Vibration Control.

5.8.5 MECHANICAL DESIGN CONSIDERATIONS

In addition to the design considerations mentioned in the previous sections, the following considerations apply specifically to the MER providing mechanical engineering services for EMTC up to 12 storeys.

5.8.5.1 Piping

Hot and Cold Water Piping, Including Expansion and Contraction

Expansion and contraction occur when service piping carrying domestic hot, cold, and recirculation water, and hydronic (water-based heating and cooling) systems, cycle through their normal operating conditions. This expansion and contraction should be addressed in conjunction with the Mass Timber shrinkage considerations previously discussed.

Additionally, specifically for piping in concealed spaces, the MER should consider controlling the condensation and/or employing ongoing moisture monitoring around those pipes likely to generate condensation. The support strategies discussed in Section 5.8.2.1 Shrinkage and Support apply.

Every building is different and there is no one "best" solution. Individual building characteristics such as support load distribution, amount of shrinkage, accommodations for expansion and contraction, weight of pipe, weight of water, type of structure, and the point load carrying ability of the structure all need to be considered when determining the most appropriate solution for any particular building.

Drainage Piping

Drainage piping presents fewer concerns related to expansion and contraction, compared to water-filled services, but shrinkage still needs to be considered, as it relates to the grade of the horizontal drainage piping.

The minimum grade required for the piping must be maintained after the Mass Timber shrinkage and movement occurs, so the system continues to function as designed. This can be dealt with by over-grading the drainage piping such that when the shrinkage and any differential movement between connection points has occurred, there will still be sufficient grade for adequate drainage. Refer to Section 5.7.4.1 Shrinkage Over Building Height.

In a building where shrinkage is not contained on each level, the over-grading would need to increase as the elevation of the drainage connection increases. It is therefore recommended that with EMTC tall buildings, shrinkage should be addressed on each level, as this will make it easier to manage.

5.8.5.2 Sprinklers and Standpipes

Sprinklers

The design of sprinkler systems is essentially the same as that of other Noncombustible Construction for the occupancy classifications allowed; however, there are a few major differences that apply to EMTC.

First, the requirements of individual spaces that are to be sprinklered must be determined and coordinated with the Architect and FPE. Many of the exemptions of NFPA 13, Standard for the Installation of Sprinkler Systems that are available to Noncombustible buildings are not available to EMTC buildings. In general, more sprinklers will be required in EMTC. Refer to Section 5.5.4 Concealed and Service Spaces for more information.

Second, restrictions on penetrations through structural members in EMTC are significantly greater than those for more conventional Noncombustible Construction. The routing of sprinkler systems should be coordinated with the SER, Architect, and FPE. Refer to Section 5.7.5.6 Mechanical and Electrical Penetrations for structural requirements.

Last, recessing the pipes and heads of sprinkler systems into Structural Mass Timber is generally not permissible or advisable. Sprinkler routing should be coordinated with the Architect and SER. Any concealed spaces required will need to be appropriately fire protected. Providing water-based solutions for these concealed spaces or voids should be avoided, to eliminate the risk of water leakage or accidental discharge in these spaces.

Article 3.2.5.12. of the Code requires sprinklers to be provided for balconies and decks projecting more than 610 mm, to suppress or control the spread of a fire originating from a balcony or deck to the roof assembly above, or to other parts of the building. Examples of how these sprinklers can be provided are shown in

Section 5.4.4.5 Balconies in Table 5-18: Overview of Balcony Design Considerations for EMTC.

Due to the complexity of EMTC and the high level of coordination required among all disciplines, it is recommended that Scenario 1 in Subsection 3.2.4. Fire Suppression, in Note A-2.2.7.3, Division C of the Code be used for the design of sprinkler and fire suppression systems. Scenario 2 creates opportunities for gaps in responsibility and coordination and should be avoided for EMTC. Refer to the *Guidelines for Fire Protection Engineering Services for Building Projects* (Engineers and Geoscientists BC 2013).

Standpipes

Standpipes are required in buildings over 3 storeys or over 14 m in height. As such, and although Subsection 3.2.5. of the Code does not prescribe any additional standpipe design requirements for EMTC, most EMTC up to 12 storeys will require standpipes.

In addition to the standpipe system requirements of Article 5.6.1.6. of the Fire Code, the standpipe installation requirements of Article 5.6.4.2. of the Fire Code must also be met. Requirements include conducting testing at each new level where hose valves are installed, and installation of signage, gauges, and audible warning systems to provide awareness of pressures and contents in the standpipe. Furthermore, the *BC Fire Code* requires that a progressively installed standpipe system, whether temporary or permanent, must be in operable condition at all times when it is not actively being worked on during construction. For this reason, and as per Article 5.6.3.5. of the *BC Fire Code*, adequate water supply is required during construction.

See Section 5.5.7 Construction Fire Safety Planning in EMTC and Section 5.5.8 Encapsulation for Construction Fire Safety Plan for further details on construction fire safety.

5.8.5.3 HVAC Systems

The selection and design of HVAC systems in EMTC is not inherently different from that of other construction types. Occupant safety, health, and comfort, as well as energy use, carbon dioxide (CO_2) generation, serviceability, capital cost, and operating cost all need to be considered when selecting a system, along with the structure type and the effects of HVAC on the other building systems.

Three of the most common systems for heating and/or cooling buildings are:

- in-floor hydronics, with or without ground-source heat pumps;
- forced-air systems, with or without ground-source heat pumps; and
- baseboard heaters.

For all systems discussed in this section, it is important to consider the holistic cost of the system and not simply the cost of the unit.

The ground-source heat pump is a fluid-based system—usually combined with in-floor hydronic systems—that draws heat from pipes in the earth to release inside during the heating season, and removes heat from inside and dumps it back into the earth during the cooling season. The ground-source heat pump requires a geothermal field.

In-floor hydronics can be a very effective system in EMTC, because concrete topping is often already a design feature and the creation of concealed spaces, which would need to be appropriately detailed for fire protection, is not required. Furthermore, these systems can be highly energy efficient and cost effective, compared with other systems that need encapsulated concealed spaces. Common practice is to include an acoustic membrane between the concrete topping and the Cross-Laminated Timber (CLT) floor. Electrical raceways, hydronic heating, and other services may be laid in the concrete topping. This is acceptable practice, provided topping has an equivalent thickness of 38 mm. As with any concrete topping, care should be taken to avoid cracking.

Forced-air systems are often efficient and cost effective for buildings, with many open or concealed volumes in which to locate the ductwork. However, due to the concealed space encapsulation requirements, EMTC typically will have fewer inherent concealed spaces than a comparable building of steel or concrete construction. Creating and encapsulating concealed spaces for forced-air systems can be costly and should be coordinated with the Architect. Forced-air systems also typically require large mechanical rooms for the distribution units. The variable-air-volume (VAV) heat pumps and other air-based heat pumps are often combined with a forced-air system to draw heat from the outside air and move it inside during the heating season, and to release heat from the inside air to the outside air during the cooling season.

