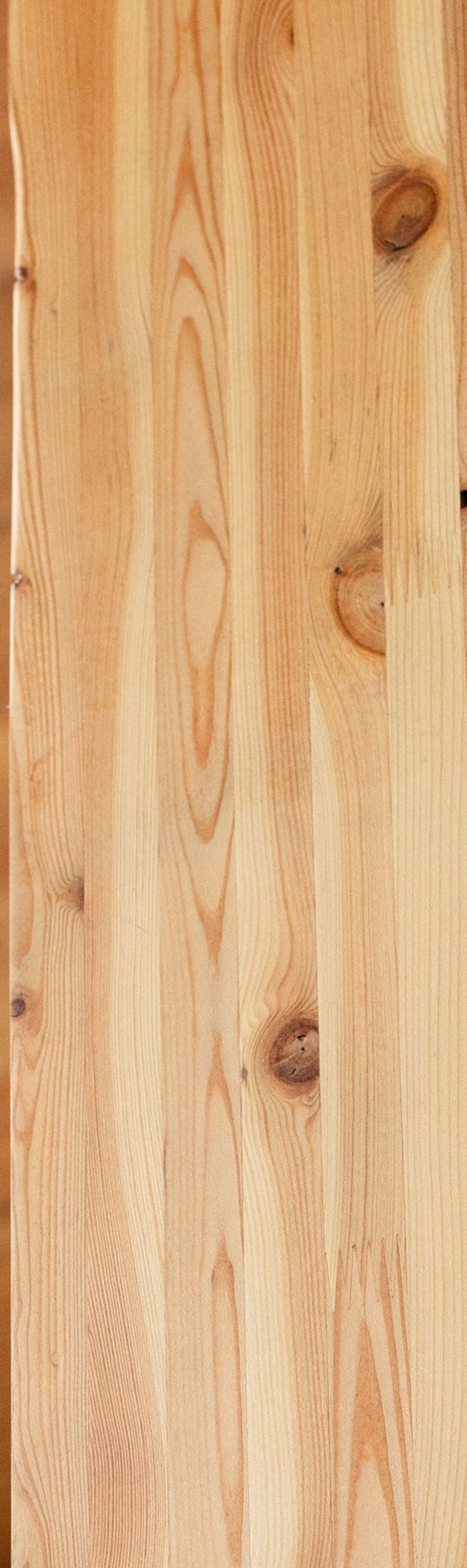
Alternative Solutions Guide



WoodWorks | Canadian Wood Council Resource Program

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Introduction

While alternative solutions have been an important feature of the National Building Code of Canada since 2005, there remains a lack of understanding among building professionals on how to approach their use. As the construction industry evolves, with increasing innovation in design and construction capabilities, new ways of building that may not be well addressed by building codes will emerge. At the same time, tools for performance testing and simulation are becoming more widespread. In light of the diverse and evolving building industry, alternative solutions that enable new ways of building are likely to become more commonplace. A critical area where alternative solutions may be employed is in the use of mass timber construction. The introduction of mass timber construction techniques, enabled by a range of engineered wood products, associated connection technologies, and fabrication methods, has resulted in a wide range of possible building solutions that may not have been considered by building codes.

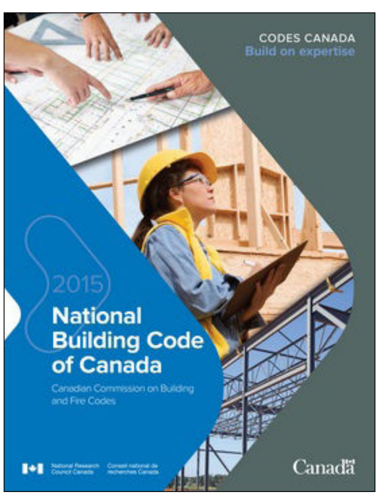
Statutory Framework

The regulation of buildings in Canada is a responsibility of provincial governments, with the application of regulations generally delegated to municipalities. In most jurisdictions across Canada, buildings are required to comply with a building code, typically based on the National Building Code of Canada (NBCC). Some provinces use the NBCC directly, while others create provincial codes that are based on the NBCC, but modified to suit specific requirements. In exceptional cases, building regulation is a municipal responsibility, such as in the City of Vancouver, where the Vancouver Building By-law is applied (based on the British Columbia Building Code/National Building Code of Canada).

The purpose of a building code is to ensure buildings meet a minimum standard for safety, occupant health, accessibility, and energy efficiency. The National Building Code of Canada (and its derivatives) has evolved to become an objective-based code, intended to offer greater flexibility to design professionals. It is structured around specific objectives and functional statements that generally describe intent, while establishing a set of prescriptive requirements that correspond with building characteristics and performance.

Compliance with the building code may either be achieved by following and complying with the "acceptable solutions" defined in Division B, or by demonstrating an equivalent level of performance through an alternative solution. Although acceptable solutions are more common, either route may be pursued.

The prescriptive requirements of the code are referred to as acceptable solutions and are described in Division B of the code, representing the common and contemplated solutions for specific types and configurations of buildings.



Alternative solutions offer a path to code compliance in acknowledgement that the acceptable solutions described in the code may be unable to predict the diversity of designs in practice, and to allow innovation in construction. The key principle behind the alternative solution compliance path is that the alternative solution proposed must at least meet (or exceed) the performance level provided by the acceptable solution it is intended to replace. Unlike acceptable solutions, which are intended to be predictably accepted, alternative solutions require judgement by both the professional proposing them, as well as the Authority Having Jurisdiction (AHJ) that exercises discretion to approve their use. As such, alternative solutions typically involve direct consultation and collaboration between professionals to arrive at a solution that is supported and permitted.

Intent

Alternative solutions and innovative approaches are generally project specific, and often similar projects (in terms of scope, size, program, and construction) must still start from the beginning, spending enormous amounts of time to demonstrate if an innovative idea can even be applied.

Alternative solutions may either be familiar or tailored to a specific set of conditions. Often alternative solutions are "adjacent" to an acceptable solution but require some flexibility to satisfy the intent.

Alternative solutions often require input from various parties including designers, engineers, and code consultants, as well as contractors and manufacturers who can offer a better understanding of possibilities and performance criteria. If important input is left out when writing an alternative solution, it is possible that addressing a problem in one segment of design might result in increased cost and complexity in other segments.

This guide has been created to provide direction for designers to better understand how to enable new and innovative ideas that may not neatly fit the acceptable solutions described in the building code. It provides general direction on what should be included in an application when proposing an alternative solution, who should be included to provide relevant input, and what are the important requirements to be considered and documented.