Electric baseboard heaters are traditionally simple heating systems that are easy to install, require no massive plant, and only need electricity to run. Electric baseboard heaters do not provide cooling; a cooling system may also need to be provided for the building. Baseboard heating can also be hydronic. Subsection 6.4.3. of the Code requires hydronic radiators and convectors to have Noncombustible backing for mounting on a Structural Mass Timber wall panel.

The relative ease with which the systems can be coordinated, prefabricated, and installed should also be considered in the selection. Forced-air systems require plenum spaces, which must be encapsulated in EMTC, or must be run in exposed ducting. Hydronic systems are well suited to being placed in the concrete topping that is often used in EMTC for fire and acoustic separations. Hydronic systems are also well suited to the prefabrication process.

In general, the sensitivity of EMTC to MC, both during construction and in service, needs to be considered during system selection. Distribution systems that are not hydronic may be somewhat favoured over hydronic distribution systems. For example, systems that are based on refrigerant rather than water throughout the occupied spaces would eliminate the risk of water damage from the HVAC system. Such systems include incremental split direct expansion (DX) systems, variable refrigerant flow (VRF) systems, or electric resistance heat, if no space cooling is required. VRF systems could be a good selection for EMTC buildings, because they do not contain water, have relatively good energy efficiency, and are able to provide heat recovery. Where air conditioning is required, it is important to consider installing drip pans to minimize the risk of mold and to monitor changes in MC of the supporting Structural Mass Timber.

Humidity control to deal with long durations of cold temperatures that lower indoor relative humidity (RH) levels below 30% to 40%, or as specified by the Architect and BEC, should be dealt with by providing humidification. This may be relatively simple with Group D (office/mercantile) occupancies, but could be significantly more difficult with Group C (residential) occupancies, depending on the HVAC system selected for the building. The requirements should be addressed early in the project, to allow time for an appropriate system to be selected and designed.

Interior RH is generally controlled, with higher than desirable RH prevented by air conditioning the spaces. However, in the heating season or in buildings without air conditioning, managing RH in a building can be more challenging. While the cooling season in British Columbia (BC) is relatively short in most jurisdictions, the higher levels of insulation that are increasingly common has caused many buildings to overheat; mitigation by air conditioning is one way to deal with this issue. When air conditioning is required, and during the winter, particularly in regions of the province that have colder design temperatures and longer heating seasons, low RH for extended periods of time can occur, which could result in moisture loss from the Structural Mass Timber, causing shrinkage, cracking, or checking. To mitigate against moisture loss and shrinkage in the Structural Mass Timber, humidification can be provided, to maintain a minimum of 30% to 40% RH during the heating season.

Corridor pressurization in residential buildings is another aspect of the mechanical system design that the MER needs to consider. In construction types other than EMTC, air-handling systems are typically located in concealed spaces. Due to the fire protection requirements for concealed spaces in EMTC, encapsulating concealed spaces for services can be costly; the MER and Architect should coordinate system routing early in the design and explore other options, such as exposed services, where appropriate. T-bar ceilings are often used in commercial buildings and could be considered for encapsulated Mass Timber residential buildings, to facilitate easy access to the systems.

Kitchen and bathroom exhaust systems in residential occupancies in EMTC can be more challenging than those in other construction types. Kitchen and bathroom exhaust systems in concrete and steel buildings are often done on a per-suite basis, through the slab or through concealed spaces, respectively. Neither of these routing options are available in EMTC. Instead, the distribution system could be accommodated using dropped ceiling or bulkheads at interior room walls. The routing and fire protection requirements need to be coordinated with the Architect and FPE.

Finally, for routing of all MEP systems, penetration of Structural Mass Timber beams and columns should be avoided and, if required, penetration of Structural Mass Timber panels should be coordinated with the Architect and the SER.

5.8.5.4 Ventilation Control for Commercial Cooking Operations

The requirements for commercial cooking exhaust systems need to be addressed in the same way as for other building types, in that the exhaust duct must be enclosed in a Fire-Resistance Rating (FRR) that matches the FRR of any fire separations it penetrates. In addition, the FRR on the duct must be maintained continuously to the outdoors, as required in NFPA 96, Standard for Ventilation Control and Fire Protection of Commercial Cooking Operations.

Considerations such as duct clearances to Combustible, limited Combustible (defined in NFPA 96), and Noncombustible Construction need to be maintained. Generally, solutions that work in conventional light wood frame construction will be sufficient for EMTC.

Where NFPA 96 exhaust systems are permitted by the Authority Having Jurisdiction (AHJ) to exhaust from an outside wall, and not above a roof, care should be taken to protect Mass Timber Combustible enclosure finishes where they occur. This situation may occur on a High Building with restaurants permitted on the lower levels, and office and/or residential spaces on the levels above, where it is not practical to run multiple potential exhaust shafts up to the roof and waste valuable floor space.

5.8.5.5 Concealed and Service Spaces

Concealed spaces in EMTC must be either fully encapsulated or otherwise fire protected by sprinklers or insulation, as per Subsection 3.1.18. of the Code. See Section 5.4.4 Building Enclosure Assemblies and Materials for additional information.

The MER should consider that accessing sprinklers in concealed spaces is likely to be very difficult, if not impossible, once the building is in service. As such, the design of concealed spaces to be sprinklered should be done with great caution, as any failure or accidental discharge could introduce water into the concealed space and cause significant damage to both the structure and the finishes. Additionally, sprinkler heads in concealed spaces cannot be inspected. In order to mitigate the risks, the MER should consider including ongoing moisture monitoring or water detection technology, if concealed spaces are to be sprinklered.

Service rooms, vertical service spaces, and horizontal service spaces, including plenums and attics or roof spaces, need to be dealt with in the same manner as Noncombustible Construction with respect to sprinklers. See Section 5.8.5.2 Sprinklers and Standpipes.

5.8.5.6 Smoke Control

EMTC is required to be fully sprinklered, as per the Code, Article 3.2.2.48EMTC. Group C, up to 12 storeys, Sprinklered, and Article 3.2.2.57EMTC. Group D, up to 12 storeys, Sprinklered. Most EMTC buildings of 7 to 12 storeys are considered High Buildings, as defined in the Code under Subsection 3.2.6. Additional Requirements for High Buildings; as such, they also require smoke control.

Pressurization of stairs above grade will only be required when pressurization is necessitated by special application or alternative solution under the Code. Stairs serving below-grade spaces will require pressurization. The methodology of pressurization is the same as for conventional stair construction meeting the prescriptive requirements of Subsection 3.2.6. of the Code.