L'Alliance française – Vancouver

Photo Credit: Arkitek Creative (courtesy of naturally:wood)

Best Practices for Engaging with Jurisdictions

Pursuing alternative solutions requires detailed collaboration with the AHJ. Proposals are successful when design teams engage with the AHJ early, are forthcoming with communication, and bring well-organized and defensible solutions for consideration.

The viability of a building project is the result of both land use regulations and building regulations. Each requires an approvals process, and each takes time. Understanding the relationship between the two is key. Land use planning regulations concern what you can build, and where. Planning permission is normally the result of a development application or a rezoning application, or both. These permissions concern the form and configuration of the building and generally do not specify a construction material or method. The viability of any development or rezoning application will, however, be predicated on a construction method that is appropriate for the conditions. Beyond land use planning regulations, which define ***what*** can be built, building regulations dictate ***how*** you go about building it.

Building materials are not interchangeable – a building designed as a concrete or steel structure is not interchangeable with a mass timber structure. As such, even at the planning approvals stage a clear plan for the material of construction is essential. Therefore, when considering alternative solutions, it is important to confirm the impact that planning and building regulations will have on the viability of the proposal.

When do you need to apply within the project schedule?

When determining the application timeline, it is critical to find out what permits and processes are required for the development. Most jurisdictions require rezoning and a development permit (DP) for new buildings or major alterations to existing buildings. The review of alternative solutions, in most jurisdictions, lies with the Building Division during the building permit (BP) review stage. However, the jurisdiction may not allow the BP review to be done concurrently with the DP or rezoning. So, it is important to determine the permitting strategy with the jurisdiction during the design development stage. It is at the development or rezoning stages of the project that engagement should begin with the authorities' departments that may have comments on the alternative solution(s). This is especially important if the alternative solutions have an impact on the "form and character" of the project. Form and character are reviewed at the DP stage (this is typically done by the Planning Department). This can be tricky to navigate as the DP is reviewed and approved prior to submission of the BP. If the alternative solution is not accepted (at the BP stage), it may require an amendment to the DP. Note that a DP amendment likely will need a review by the local council, so the amendment review will be subject to the council's schedule and the number of items in queue for the agenda, which can affect the project schedule.

After determining the required jurisdiction's processes, it is essential to contact the persons responsible for the building reviews early in the project schedule, preferably at the DP stage. This is especially true for projects using complex alternative solutions. A potential concern with this approach is that the AHJ may not issue a formal approval of the alternative solution at the DP stage. Normally this is because the alternative solutions are still under development, and a complete application has not been submitted. However, the jurisdiction may provide an "acceptance in principle", which is an informal approval, but still leaves an opportunity for the reviewer to comment on the details in the future. It is essentially a check for any red flags.

In most jurisdictions, the plan reviewer or supervisor is the person to communicate with to discuss alternative solutions; however, in larger municipalities the code engineer reviews the engineering reports, so it is important to include them in the conversation.

How much time should an applicant allow for discussion and approval?

Ample time should be provided to allow for discussion and revisions of the alternative solutions. This is usually done by email, but for some complex projects, in-person or virtual meetings may be the fastest approach to communicate ideas and share opinions. If drawing or report revisions are required, additional review time for the revisions will also be required. Depending on the complexity of the submission, allowance of one to two months should be included for correspondence.

Approval timelines can vary significantly from jurisdiction to jurisdiction and very few or none will provide “approval” timelines, as approval is dependent on the content of the submission. However, most jurisdictions will provide “review” timelines, but these will also vary depending on staffing levels, complexity of the report, and number of projects in the queue. Some jurisdictions have a general policy to provide feedback within a month of an application. However, this is not a complete review; it is a documentation review to make sure they have all the documents and information they need to complete the necessary reviews. Generally speaking, it is good practice to allow two to four months to receive comments.

What information do you need from the AHJ prior to application?

It is essential to meet and discuss the proposed alternative solutions early in the process – this is best done at the DP stage before the BP drawings or reports are fully developed. Below is a list of items to include in this discussion.

- High-level comments from the AHJ and areas of concern
- Specific policies or bulletins that the applicant needs to follow
- Requirements for BP submission
- Permit process and application documents required
- When BP documents can be submitted:
  - Concurrent with DP/rezoning?
  - Can the BP be divided to allow earlier scope to begin construction?
- Is a peer review process required:
  - Will that process be supported by the applicant/project team?
    - Choosing reviewers, providing scope
  - Will that be independent of the applicant/project team?

What do you need from the AHJ to show acceptance?

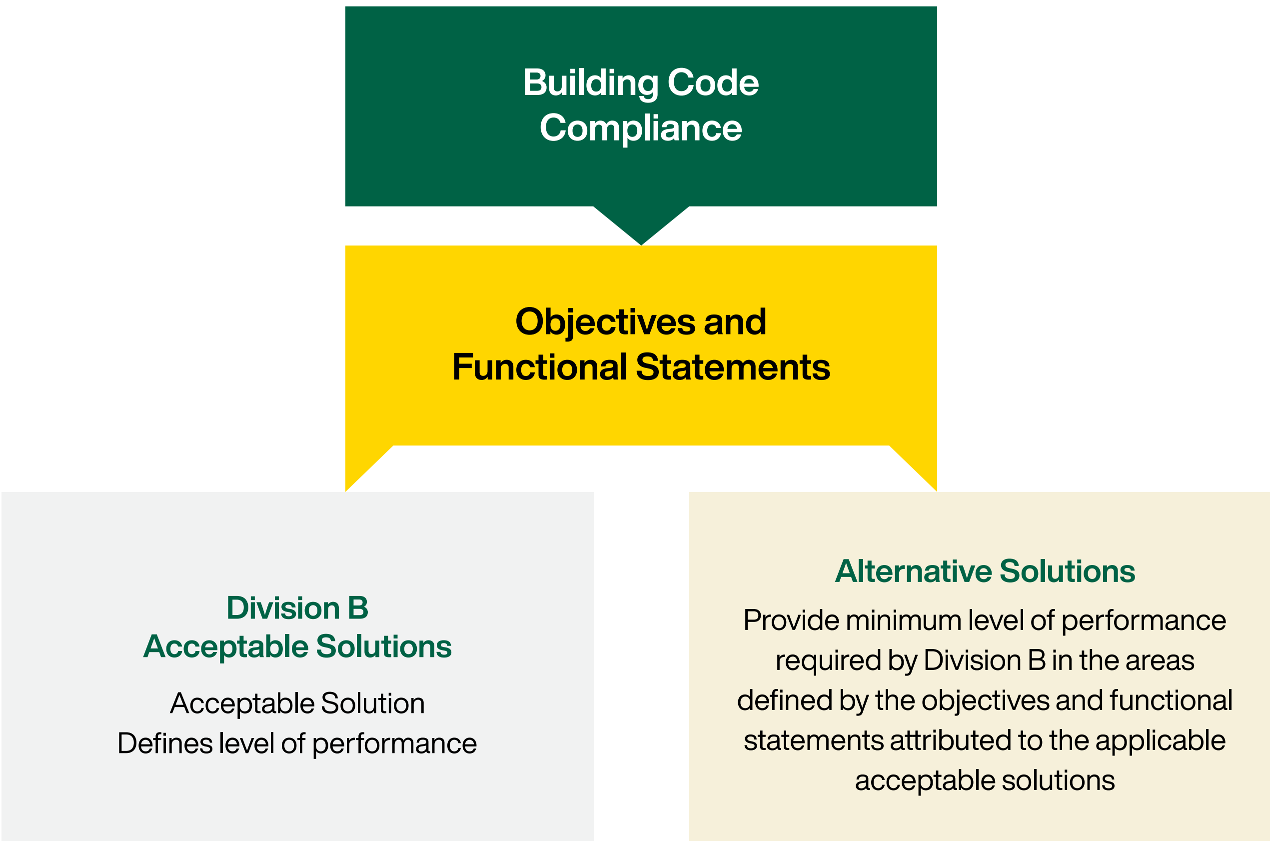
You may need to ask the AHJ for specific requirements for sign-off. Certain AHJs issue official sign-offs for alternative solutions, and some do not. Clients generally require an acknowledgement of some kind that confirms the approach to code compliance is supportable, to reduce risk and confirm any deliberations to that point. Typically, smaller municipalities do not issue approval letters, but list the alternative solutions on the BP, so issuance of the BP in effect means acceptance of the alternative solution(s).

Requirements in the Application

When proposing an alternative solution it is essential to present all the relevant information in a format that is logical and clear.

Introduction

Since 2005, the NBCC has been an objective-based code organized around the satisfaction of specific objectives and functional statements. Conformance with the objectives and functional statements may be achieved through acceptable solutions or alternative solutions.



Acceptable solutions generally anticipate typical building situations that are common, with limited complications. The alternative solution path is an option for other situations, where acceptable solutions may not be appropriate, to enable flexibility in building construction. It provides design teams the ability to employ different design or construction methods that may differ from the prescriptive options envisioned by the building code.

Applicant Credentials

Alternative solutions should be prepared by a registered professional, whether an architect or an engineer, as defined by the Architectural Institute of British Columbia (AIBC) or the Engineers and Geoscientists (EGBC) Association of BC. The application documents should bear the professional seal of the registered professional. Evidence of specific knowledge of the topic matter of the alternative solution should be demonstrated by the applicant.

Design Information

Sufficient documentation for any alternative solution application should be provided. The submission should be "complete" and standalone, to facilitate review without further resources other than the building permit application drawings provided in support. Typical submissions should include:

- Project address
- Project description and scope of work
- Building code edition
- Applicable building code references
- Summary of deviations from prescriptive solution(s)
- Objective and functional statements attributed to the applicable acceptable solutions
- Relevant intent statements
- Summary of design features of alternative solution
- Analysis and evaluation of alternative solution design features, to demonstrate the minimum level of performance is met or exceeded

Rationale to Aid a Decision

Division B of the British Columbia Building Code consists primarily of prescriptive requirements as acceptable solutions. Division A, Clause 1.2.1.1.(1)(b) and Division C, Section 2.3 allow the development of alternative solutions that should achieve at least the minimum level of performance required by Division B in the areas defined by the objectives and functional statements attributed to the applicable acceptable solution. Further, Division A, Notes to Part 1 indicates that a design meeting provisions of a Division B acceptable solution is deemed to satisfy the objectives and functional statements linked to those specific provisions. Therefore, an alternative solution meeting the minimum level of performance of an acceptable solution also satisfies the objectives and functional statements attributed to the acceptable solution.

Sentence 1.2.1.1.(1) is further discussed in Note A-1.2.1.1.(1)(b) of Division A. It is important to note that where there are different acceptable solutions, each offering a different level of performance, the lowest level of performance may be used for the purposes of establishing the performance level of the alternative solution.

In general, any given alternative solution approach should:

- establish the areas of performance applicable to the acceptable solution in Division B
- establish the level of performance provided by the acceptable solution
- explain the level of performance provided by the proposed alternative solution
- compare the two levels of performance in order to demonstrate that the alternative solution meets the criteria established in Clause 1.2.1.1.(1)(b) noted above.

Difficulties frequently arise in preparation of an alternative solution because, in many instances, there are no attributed objectives or functional statements to a particular Division B requirement. An example of this is Subsection 3.1.5. There are no attributed objectives or functional statements for the majority of the prescriptive solutions in this subsection. The typical approach has been to utilize the objectives and functional statements attributed to Sentence 3.1.5.1.(1), as these are considered to establish the overall "purpose" of the acceptable solutions within the subsection. Alternative solutions may therefore be developed.

An additional difficulty arises for those issues where the alternative solution needs to address an item perceived as a "definition" in the code. An example is major occupancy classification. Sentence 3.1.2.1.(1) requires a building to be classified according to major occupancy. Appendix discussion A-3.1.2.1.(1) provides tabulated examples of uses under each major occupancy classification. Frequently, AHJs interpret these examples as "definitions" rather than a resource to be used for guidance and further evaluation. A further example is the construction requirements in Subsection 3.2.2. Many construction articles prescribe noncombustible construction, given a certain major occupancy type, building height, and building area. Objectives and functional statements are attributed to the requirement prescribing noncombustible construction, facilitating the development of an alternative solution, as such alternative solutions addressing these code provisions may be evaluated just like any other code provision.

Typical Subjects for Alternative Solutions

The following are typical subjects which may be addressed on an alternative solution basis to demonstrate compliance with fire and life safety provisions of the British Columbia Building Code 2018 relating to wood materials.

These typical subjects are sorted based on types of construction, namely combustible construction, which includes light wood-frame construction and mass timber construction (not prescribed to be encapsulated), noncombustible construction, and encapsulated mass timber construction (EMTC).