Structural Mass Timber panels are inherently less airtight than concrete or steel and gypsum board fire-rated walls, because of the joints required to connect the panels. Careful detailing should be done when Structural Mass Timber panels are used for stair shaft, elevator shaft, or vestibule construction that will require pressurization, for which both natural and active smoke control is required. This work should be coordinated with the Architect and SER, and airtightness testing for these elements of the building should be considered.

The airtightness for stairs below grade will need to be sufficient to allow the fan-forced pressurization of the stair shafts, as is required in the Code, Article 3.2.6.2. and discussed in Note A-3.2.6.2.(2).

Given the current height restrictions for CLT shearwalls in EMTC, and that stair and elevator shafts are almost always part of the lateral system, it is unlikely there will be Structural Mass Timber elevator shafts or stair shafts above grade in high-seismic areas. However, in low-seismic areas and for EMTC less than 30 m tall, the use of Structural Mass Timber cores is more probable. In this case, the airtightness of individual stair shafts needs to be carefully considered. Critical airtightness details and leakage paths include around doors, through cracks at joints in panels, and between the stair risers and treads and the wall of the shaft.

Scissor stairs will be the most critical situation to address, as leakage between the stairs and shaft wall will allow contamination of the other stair in the scissor. In that case, the Structural Mass Timber panel wall assembly must be designed such that during a period of 2 hours after the start of a fire, each exit stair serving storeys above the lowest exit level will not contain more than 1% by volume of contaminated air from the fire floor, assuming an outdoor temperature equal to the January design temperature on a 2.5% basis. This will require detailed leakage testing and calculation and should be avoided if possible. The airtightness for stairs above grade will need to be sufficient to allow the natural pressurization of the stair shafts, as is required in Article 3.2.6.2. and discussed in Note A-3.2.6.2.(3) of the Code, or as required by an alternative solution under the Code, for fan-forced stair pressurization.

5.8.6 ELECTRICAL DESIGN CONSIDERATIONS

In addition to the design considerations mentioned in the previous sections, the following considerations apply specifically to the EER providing electrical engineering services for EMTC up to 12 storeys. EMTC provisions are not yet addressed specifically in the Canadian Electrical Code and electrical-related sections of the Code. As per the Information Bulletin: Encapsulated mass timber construction and the electrical code (Technical Safety BC, 2021), “EMTC buildings, designed and constructed according to the provisions of BCBC Articles 3.2.2.48EMTC. and 3.2.2.57EMTC., are interpreted to be non-combustible construction for the application of the BC Electrical Code.”

Electrical systems in EMTC must therefore be designed and constructed to meet the requirements of the current Code and the provisions of the *Canadian Electrical Code* for Noncombustible buildings (Rule 12-504, Appendix B). All clauses related to the electrical services, in particular, those in Division B, Part 3 of the Code, must be met in EMTC. EMTC provisions are expected in the next revision of the *Canadian Electrical Code*.

This section emphasizes aspects of electrical systems important to life safety, and discusses special considerations for EMTC compared to concrete or steel buildings, specifically as they relate to High Building provisions. However, the following should not be considered an exhaustive list of all applicable Code requirements.

5.8.6.1 Electrical Life Safety Systems

EMTC up to 12 storeys is considered a form of Noncombustible Construction. The flame ratings of electrical wires and cables, and communication cables, must satisfy the requirements of Article 3.1.5.21. of the Code for buildings of Noncombustible Construction. For the majority of EMTC of 7 to 12 storeys, the fire alarm system must also satisfy the requirements of Subsection 3.2.6. Additional Requirements for High Buildings.

Smoke control and monitoring in public corridors, in stairwells, and at air-handling units is highly important for the life safety of the occupants of the building. Pressurization and smoke control may be complicated, if shafts are EMTC instead of solid concrete or masonry construction. Details for the integrity of the shafts and field reviews of the shafts may be more involved.

For EMTC up to 12 storeys, emergency power for lighting, fire alarm systems, and building services (e.g., water, fans) should be available, as per relevant clauses of the Code in Subsection 3.2.7. Lighting and Emergency Power Systems. As is required for any High Building, all life-safety systems must be provided with an emergency power supply that has the capacity to run for a minimum 2-hour period.

It must also be emphasized that electrical conductors serving life-safety systems must be able to keep circuit integrity for no less than 1 hour, or must be located in a service space that is separated from the rest of the building by a fire separation with an FRR of no less than 1 hour. Certain areas require 2-hour protection rating for electrical conductors serving mechanical systems, such as areas of refuge and contained areas, per Clause 3.2.7.10.(1)(c) of the Code; as these occur only in group B occupancies, any such areas would be subsidiary to the major occupancies permitted in EMTC.

5.8.6.2 Lighting and Power Systems

The lighting system in EMTC must satisfy all applicable provisions of Subsection 3.2.7., Article 9.34.2.7., and Part 10 of the Code, and, in particular, the requirements related to minimum lighting requirements and emergency lighting. Importantly, minimum illumination levels for exits, public corridors, and access to exits must be provided for the public. The lighting outlet boxes and lighting control systems must also satisfy provisions of CSA-C22.1-18, Canadian Electrical Code, Part I, Safety Standard for Electrical Installations, Section 30, for installation of lighting equipment in Noncombustible Construction.

All power systems in EMTC buildings, except power substations, operate at less than 750 V and are classified as low-voltage (LV) systems. All provisions of the Canadian Electrical Code (CEC), Part I related to LV systems apply to Noncombustible Construction. Special attention must be given to the installation of power outlet boxes and wiring in the Structural Mass Timber, with safety measures undertaken as indicated in Section 5.8.6 Electrical Design Considerations. The way in which power outlet boxes, switches, lighting, and wiring will be installed within the Structural Mass Timber system must be coordinated with the Architect and SER from the earliest stage of design.

5.8.6.3 Data Communications

Methods of installation of data rooms and closets used for Noncombustible concrete High Buildings also apply to EMTC buildings. Separate raceways and shafts for data communication cabling must be provided through openings in the Structural Mass Timber, as indicated in Section 5.8.6 Electrical Design Considerations and Section 5.8.7 Construction Considerations.

Installation of data outlet boxes in Structural Mass Timber members should follow identical methods as the installation of power outlet boxes. If communication wiring will be run under the raised floors in data rooms, data processing systems must be separated from power circuiting and satisfy provisions of the CEC, Part 1, Section 16 for electrical, and of ANSI/BICSI N1-2019, Installation Practices for Telecommunications and ICT Cabling and Related Cabling Infrastructure for telecommunications. Additionally, raised floors create concealed spaces that must be appropriately fire protected.