Note that the following typical subjects are based on the British Columbia Building Code 2018. The British Columbia Building Code 2024, which has come into effect since March 8, 2024, may have an impact on some of the typical subjects for use of wood materials.

Combustible Construction (Light Wood-Frame and Mass Timber)

Building Height or Building Area Exceeding BC Building Code Limits for Combustible Construction

The BC Building Code under Division B, Subsection 3.2.2 prescribes limits to building area and building height for combustible construction depending on occupancy type. A typical alternative solution would be to allow combustible construction while these limits are exceeded.

For residential occupancy, for example, the building height limit is 6 storeys for use of combustible construction. Beyond 6 storeys, such buildings would have to be of noncombustible construction or encapsulated mass timber construction. With respect to building height, a common condition designers encounter where this approach is applied is for a residential building located on a sloping site, resulting in building height exceeding 6 storeys due to the lowest average grade, based on which the first storey of the building is established. The following schematic diagram illustrates this condition.

Combustible Midrise

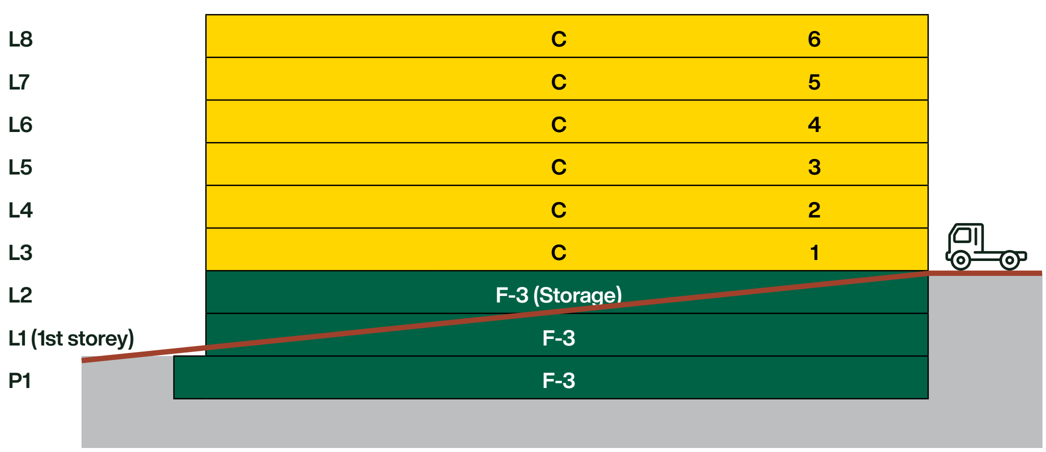


Figure 1. Building height addressed by alternative solution for allowing combustible construction (yellow) on a sloping site.

With respect to building area, a commonly encountered design where an alternative solution approach can be developed is when the podium of a building exceeds the building area limit for combustible construction. The following schematic diagram illustrates a design where the ground floor area exceeds 1500m² for a 6-storey wood-frame construction per Division B, Article 3.2.2.50.

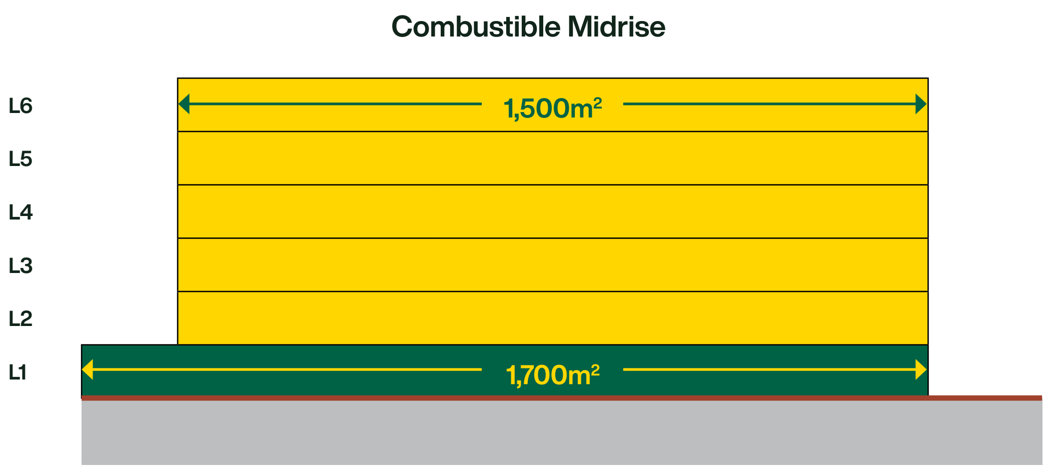


Figure 2. Excess building area addressed by alternative solution for allowing combustible construction (yellow).

The alternative solution should address the objectives and functional statements corresponding to reference code provisions such as [F02,F04-OS1.2,OS1.3] and [F02,F04-OP1.2,OP1.3] per Division B, Table 3.10.1.1.

Use of Mass Timber for Firewall Construction

The construction of firewalls is prescribed to be noncombustible and, in some cases, to be of masonry or concrete construction by Division B, Article 3.1.10.2 of the BC Building Code.

To allow for a higher degree of material compatibility, an alternative solution can be developed to construct a firewall using mass timber elements such as cross-laminated timber (CLT). It has been demonstrated that the use of CLT can achieve the level of performance required on an alternative solution basis. CLT firewalls can be a viable alternative to noncombustible firewalls for subdividing midrise wood-frame construction where differential shrinkage and settlement may cause issues in the long term.

The alternative solution should address the objectives and functional statements corresponding to reference code provisions such as [F03-OS1.2], [F03-OP1.2], and [F03-OP1.3] per Division B, Table 3.10.1.1.

ON5 Project

Code Consultant: Evolution Building Science
Architect: Hemsworth Architecture
Structural Engineer: Timber Engineering

"The alternative solution developed for the ON5 project was specifically focused on the use of mass timber 5-ply CLT vertical panels for the 0-lot line exterior wall assemblies, which would normally be required to be of "noncombustible construction" based on the applicable spatial separation requirements of the Vancouver Building By-law. The specific "mitigating features" for this alternative solution included the passive fire protection features of the exposed mass timber wall panels (i.e., charring of exposed layer), in combination with active fire protection via the sidewall sprinkler protection installed at the intersection of the CLT floor and wall panels (both sides of floor areas)."

– **Geoff Triggs, P.L. Eng.** formerly of Evolution Building Science Ltd. (now Senez Consulting Ltd.)