5.8.6.4 Elevators

Elevator service can be established as vertical transportation in EMTC. In a wood-hybrid type of EMTC, the shaft may be constructed out of concrete, steel, Structural Mass Timber, or a combination of the three. In any case, the elevator has to satisfy Section 3.5. Vertical Transportation of the Code. Refer also to the *Professional Practice Guidelines – Professional Responsibilities for the Design and Installation of Elevating Devices in New Buildings* (Engineers and Geoscientists BC 2020b).

For High Buildings, the firefighting elevator must be provided with an emergency power supply. Due to potential vertical movement in the elevator shaft caused by dimensional changes in Structural Mass Timber, rail sensor sensitivity should be adjusted to improve reliability when in service. Communication and security services must be run separately from the electrical and other services, such as in the sealed raceways, and must adhere to the CEC and Code requirements.

5.8.6.5 Power Substations

Power substations and power emergency sources are recommended to be located at the ground level in service rooms constructed of concrete or masonry. For EMTC, it is recommended to locate any power substation outside or in a concrete portion of an EMTC building.

Although all EMTC buildings up to 12 storeys are sprinklered, this space can be either sprinklered or non-sprinklered, per NFPA 13, Standard for the Installation of Sprinkler Systems.

Power substations, including emergency generators, can be installed on floors other than the ground floor, or may be stacked over two levels. In cases where power substations are located in an area other than on the ground floor, close coordination between the Architect, SER, and FPE is required, as the substation has a high fire risk.

If arc flash ducts will be installed and extended to penetrate any Mass Timber, they must be insulated with mineral wool at the place of penetration. Extremely high temperatures develop during arcing in the electrical switchgear; the hot gas that develops will flow through the arc duct outside and must be protected, so it does not heat the Structural Mass Timber. The thickness of the mineral wool should be 25 mm plus-or-minus 12.7 mm. Additionally, firestopping is required to close the gap around the metal duct and the penetrated wall, and to protect the metal duct from causing the Mass Timber to char during a fire.

5.8.6.6 Lightning Protection Systems

Special attention should be given to lightning protection systems, as only solutions that are both functional and aesthetic should be considered, and these should be coordinated with the Architect.

In the case of a hybrid type of EMTC, it is recommended that concrete shafts of elevators and stairwells be used for installation of down conductors. For both wood and wood-hybrid types of EMTC, per Article 3.6.1.3. of the Code, the provisions of CAN/CSA-B72-M87 (R2013) Installation Code for Lightning Protection Systems apply.

If the building is required to be equipped with a lightning protection system, the traditional network of air terminals and down conductors will be typically provided and grounded. Installation of lightning protection conductors is the same for encapsulated Mass Timber High Buildings as for any Noncombustible High Buildings.

5.8.6.7 Electrical Service Rooms

Service rooms designed for EMTC should conform to Subsection 3.6.2. of the Code, which requires specific, rated fire separations.

It is recommended that the main power substation, entry telecommunication room, and emergency power supply are located at the ground or basement level of the EMTC building. If the building is a wood-hybrid type with a parkade, ground floor, elevator core, and stairwell shafts of concrete structure, the main power and communication utility service should be located within the concrete. This is to allow for easier servicing and maintenance, and reduce the effects of vibration and acoustic transmission throughout the building.

Sub-electrical and telecommunication rooms and closets should be spread throughout the building and can be of EMTC or another Noncombustible assembly that meets the

FRR of the room. The Fire-Protection Rating (FPR) of those rooms should be in accordance with the Code. Early design planning will allow for cutouts of the prefabricated structure to be done in the factory, thus allowing for easy and efficient installation of equipment at the construction site. All cutouts and penetrations should be coordinated with the Architect and SER prior to fabrication and construction.

In EMTC, consideration should also be given to potential airborne and structure-borne noise transfer to nearby occupied spaces, due to a lack of mass and sound control around the service room. This will require acoustic protection for the room, with measures to limit noise transfer, as detailed in Section 5.6.4.2 Airborne Noise. The most common solution for the floor is to provide a layer of concrete and appropriate vibration isolation, as further discussed in Section 5.6.4.3 Structure-Borne Noise. Acoustic treatments should be coordinated with the Architect and acoustical engineer.

5.8.7 CONSTRUCTION CONSIDERATIONS

EMTC up to 12 storeys are often categorized as tall buildings and have a number of different construction considerations for mechanical and electrical systems compared to tall buildings constructed of other materials.

A primary difference is the solid nature of the Structural Mass Timber itself. In many cases Structural Mass Timber comprises glulam columns and beams, combined with CLT floors and shearwalls. Refer to Section 5.3.2.3 Material Considerations, under the subsection Mass Timber Products for more information. Mass Timber is hygroscopic and requires continuous protection from moisture during the construction, to avoid significant damage. Additionally, EMTC requires fire protection during construction. In this type of construction, the MER and EER must collaborate, and may require considerable input from the applicable construction trades and the Mass Timber manufacturer.

Consideration should be made to creating a 3D virtual model, with input from the Architect and Engineering Professionals to reveal conflicts early in the design stage, so they can be addressed prior to construction. This approach could also aid in the planning of construction sequencing and planning of installation crews by the constructor.

5.8.7.1 Prefabrication

A prefabricated approach is almost always used for EMTC. Efficient construction is important for EMTC, in order to protect the structure from moisture during the construction process. As such, the pace of structural erection is often quicker than that of an equivalent concrete or steel tall building.

The mechanical and electrical rough-in must keep up with the progress of construction. This may require simultaneous work and a higher level of coordination among the MEP subtrades. The MER and EER, as well as the mechanical and electrical subtrades, should anticipate component prefabrication to meet the need for accelerated rough-in and testing.

Coordination between the Architect and the MER and EER, to determine the size and location of all the openings, must be completed in the design phase, prior to the manufacturing of the Structural Mass Timber components. In prefabricated construction, once fabrication and construction starts, creating additional openings or making changes to locations or sizes of openings in the structure will be much more restricted than in other types of structures. Refer to Section 5.7.5.6 Mechanical and Electrical Penetrations for additional structural requirements.

The MER and EER may be required to conduct factory field reviews of the mechanical and electrical services routing, to confirm that the extensive coordination carried out early in the design phase is incorporated in the actual construction. Factory field reviews do not eliminate the need for on-site field reviews. See Section 7 Quality Assurance for more information.

5.8.7.2 Encapsulation

Temporary encapsulation may be necessary to meet the requirements for encapsulation during construction, which means the installation of mechanical and electrical services may need to be done beforehand.

The temporary encapsulation is often sacrificial and intended to be removed and replaced once the structure is enclosed, but it is generally expected that the mechanical and electrical services would already have been installed and tested.

This will require careful design that considers construction sequencing and coordination between the trades. Refer to Section 5.5.8 Encapsulation for Construction Fire Safety Plan.