Photo Credit: KK Law (courtesy of naturally:wood)

Spatial Separation and Mass Timber Exterior Wall Assemblies

Where restrictive limiting distance applies to an exterior building face, Division B, Subsection 3.2.3 of the BC Building Code may prescribe noncombustible construction for the exterior wall.

This condition may arise where a building is located close to a property line when building in mass timber construction, such as a zero-lot line exterior wall. An alternative solution may be developed to address the prescription of noncombustible construction for spatial separation purposes.

The alternative solution should address the objectives and functional statements corresponding to reference code provisions such as [F03,F02-OP3.1] per Division B, Table 3.10.1.1.

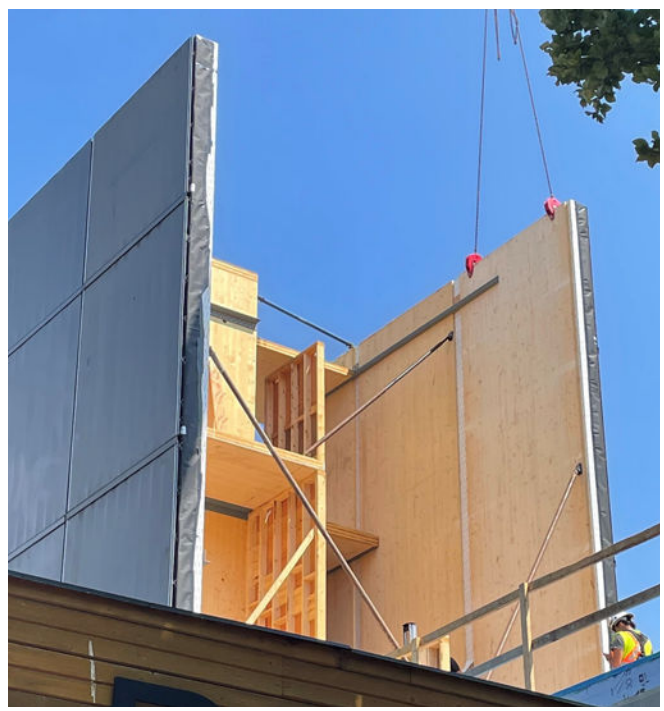


Photo Credit: Geoff Triggs

Noncombustible Construction

Use of combustible soffits in noncombustible buildings

For buildings prescribed to be of noncombustible construction, only combustible materials permitted by Division B, Subsection 3.1.5 of the BC Building Code may be used. Only materials that are deemed noncombustible are permitted for soffits. While exterior soffits are not explicitly addressed by the provisions under Subsection 3.1.5, an alternative solution may be developed to address the use of combustible materials in soffits with protection measures targeting the fire risks associated with the presence of such combustible materials.

The alternative solution should address the objectives and functional statements corresponding to reference code provisions such as [F02-OS1.2] and [F02-OP1.2] per Division B, Table 3.10.1.1.

Use of exposed mass timber canopies in noncombustible buildings

For buildings prescribed to be of noncombustible construction, only fire-retardant-treated wood conforming to conditions under Division B, Article 3.1.5.24 of the BC Building Code can be used as decorative wood materials for canopies or marquees. All other materials that are not deemed noncombustible are not permitted for canopies or marquees.

With limited availability of products and long-term materials characteristic of compliant fire-retardant-treated wood, an alternative solution may be developed to allow the use of exposed mass timber canopies with protection measures targeting the fire risks associated with such design.

While no specific code objectives and functional statements are attributed to Article 3.1.5.24, the alternative solution should consider the intent statements corresponding to the referenced code provision.

Mass Timber Canopy at Orchard Commons – UBC

Code Consultant: *GHL Consultants Ltd*
Architect: *Perkins+Will*
Structural Engineer: *Glotman Simpson and StructureCraft*

Photo Credit: Michael Elkan

Alternative to pressure impregnated fire-retardant-treated wood

The use of fire-retardant-treated wood permitted for noncombustible buildings (or combustible buildings, for that matter) shall meet the provisions under Division B, Article 3.1.4.5 of the BC Building Code.

Essentially, only products having gone through a pressure impregnated fire retardant treatment process can be recognized by the BC Building Code. An alternate treatment process for wood products can be proposed based on its performance. Such products can be used on an alternative solution basis as interior ceiling finish in virtue of Division B, Sentence 3.1.5.12.(4).

The alternative solution should address the objectives and functional statements corresponding to reference code provisions such as [F02-OS1.2] and [F02-OP1.2] per Division B, Table 3.10.1.1.

EMTC per BCBC 2018 and Hybrid Construction

Building height exceeding BCBC limits for EMTC

The BC Building Code under Subsection 3.2.2 prescribes limits in building area and building height, namely up to 12 storeys, for EMTC buildings depending on occupancy type (note that proposed code changes will increase height limits for EMTC and mass timber buildings). An alternative solution can be developed to allow EMTC for taller buildings. These types of projects will require early discussion with AHJs to establish design parameters for addressing typical fire safety concerns associated with the increased building height.

The alternative solution should address the objectives and functional statements corresponding to reference code provisions such as [F02,F04-OS1.2,OS1.3] per Division B, Table 3.10.1.1.

Brock Commons Student Housing at UBC

Used a site-specific regulation in place of an alternative solution to exceed height and storey limits for timber buildings at time of construction.

Code Consultant: *GHL Consultants Ltd*
Architect: *Acton Ostry Architects*
Structural Engineer: *Fast + Epp*

Photo Credit: naturally:wood

Mass timber encapsulation limits

The BC Building Code under Division B, Article 3.1.18.4 prescribes minimum encapsulation limits for mass timber elements such as ceilings, walls, beams, and columns.

An alternative solution can be developed to allow greater surface area of exposed mass timber elements. These types of projects will require early discussion with AHJs to establish design parameters for addressing typical fire safety concerns associated with exposed timber elements.

The alternative solution should address the objectives and functional statements corresponding to reference code provisions such as [F02-OS1.2] and [F02-OP1.2] per Division B, Table 3.10.1.1.

Typical Solutions and Strategies

Design Rationales for Alternative Solutions

The following are potential considerations and rationales justifying fire and life safety concerns addressed by the BC Building Code. As discussed in previous sections, in order to justify an acceptable alternative solution, it is necessary to demonstrate that the level of performance offered by the proposed alternative solution is at least equivalent to that offered by one Division B acceptable solution as prescribed under a specific code reference. In addition to a description of the proposed solution and its features, the discussion surrounding rationales for the proposed solution, as documented by the alternative solution report, should clearly demonstrate the level of performance and how this level of performance is established.

As examples, potential approaches and rationales for mass timber element fire-resistance rating and building area and height limits are discussed following the above-mentioned alternative solution framework regarding performance.

Mass Timber Element Fire-Resistance Rating

While fire resistance is the design fundamental of fire safety for a building, it is important to understand what a fire-resistance rating entails for establishing and evaluating fire performance within the context of an alternative solution. As per the definition provided in Division A of the BC Building Code, the fire-resistance rating is based on a time period that a material or assembly of materials will withstand the passage of flame and transmission of heat when exposed to specified conditions.

For mass timber projects, the fire-resistance rating of structural elements can be readily established either by the standard fire test CAN/ULC-S101 or in conformance with Division B, Appendix D of the BC Building Code per Division B, Article 3.1.7.1.

From a performance standpoint, resistance against the passage of flame and transmission of heat is one of the key performance parameters to establish in justifying a fire-resistance rating. Measures with respect to transmission of heat applicable to a mass timber floor assembly, for example, can be found in the standard fire test CAN/ULC-S101, namely:

- maximum average temperature rise on non-fire exposed surface is 140°C, and
- maximum individual point temperature rise on non-fire exposed surface is 180°C.

These test criteria can be taken as benchmark performance parameters of a Division B acceptable solution.

In addition to the Division B acceptable solutions, compliance with the prescribed fire-resistance rating can be achieved by an alternative solution. In this case, the level of performance should meet the standard test criteria as described above or the performance of a design conforming to Appendix D for the required fire-resistance rating.

It is also important to note that the goal of establishing a fire-resistance rating is to meet the objectives and functional statement attributed to Division B, Sentences 3.1.7.1.(1) and (2), namely [F03-OS1.2], [F04-OS1.3], [F03-OP1.2], and [F04-OP1.3] per Division B, Table 3.10.1.1.

For a fire-resistance rating on an alternative solution basis, the level of performance can be demonstrated by an engineering analysis, which may involve a detailed review of the fire behaviours of the proposed mass timber design. The following are some engineering approaches to justifying the level of performance:

- **Mass Timber Char Rate:** For mass timber structural design, char analysis is required to be carried out in order to determine the fire-resistance rating. The charred layer can be calculated to estimate the charred thermal insulating thickness and the residual load-bearing capacity of the structural elements. The estimation of uncharred residual mass timber elements is a critical design parameter in establishing a fire-resistance rating. The determination of the charred layer and a char rate other than pre-established design rates, such as those provided in Division B, Appendix D of the BC Building Code or CSA O86, "Engineering design in wood", can be addressed in an alternative solution. Justification will be required if alternate methods are used.
- **Engineering Calculations and Modelling:** As part of fire-resistance rating analysis, engineering calculations can be performed based on the materials and composition to determine the rating for the assembly.

  The calculations may be carried out in the form of computer modelling simulations, such as 3D computation fluid dynamics (CFD) fire models or 2D heat transfer calculation using the finite element method (FEM). Fire modelling tools, such as Fire Dynamics Simulator (FDS) by NIST and OpenFOAM, are commonly used CFD modelling packages that may provide insight into compartment temperature in order to estimate fire exposure conditions. These tools are often used to study more complex fire design including performance in terms of fire-resistance rating.

  Engineering calculations of this nature are complex and require specialized knowledge to perform properly. Qualifications of practitioners should be provided if these calculations are included as part of an alternative solution report.

  The selection of modelling tool or calculation method for an alternative solution should be well documented with assumptions clearly stated when carrying out calculations and fire simulations. Justification should be provided by the fire engineer for the choice of fire models or other engineering tools to confirm suitability for the objective of analysis. These aspects should form part of the alternative solution documentation for the AHJ.

  If performed and documented properly, engineering calculations and modelling can be presented to demonstrate the level of performance offered by an alternative solution design in terms of fire-resistance rating for mass timber design.
- **Combination of Passive and Active Fire Protection Measures:** It is not uncommon to address existing conditions by an alternative solution for a renovation project where existing mass timber elements are deemed insufficient to provide the required fire-resistance rating, triggered as a result of the renovation project.

  Depending on the deficiency of the existing conditions, the shortfall may be addressed by the following approaches using passive and active protection measures:

  - addition of fire resistive materials, where deficient
  - additional compartmentation
  - provision of additional fire protection systems such as sprinkler protection

  Similar to fire safety design for a non-mass timber project, the concept of fire risk can be applied to determine the level of safety of a particular design.

  Given the deficiency of the existing conditions, rationales for such design approach may be supported by fire risk analyses, by which the fire hazards specific to the project are identified and evaluated. On this basis, an appropriate design solution can be developed and demonstrated to address the level of fire risk while working within the constraints associated with the existing conditions. Fire risk analysis should be developed and performed with consideration given to the probabilistic and deterministic aspects of the fire safety concerns addressed, in order to establish the level of safety provided by the design as a performance parameter within the context of an alternative solution. Similar to engineering calculations and fire simulations discussed above, it is important to include proper documentation on the choice of fire risk assessment methodologies and assumptions as part of the alternative solution development process.

The foregoing discusses primarily the fire performance of mass timber design within the context of alternative solutions. It should be noted that the fire-resistance rating for structural elements consists of both fire performance and structural performance. When an alternative solution is proposed to address performance with respect to the required fire-resistance rating, both fire and structural performances should be taken into consideration from a compliance standpoint. The scope and limitations of the alternative solution should be clearly indicated in the documentation by the proponent. It is not uncommon to demonstrate the level of performance of an alternative solution design by a collaborative effort between fire and structural engineers addressing mass timber fire rating.

Excess in Building Area and Building Height

The use of an alternative solution addressing excess building area or building height for combustible construction and EMTC in order to achieve code compliance is typical design practice, for new construction in particular. This approach can also be used for building expansion or addition projects. In these cases, careful evaluation of the existing conditions will be required. The rationales for these types of alternative solutions may vary depending on project-specific conditions. However, despite project-specific conditions, the applicable fire safety concerns associated with excess area and height correspond to the attributed code objectives and functional and intent statements for applicable construction requirements under Division B, Subsection 3.2.2, notably [F02,F04-OS1.2,OS1.3] and [F02,F04-OP1.2,OP1.3] per Division B, Table 3.10.1.1.