5.8.7.3 Moisture Considerations

The MER and the EER must be aware of the potential impact of EMTC on the installation of services, and also on the maintenance requirements during the life of the building. The most common effect that may impact mechanical and electrical systems is MC changes causing dimensional changes in the Mass Timber (expansion and contraction) and vertical movement in tall buildings. The amount of movement to be accounted for needs to be confirmed by the Architect and SER prior to designing systems to accommodate the expected movement.

Ducts, pipes, and raceways, such as cable trays, conduits, cable bus, and bus ducts, have to integrate flexible portions in the long runs, similar to allowances for movement joints, to accommodate the building shrinkage. It is important that the decisions made during design to provide movement joints in ducts and pipes, include slack in the cable runs, and incorporate flex runways to accommodate potential movement of the building structure are correctly and accurately executed during construction.

5.8.7.4 Penetrations

The MER and EER have to consider that all openings, including small openings (less than 50 mm), will be made during the prefabrication process at the factory using a computer numerically controlled (CNC) machine. The precision of these machines and the tight tolerances achievable ensure that the installation of services at the finishing stages is exactly as designed and coordinated with other disciplines.

Structural Mass Timber opening sizes are dependent on factors such as location, member and material type, fire protection separation, and insulation requirements. The running of ducts, pipes, conduit, or cables through Structural Mass Timber beams and columns is generally not possible. The SER may permit some devices to be recessed into the face of Structural Mass Timber elements, but that cannot be assumed as a strategy without the prior agreement of the architect and the SER.

The MER and EER, along with the mechanical and electrical constructors, if available during the design process, should consider consolidating vertical runs in electrical shafts and limiting horizontal runs, to minimize penetrations through the Structural Mass Timber and building enclosure. Increasing the number and size of openings may affect the structural integrity of the building, and therefore early planning is important. Close cooperation during design with the other Registered Professionals of Record (RPR), in particular the Architect, SER, FPE, and BEC, is paramount. In essence, the entire consulting team, including the MER and EER, must determine the location and method of fire protection for each item that they design and specify.

5.8.7.5 Firestopping

Large or unusual firestopping conditions, where no listed solutions are available, may need to be designed by an FPE. The MER and EER should be familiar with the firestopping requirements outlined in Section 5.5.3.5 Firestopping. Firestopping requirements and penetrations should be reviewed and coordinated with the Architect, SER, and FPE.

5.8.7.6 Heating During Construction

For EMTC buildings in areas subject to cold temperatures, it may be necessary to heat the building during construction. See Section 5.5.8 Encapsulation for Construction Fire Safety Plan for more information on building heating options.

Considerations when selecting the appropriate system for heating during construction include:

- site accessibility (for natural gas);
- cost of source;
- feasibility and safety effects of running cables throughout the building; and
- cost of using or renting a generator.

6. Professional Registration & Education, Training, and Experience

6.1 PROFESSIONAL REGISTRATION

The design of components and systems of Encapsulated Mass Timber Construction (EMTC) projects that fall within the practice of architecture or professional engineering must be done by appropriately registered and experienced Architects or Engineering Professionals.

Architects and Engineering Professionals have met minimum education, experience, and character requirements for admission to their professions. However, the educational and experience requirements for professional registration do not necessarily constitute an appropriate combination of education and experience for professional services related to EMTC. Professional registration alone does not automatically qualify an Architect or Engineering Professional to take professional responsibility for all types and levels of professional services in this area of practice.

It is the responsibility of Architects and Engineering Professionals to determine whether they are qualified by education, training, and experience to undertake and accept responsibility for carrying out architectural design, and/or structural, mechanical, electrical, fire protection, building enclosure, and/or acoustical engineering services for EMTC buildings. Similarly, it is the responsibility of Architects and Engineering Professionals to understand that they are ultimately responsible for their design decisions, and that they must only rely on the advice, opinions, or designs of others who are also appropriately registered Architects and Engineering Professionals.

Many components of an EMTC building can be premanufactured. The Registered Professional of Record may delegate the design of premanufactured components by engaging Supporting Registered Professionals or by specifying manufacturer-tested and -listed components or assemblies. The Registered Professional of Record must ascertain that all premanufactured components specified have the assurance of an Architect or Engineering Professional, otherwise the Registered Professional of Record must be prepared to directly supervise and take professional responsibility for the design of the component or assembly themselves.

For an example of premanufactured components and professional responsibility, refer to the *Practice Advisory – Engineering Modifications to Fire-Tested and Listed Assemblies* (Engineers and Geoscientists BC 2020a).

For more information on engaging Supporting Registered Professionals, see the *Joint Professional Practice Guidelines – Professional Design and Field Review By Supporting Registered Professionals* (AIBC and Engineers and Geoscientists BC 2020).

6.2 EDUCATION, TRAINING, AND EXPERIENCE

Those who provide the architectural and professional engineering services, as described in these guidelines, must have appropriate levels of education, training, and experience. Architects and Engineering Professionals may undertake and accept responsibility for professional assignments only when they are qualified by training or experience, as required under their respective regulator's codes of ethics, for either the Architectural Association of British Columbia (AIBC) or Engineers and Geoscientists BC.

Appropriate qualifications for Architects and Engineering Professionals must include core competencies that are considered basic and fundamental to providing services in their respective disciplines. These core competencies include theoretical and academic knowledge, as well as practical experience.

The level of education, training, and experience required of Architects and Engineering Professionals should be adequate for the complexity of the project. EMTC buildings are unique in the level of coordination required between multiple disciplines. Consequently, the skill levels and experience required for Architects and Engineering Professionals to take on these types of projects may be higher than that required for other types of material and construction projects.

6.2.1 EDUCATION

Architects and Engineering Professionals must have appropriate education related to the design of EMTC.

They may demonstrate their education in EMTC through:

- taking college or university courses;
- participating in programs provided by professional organizations such as the AIBC and Engineers and Geoscientists BC;
- attending programs provided by industry groups such as Wood *Works!* BC (a program of the Canadian Wood Council), ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers), IBPSA (International Building Performance Simulation Association), CHBA-BC (Canadian Home Builders' Association of BC), BCBEC (BC Building Envelope Council), and SEABC (Structural Engineers Association of BC);
- attending training courses facilitated by the Architect or Engineering Professional's employer; or
- completing a rigorous and documented self-study program involving a structured approach that contains materials from textbooks and technical papers.

6.2.2 CONTINUING EDUCATION

Architects and Engineering Professionals must remain current with evolving topics through continuing professional development.

Continuing education options for remaining current and expanding capabilities include:

- taking specific training in the use of software tools;
- attending courses, workshops, seminars, webinars, technical talks, and conferences;
- reading texts and periodicals; and
- demonstrable self-study.