Essentially, the alternative solution should address how the design limits the severity of fire [F02] and limits the risk of structural failure or collapse [F04]. Rationales and discussions should be provided accordingly specifically for these fire safety concerns. In most cases, the design approach would be based on the following design considerations:

- **Enhanced Compartmentation:** One viable strategy to limit the risk of fire severity in combustible construction is to provide enhanced compartmentation. The fire concern addressed by this code objective is the contribution to fire growth from combustible building materials in the excess building area and height (additional storeys). This can be achieved by additional vertical fire separations beyond what is prescribed by the BC Building Code as well as increased fire-resistance rating of fire separations. It can be determined that with increased passive protection from incorporating added fire separations and higher fire-resistance rating, the overall design would offer a level of performance at least equivalent to an acceptable solution in Division B of the BC Building Code.

  In addition, increased fire-resistance rating will reduce the risk of structural failure and collapse, as structural elements are more fire resistive to the same degree of fire exposure in theory, as well as to fire spreading from one compartment to another. The impact of increased fire-resistance rating on vertical and horizontal fire spread can be determined accordingly based on the project design.

  On this basis, the intrinsic fire concerns from the combustible building materials within the excess building area or storeys can be addressed by this passive protection design approach.

- **Enhanced Fire Protection Systems:** Enhanced active fire protection systems can also be an effective design approach to address fire severity. The following is list of potential design approach to increase the level of fire safety in a building with excess area or height on an alternative solution basis:

  - Enhanced sprinkler protection by increasing design area and reliability of water supply.
  - Additional pressurization to limit smoke and fire movement.
  - Enhanced ventilation to limit cumulation of fire gases within a building.

  The level of performance for these active protection design features should be demonstrated following the framework for establishing an acceptable alternative solution as provided by the BC Building Code. Similar to alternate methods for determining fire resistance rating for mass timber elements, evaluation of system performance in addressing fire risk should be carried out by qualified professionals with proper documentation of design analysis, assumptions, factor of safety, etc.

- **Fire Department Provisions:** As shown in research by fire scientists, the severity of fire, usually expressed in heat release rate, is a function of time. More specifically, the progression of fire at its initial stage tends to ramp up as more and more combustible contents are involved in the fire condition. Given this initial upward trend in fire severity, the response time of emergency responders such as the fire service can be critical at the initial stage for intervening and controlling the fire in order to limit further fire growth.

To address this from a design standpoint, fire department provisions such as emergency response entry points to buildings, access route design, firefighting installation locations, etc. can play a role in reducing the time required for emergency responders to get to the fire. While the provisions of the BC Building Code are based on certain assumptions such as fire service response time to arrive on scene, the building design with respect to fire department provisions can be improved to facilitate firefighting operations in case of emergency.

Although not specifically addressed by the code objectives, enhanced fire department provisions such as the following may constitute effective means to address objectives [F03] and [F04].

- Additional targeted fire department entry lobbies
- Access routes in close proximity
- Building perimeter served by access routes in close proximity
- Enhanced fire detection and signalling devices within the building
- Enhanced fire department notification
- Additional fire hydrants and fire department connections
- Provision of voice communication
- Additional hose connections

Beyond building design and a building's surroundings, additional consideration can also be given to the type of responding fire service, such as the availability of on-duty fire responders, travel distance from the closest firehall to the project building, and strategically synchronized traffic control measures, which may potentially have an impact on the response time to the building upon reception of a dispatch call.

While building design and these additional considerations relate to firefighting operations, discussion with the responding fire department may be required to develop an optimal solution based on the characteristics of the project as well as stakeholders' fire safety concerns.

One area of building design that does not affect building protection or damage but is related to life safety is the topic of egress. Alternative solutions that involve a reduction in travel distance or otherwise reduce the risk to building users when exiting the building may not directly respond to code objectives related to the alternative solution in question, but may increase the willingness of the AHJ or fire department to engage with the project team to find solutions, and show the flexibility of the project team in providing design options that increase the life safety parameters of the building. This engagement and discussion on quantitative and qualitative requirements is critical to encouraging dialogue between project teams and those reviewing alternative solutions.

Troubleshooting and Moving Forward

Developing alternative solutions means navigating codes, building science, and the approvals process in a methodical way. The need for alternative solutions arises when the pathways for code compliance through prescriptive routes are impractical or limiting in some way. It is unreasonable to imagine that the building code optimally anticipates the incredible variety of building types and configurations possible. Using a systematic approach that demonstrates the intent and functionality required by the code are satisfied using defensible alternate means relies on rational evaluation, thorough analysis, and a practical mindset.

At the same time, AHJs must exercise their judgement when considering proposals for alternative solutions. It is important to recognize their role and ensure any proposal is justified and defensible.

When developing an alternative solution related to innovative uses of mass timber, a number of considerations will help troubleshoot common and predictable obstacles.

Authorities Having Jurisdiction

Undertaking any building project normally requires approval from the municipality. Straightforward applications that comply with land use regulations and the prescriptive requirements of the appropriate building code generally proceed predictably to achieve development and building approval. Timber buildings that seek alternative solutions to achieve code compliance generally invite greater scrutiny, and often involve consideration by the local planning department, building department, and fire department.

Early input

Collaborating with representatives from the AHJ to shape how the alternative solution is devised should be prioritized wherever possible. Communicating the intent of the alternative solution, and the specific strategies proposed, at the earliest opportunity will help create conditions where the proposal is accepted. Socializing the approach to code compliance early will help reduce risk, as the eventual application will be familiar and will have responded to specific directives or concerns.

Expect misalignment, at least to start

With the imperative to reduce greenhouse gas emissions, politically-driven measures to encourage or incentivize more timber buildings are a feature of the current culture, generally falling within a broader regulatory context that is not optimized to enable mass timber construction. Balancing building safety with imperatives to reduce carbon emissions from construction is challenging, and not implicitly contemplated by the building code.

Fire officials

Local fire departments have a critical mandate for fire safety in the community. There are two main factors to anticipate – the fire safety of the building in operation, and the fire safety of the building project during construction. In each case fire officials consider the intent and requirements of the code, as well as their own capabilities and factors related to the specific application. Expect varying comprehension around timber construction between jurisdictions. It is highly important to share detailed and well-prepared Construction Safety Plans with the fire department, particularly where new or innovative timber building approaches are applied. Consultation with fire officials is recommended as early as practical, to gain their perspective and favourable disposition, and to influence the development of the alternative solution to quickly find consensus. Late involvement may result in unforeseen requirements, resistance, or reluctance.