6.2.3 EDUCATION (THEORETICAL AND TECHNICAL KNOWLEDGE)

Architects and Engineering Professionals must have appropriate theoretical and technical knowledge related to the design of EMTC up to 12 storeys, which can be gained through education and continuing education.

As it relates to the various disciplines, some examples of required knowledge include understanding of:

- specific Code requirements for EMTC;
- specific Fire Code requirements for EMTC;
- topics unique to EMTC fire-resistance characteristics, including char; and

- topics unique to EMTC characteristics of prefabricated Structural Mass Timber, including design, manufacturing, and transportation constraints.

6.2.4 BUILDING INDUSTRY CODES AND STANDARDS

Architects and Engineering Professionals involved in EMTC buildings must have an understanding of the Code and its referenced standards applicable to the project.

EMTC is applicable to Part 3 buildings. EMTC buildings are to be differentiated from buildings of Combustible Construction, which incorporate a few or many Mass Timber elements. EMTC also is also to be differentiated from Heavy Timber Construction, which may occur in Part 9 or Part 3 buildings.

Standards and guidelines are being developed and revised by subject matter experts as this industry progresses, experience increases, and new materials and technologies are established. Architects and Engineering Professionals are responsible for keeping up to date with the current Code-referenced standards and incoming provisions, and to be aware of other documents published by industry sources, such as the Canadian Wood Council (CWC), that affect the standard of practice.

6.2.5 EXPERIENCE

Architects and Engineering Professionals must have knowledge and experience relevant to the complexity of the project in the application of architectural design, building enclosure, fire protection, acoustical, structural, mechanical, and electrical engineering principles, as they relate to the assessment of performance of an EMTC building.

This competency includes being able to apply informed and professional judgment where risk assessment is required, including by:

- identifying risks and the benefits of alternatives;
- assessing the consequences of the selection of alternatives, decisions, and actions;
- assessing the relative costs of various acceptable alternatives; and
- considering the application and implication of local construction practices.

EMTC is a construction type new to Canadian codes. As with any new type of construction, project, or material, Architects and Engineering Professionals are required under their respective regulator’s codes of ethics (AIBC and Engineers and Geoscientists BC) to do their due diligence and research to gain the skills required to take on the professional responsibility, prior to doing so.

Architects and Engineering Professionals may consider allowing a contingency in their fees and/or schedule in order to familiarize themselves with any new processes. They may also consider collaborating with others with more experience.

7. Quality Assurance

7.1 PROFESSIONAL PRACTICE GUIDELINES

Engineering Professionals are required to have regard for any applicable professional practice guidelines related to the engineering or geoscience work they undertake. As such, Engineering Professionals must implement and follow documented procedures to ensure they stay informed of, knowledgeable about, and meet the intent of professional practice guidelines that are relevant to their professional activities or services. These procedures should include periodic checks of the Engineers and Geoscientists BC website to ensure that the latest versions of available guidance are being used.

The Architectural Association of BC (AIBC) Code of Ethics and Professional Conduct is a compilation of three components. First, the Bylaws – *Architects Act* that establish, with statutory authority the underlying principles, values, standards, and rules of behaviour for AIBC members, firms, associates, and licensees. Second, the Bylaws – *Architects Act* are supplemented by council rulings. Third, the advisory commentary is included throughout the Code in an effort to provide practical, updated information. In the interest of the public, the AIBC regulates the profession of architecture through a responsive regulatory framework. Joint professional practice guidelines are one means by which the AIBC and Engineers and Geoscientists BC fulfill these obligations.

For Engineering Professionals, these guidelines are intended to describe the standard of professional practice, conduct, and competence when Engineering Professionals are engaged on an EMTC building. For Architects, these guidelines inform and support relevant competency standards of practice to be met when Architects are engaged on an EMTC building.

For more information, refer to *Quality Management Standards – Use of Professional Practice Guidelines* (Engineers and Geoscientists BC 2021a), which also contains guidance for how an Engineering Professional can appropriately depart from the guidance provided in professional practice guidelines.

7.2 QUALITY MANAGEMENT

7.2.1 AUTHENTICATING DOCUMENTS (USE OF SEAL)

Engineering Professionals are required to seal all engineering documents, including electronic files that they prepare or deliver in their professional capacity to others who will rely on the information contained in them. This applies to engineering documents that Engineering Professionals have personally prepared and those that others have prepared under their direct supervision.

Failure to appropriately seal engineering documents is a breach of the Bylaws – *Professional Governance Act*.

In accordance with sections 77 and 78 of the *Architects Act*, Architects must apply a seal with signature and date to letters of assurance, certificates, drawings, and specifications prepared by or under the Architect’s supervision, direction, or control.

For more information, refer to *Quality Management Standards – Authentication of Documents* (Engineers and Geoscientists BC 2021b) and Bulletin 61: Seal of an Architect (AIBC 2013).

7.2.2 DIRECT SUPERVISION

Architects and Engineering Professionals are required to directly supervise any architectural or engineering work they delegate. When working under the direct supervision of an Architect or Engineering Professional, an individual may assist in performing architectural or engineering work, but they may not assume responsibility for it. Architects and Engineering Professionals must demonstrate active involvement and ongoing interaction with individuals under their direct supervision throughout the project. Engineering Professionals who are professional licensees engineering may only directly supervise work within the scope of their licence.

When determining which aspects of the work may be appropriately delegated using the principle of direct supervision, the Architect or Engineering Professional having ultimate responsibility for that work should consider:

- the complexity of the project and the nature of the risks associated with the work;
- which aspects of the work should be delegated;
- the training and experience of individuals to whom the work is delegated; and
- the amount of instruction, supervision, and review required.

Careful consideration must be given to delegating field reviews. Due to the complex nature of field reviews, Architects and Engineering Professionals with overall responsibility should exercise judgment when relying on delegated field observations and should conduct a sufficient level of review to have confidence in the quality and accuracy of the field observations.

When delegating field review activities, Engineering Professionals must document the field review instructions given to a subordinate. (See Section 7.2.5 Documented Field Reviews During Implementation or Construction.)

Note that the definition of field review in the Code requires actual attendance on site.

For more information, refer to *Quality Management Standards – Direct Supervision* (Engineers and Geoscientists BC 2021c).

7.2.3 RETENTION OF PROJECT DOCUMENTATION

Retaining complete and easily retrievable project documentation such as reports, models, calculations, drawings, and correspondence is critical to professional practice. It facilitates quality assurance, and allows for expedient review by other qualified professionals, if necessary. When completing an EMTC building, comprehensive reporting and supporting documentation enables Architects and Engineering Professionals to demonstrate that they have satisfied the applicable Code and Authority Having Jurisdiction requirements. It may also allow for resolving contentious issues, meeting legal and regulatory requirements, documenting decisions, and defending claims. Further, comprehensive reporting may facilitate the ability to effectively undertake future work or make intellectual property readily retrievable for future solutions.

The project documentation should thoroughly describe the project, allowing another Architect or Engineering Professional to fully understand the scope and design process, as well as all assumptions and decisions made to arrive at the final design.

Such documentation and records must be archived and retained in accordance with the Engineers and Geoscientists BC's quality management standards.

For more information, refer to *Quality Management Standards – Retention of Project Documentation* (Engineers and Geoscientists BC 2021d).

7.2.4 DOCUMENTED CHECKS OF WORK

Engineering Professionals are required to perform a documented quality checking process of engineering work, appropriate to the risk associated with that work. All Engineering Professionals must meet this quality management requirement.

The checking process should be comprehensive and address all stages of the execution of the engineering work. This process would normally involve an internal check by another Engineering Professional within the same organization. Where an appropriate internal checker is not available, an external checker (i.e., one outside the organization) must be engaged. In some instances, self-checking may be appropriate. Where internal, external, or self-checking has been carried out, the details of the check must be documented. The documented quality checking process must include checks of all professional deliverables before being finalized and delivered.

Engineering Professionals are responsible for ensuring that the checks being performed are appropriate to the level of risk associated with the item being checked. Considerations for the level of checking should include:

- the type of item being checked;
- the complexity of the subject matter and underlying conditions related to the item;
- the quality and reliability of associated background information, field data, and elements at risk; and
- the Engineering Professional's training and experience.

As determined by the Engineering Professional, the individual doing the checking must have current expertise in the discipline of the type of work being checked, be sufficiently experienced and have the required knowledge to identify the elements to be checked, be objective and diligent in recording observations, and understand the checking process and input requirements.

For more information, refer to Quality Management Standards – Documented Checks of Engineering and Geoscience Work (Engineers and Geoscientists BC 2021e).

In accordance with the *Architects Act* and the AIBC Code of Ethics and Professional Conduct Bylaw 30.3, an Architect shall undertake to perform professional services only when qualified, together with those whom the Architect may engage as consultants, by education, training and experience in the specific areas involved. In accordance with the *Architects Act* and the Code of Ethics and Professional Conduct Bylaw 33.4 in practicing architecture, an Architect shall take into account all applicable federal, provincial, and municipal building laws and regulations, and an Architect may rely on the advice of other professionals and other qualified persons as the intent and meaning of such regulations.

7.2.5 DOCUMENTED FIELD REVIEWS DURING IMPLEMENTATION OR CONSTRUCTION

Field reviews are reviews conducted at the site of the construction or implementation of the architectural design or engineering work. They are carried out by an Architect or Engineering Professional, or a subordinate acting under the Architect or Engineering Professional's direct supervision. (See Section 7.2.2 Direct Supervision.)

Field reviews enable the Architect or Engineering Professional to ascertain whether the construction or implementation of the work substantially complies in all material respects with the concepts or intent reflected in the documents prepared for the work. (See Section 7.4 Prefabricated and Factory-Built Components regarding field reviews of Factory Built Components.)

A Registered Professional of Record who signs and seals a Letter of Assurance is accepting responsibility for the obligations committed to in that Letter of Assurance. For example, in signing and sealing a Schedule C-B, Assurance of Professional Field Review and Compliance, Registered Professionals of Record are giving assurance that, based on field reviews conducted either by themselves or a Supporting Registered Professional, that the relevant aspects of the project for which they are responsible substantially comply, in all material respects, with the applicable requirements of the Code and the plans and supporting documents submitted in support of the application for the building permit (design documents).

For more information, refer to *Quality Management Standards – Documented Field Reviews During Implementation or Construction* (Engineers and Geoscientists BC 2021f). For further information on field reviews by Supporting Registered Professionals, refer to *Joint Professional Practice Guidelines – Professional Design and Field Review by Supporting Registered Professionals* (AIBC and Engineers and Geoscientists BC 2020).

7.2.6 DOCUMENTED INDEPENDENT REVIEW OF STRUCTURAL DESIGNS

Engineering Professionals developing structural designs are required to engage an independent review of their structural designs. An independent review is a documented evaluation of the structural design concept, details, and documentation based on a qualitative examination of the substantially complete structural design documents, which occurs before those documents are issued for construction or implementation. It is carried out by an experienced Engineering Professional qualified to practice structural engineering, who has not been involved in preparing the design.

The Engineering Professional providing services as the Registered Professional of Record must conduct a risk-assessment after conceptual design and before detailed design to (1) determine the appropriate frequency of the independent review(s); and (2) determine if it is appropriate for the independent reviewer to be employed by the same firm as the Registered Professional of Record, or if the independent reviewer should be employed by a different firm.

The risk-assessment may determine that staged reviews are appropriate; however, the final independent review must be completed after checking has been completed and before the documents are issued for construction or implementation. Construction must not proceed on any portion of the structure until an independent review of that portion has been completed.

For more information, refer to *Quality Management Standards – Documented Independent Review of Structural Designs* (Engineers and Geoscientists BC 2021g).

7.2.7 DOCUMENTED INDEPENDENT REVIEW OF HIGH-RISK PROFESSIONAL ACTIVITIES OR WORK

Engineering Professionals must perform a documented risk assessment prior to initiation of a professional activity or work, to determine if that activity or work is high risk and requires a documented independent review.

If the activities or work are deemed high risk, and an independent review is required, the results of the risk assessment must be used to (1) determine the appropriate frequency of the independent review(s); and (2) determine if it is appropriate for the independent reviewer to be employed by the same firm as the Registered Professional of Record, or if the independent reviewer should be employed by a different firm.

The documented independent review of high-risk professional activities or work must be carried out by an Engineering Professional with appropriate experience in the type and scale of the activity or work being reviewed, who has not been involved in preparing the design.

The documented independent review must occur prior to implementation or construction; that is, before the professional activity or work is submitted to those who will be relying on it.

7.3 PEER REVIEW

Architects and Engineering Professionals may provide a third-party Peer Review of an EMTC building in accordance with their respective regulator's codes of ethics (AIBC and Engineers and Geoscientists BC). Architects and Engineering Professionals should inform (or make every effort to inform) the Registered Professionals of Record when Peer Review is applicable, prior to reviewing their work.

In the event that a Peer Review is required, the review will involve checking several components; for example, the calculations and assumptions to confirm that the design has been done according to accepted best practices, and the results to determine that intended outcomes, such as meeting performance targets, have been achieved.

7.4 PREFABRICATED AND FACTORY-BUILT COMPONENTS

Architects and Engineering Professionals must understand that the prefabricated and factory-built components intended for an EMTC building project must be thoroughly coordinated in the design stage. Once fabrication starts, the opportunities to make changes to assemblies, connection details, and mechanical, electrical, and plumbing (MEP) routing, including penetration sizes and locations, quickly diminishes. Even fewer opportunities are available to make changes once these prefabricated components are transported and installed on site.

Due to the prefabricated nature of EMTC components, many aspects of the Architect and Engineering Professionals' scopes of work may have been completed and covered with insulation, gypsum board, or finishes, well before the component reaches site. For this reason, Architects and Engineering Professionals must be prepared to conduct factory reviews (i.e., field reviews of factory-built components during fabrication), in addition to field reviews during construction for their scope of work.

Examples of prefabricated or factory-built components that may require factory reviews by Architects or Engineering Professionals include, but are not limited to, the following:

- Prefabricated façade panels, such as:
  - air barrier;
  - vapour barrier;
  - insulation;
  - encapsulation details;
  - acoustical treatments;
  - MEP routing or penetrations;
  - window and window frame details; and
  - structural connection details.
- Prefabricated floor panels, such as:
  - permanent or temporary moisture protection during construction;
  - encapsulation details;
  - acoustical treatments;
  - mechanical and electrical routing or penetrations; and
  - structural connection details.
- Volumetric modules (see prefabricated façade and floor panels above).
- Structural members or panels with prefabricated, hidden connections;
- Prefabricated balconies, such as:

- structural connection and/or thermal bridging details;
- mechanical and electrical routing or penetrations; and
- waterproofing membranes.

As with field reviews, the frequency and extent of factory reviews is at sole discretion of the Architect or Engineering Professional. Conducting a factory review does not eliminate the obligation of the Architect or Engineering Professional to conduct field reviews to ascertain that the components are installed as per the design.

Architects and Engineering Professionals must be cautious when specifying factory-built components and be fully aware of their professional responsibilities for involvement during the fabrication phase, and not just during the construction phase.

Sentence 1.1.1.1.(3) of Division A of the Code confirms that the Code applies to both site-built and factory-constructed buildings. Architects and Engineering Professionals are advised to provide services in this context and to familiarize themselves with CSA A277, Procedure for Certification of Prefabricated Buildings, Modules, and Panels. Note A1.1.1.1.(3) Factory Constructed Buildings of the Code further explains that the CSA A277 standard describes a procedure by which an independent certification agency can review the quality control procedures of a factory and make periodic unannounced inspections of its products.

The CSA A277 standard is not a code. It is a factory-compliance procedure only, so factory and field reviews by the Architect and Engineering Professionals are required. However, if a factory-constructed building bears the label of an accredited certification agency indicating compliance with the *Code,* and if the factory has been certified using the CSA A277 procedure, the Architect and Engineering Professionals will have some assurance that the concealed components do not require on-site reinspection.

The CSA Z240 MH Series of Standards, Manufactured Homes is intended to apply only to transportable, singe-or multiple-section, one-storey dwellings. There are no building size limitations, and buildings can be constructed using multiple modules, but for CSA Z240 MH to apply, the building must be one-storey construction. It is unlikely to be useful for EMTC, as EMTC is a construction methodology to facilitate multi-storey wood construction.

Where factory-built components are designed by Supporting Registered Professionals, the Registered Professional of Record should clearly outline the scope and responsibilities of each Supporting Registered Professional, including those designing and supplying factory-built components such as windows, when it comes to both design and field reviews. The Letters of Assurance, Schedule S-B, Assurance of Professional Design and Commitment for Field Review By Supporting Registered Professional, and Schedule S-C, Assurance of Professional Field Review and Compliance By Supporting Registered Professional may be used as accountability documents, customized for the scope of work.

See Section 5.4.5.4 Prefabricated Review and Verification for factory site reviews.

See also *Joint Professional Practice Guidelines – Professional Design and Field Review by Supporting Registered Professionals* (AIBC and Engineers and Geoscientists BC 2020).

8. References and Related Documents

Related documents that may be of interest to users of these guidelines but are not formally cited elsewhere in this document appear in Section 8.4: Related Documents.

8.1 LEGISLATION

The following legislation is referenced in these guidelines.

Architects Act [RSBC 1996], Chapter 17

Professional Governance Act [SBC 2018], Chapter 47

8.2 REFERENCES

The following documents are referenced in these guidelines.

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8.3 CODES AND STANDARDS

The following codes and standards are referenced in these guidelines.

ANSI/APA PRG 320, Standard for Performance-Rated Cross-Laminated Timber

ANSI/BICSI N1-2019, Installation Practices for Telecommunications and ICT Cabling and Related Cabling Infrastructure

AAMA/WDMA/CSA 101/I.S.2/A440, NAFS 2011 – North American Fenestration Standard/Specification for Windows, Doors and Skylights

ASHRAE 90.1 – Energy Standard for Buildings Except Low-Rise Residential Buildings

ASTM E336, Standard Test Method for Measurement of Airborne Sound Attenuation between Rooms in Building

ASTM E413, Classification for Rating Sound Insulation

BC Building and Safety Standards Branch. 2018. *BC Building Code*. [accessed: 2020 Oct 23]. http://www.bccodes.ca.

BC Fire Code

CAN/CSA-B72-M87 (R2013), Installation Code for Lightning Protection Systems

CAN/ULC-S101, Standard Methods of Fire Endurance Tests of Building Construction and Materials

CAN/ULC-S107, Methods of Fire Tests of Roof Coverings

CAN/ULC-S114, Standard Method of Test for Determination of Non-Combustibility in Building Materials

CAN/ULC-S115, Standard Method of Fire Tests of Firestop Systems

CAN/ULC-S134, Standard Method of Fire Test of Exterior Wall Assemblies

CAN/ULC-S146, Standard Method of Test for the Evaluation of Encapsulation Materials and Assemblies of Materials for the Protection of Structural Timber Elements

CAN/ULC-S702, Standard for Mineral Fibre Thermal Insulation for Buildings

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CSA A23.1, Concrete Materials and Methods of Concrete Construction/Test Methods and Standard Practices for Concrete

CSA A277, Procedure for Certification of Prefabricated Buildings, Modules, and Panels

CSA-C.22.1-18, Canadian Electrical Code, Part I, Safety Standard for Electrical Installations

CSA O86-19, Engineering Design in Wood

EN [Eurocode] 1990, Basis of Structural Design

ISO 15712-1:2005, Building acoustics — Estimation of Acoustic Performance of Buildings from the Performance of Elements — Part 1: Airborne Sound Insulation Between Rooms (revised by ISO 12354-1:2017).

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NFPA 13, Standard for the Installation of Sprinkler Systems

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UL 790, Standard for Standard Test Methods for Fire Tests of Roof Coverings

8.4 RELATED DOCUMENTS

The following documents are provided for information only, and are not referenced in these guidelines.

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1.0	March 30, 2021	First issued.

9. Appendices

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APPENDIX B: LIST OF TABLES

APPENDIX C: LIST OF FIGURES