Peer review

Building departments at municipalities have limited resources and may have little familiarity with mass timber construction. One strategy to alleviate this concern is to arrange an independent peer review of the alternative solution for consideration by the AHJ. Retaining an independent expert to review the proposed alternative solution provides professional reassurance and can help in examining the content of the proposal in parallel with the authority to provide peace of mind and a spirit of professional collaboration.

Material supply

The mass timber industry is global, with competition and variations across provincial and national boundaries. Clients, contractors, engineers, and architects may seek mass timber supply from out-of-province or international sources to pursue more favourable cost, scheduling, value-added inducements, or other considerations. Unless explicitly manufactured to the domestic standards required by the regulations at your project site, expect additional effort to confirm the performance requirements and necessary certifications. Specific requirements related to adhesives, moisture durability, and fire performance are among the characteristics of certifications that may vary between jurisdictions. Determine compliance requirements in advance, as there are likely to be cost and scheduling implications for any equivalency or evaluation sought to confirm compliance.

Compatibility with other systems

Special consideration must be made to ensure that all the elements enabling timber construction are accounted for in the alternative solution. In short, alternative solutions that involve timber inevitably also encounter factors beyond the wood itself. A particular consideration relates to the design of connections and overall agreement with the fire resistance strategy of the alternative solution. For instance, steel connections must be evaluated for their exposure; a common example is the design of screw-based shear connectors. In many cases, additional wood cover is required to conceal and protect the steel elements from heat, or other methods of fire and heat resistance employed (such as intumescent coatings). Consideration for penetrations through timber elements that may impact a fire-resistance rating is also key, as fewer standard joint or penetration designs exist, often resulting in specific engineering judgements.

Worth the effort

Pursuing an alternative solution to enable timber construction demands greater planning and collaboration, and as the building code evolves, so too will buildings and the materials and methods we use to make them. The imperative to reduce GHG emissions from buildings means mass timber construction is likely to become more widespread.

Alternative solutions are one tool for enabling the design and construction industry, and the projects constructed, to evolve and progress to meet the needs of society. Like all tools, it should be used carefully and in the right circumstances to ensure applicants and reviewers are able to provide a built environment that will continue to provide safe and resilient shelter for a constantly changing world. The alternative solutions of today can lay the foundation for the acceptable solutions of tomorrow. The time and effort invested to innovate within the confines of the regulatory system provide invaluable progress in developing future prescriptive code content and ensuring our building codes reflect continuing innovations in our built environment.

Additional Resources

A number of useful references are available that provide detailed information concerning timber construction:

- Thinkwood
- NRC
- FPInnovations
- SFPE association
- International Fire Code and International Building Code – since the 2021 version applying to tall buildings up to 18 storeys

Examples

Photo Credit: naturally:wood

Below are three typical short form examples of alternative solutions intended to address issues related to mass timber construction. These are followed by two long form examples following the City of Vancouver alternative solution format, including commentary to indicate why certain content has been included.

Short Form Examples

1 3-Storey Mass Timber Community Centre and Library

Project Description: This is the construction of a new community centre, library, and natatorium which is 3 storeys in building height with Group A, Division 2 major occupancy for which a hybrid mass timber and concrete construction is proposed.

Code References: Sentence 3.2.2.24.(2) of BC Building Code 2018 pointing to [F02-OS1.2] and [F02-OP1.2] relating to noncombustible construction.

Division B Acceptable Solution: To construct the project building with noncombustible materials meeting the definition of BCBC.

Alternative Solution: To allow use of mass timber elements in a building prescribed to be of noncombustible construction beyond what is permitted under Division B, Subsection 3.1.5.

Rationales: The level of performance was established based primarily on fire control/suppression system with enhanced reliability, enhanced exiting strategy, and fire department access to building. Discussions were provided to address pre-flashover and post-flashover conditions of the proposed design in relation to the use of mass timber. It was demonstrated that the level of performance by the alternative solution was at least equivalent to that of a Division B solution.

2 Firewall in Mass Timber (CLT) Construction

Project Description: This is a new construction of a residential project which is 7 storeys in building height with Group C major occupancy for which mass timber construction is proposed. The building area of the complex is over the 1500m_2 limit for a single 6-storey building of combustible construction.

Code References: Sentence 3.1.10.2.(2) of BC Building Code 2012 pointing to [F03-OS1.2], [F03-OP1.2] and [F03-OP3.1] relating to combustibility of firewall construction.

Division B Acceptable Solution: To construct firewall with noncombustible materials meeting the definition of BC Building Code.

Alternative Solution: To allow use of cross-laminated timber (CLT) for firewall construction.

Rationales: The level of performance was established based primarily on relevant fire tests for the required fire resistance rating. Additional discussions are provided for the firewall design details such as structural independence, penetrations, openings, connections, and issues surrounding differential shrinkage.

3 Combustible Midrise in a Highrise Building on a Sloping Site

Project Description: This is a new residential complex as a high building with a midrise component. The Tower portion is over 30 storeys in building height while the Midrise is up to 8 storeys. Both the Tower and Midrise are constructed on a noncombustible podium serving as a storage garage on a sloping side. The Midrise is considered a separate building for the purpose of construction requirements under Division B, Subsection 3.2.2.

Code References: Article 3.2.2.50 of BC Building Code 2018 pointing to [F02,F04-OS1.2,OS1.3] and [F02,F04-OP1.2,OP1.3] regarding building height limits.

Division B Acceptable Solution: To limit the combustible Midrise to up to 6 storeys in height.

Alternative Solution: To allow combustible construction for the top 6 floors of the Midrise while the rest is noncombustible construction.

Rationales: The level of performance was established based primarily on enhanced compartmentation, enhanced protection measures to limit fire spread using a similar approach to building separation per Article 3.2.1.2, availability of targeted fire department access points, access routes serving the building, and additional measures with respect to spatial separation between components of the building.

Long Form Examples

Alternative Solution Sample: Flame Spread of Interior Combustible Ceiling Finish

Commentary: It should be noted that the format of this sample alternative solution follows the City of Vancouver alternative solution template to present information in a consistent manner for this guide.

1. **Brief Building Description and Scope of Project**

   Commentary: A brief description of the project or building provides context and basic information to the authority having jurisdiction and demonstrates that the alternative solution author has a basic knowledge of the project or building as a whole and that the author has not just focused on building design or construction relative to the subject code requirement. The description should be a paragraph or two and include the characteristics of the overall building, major occupancy classification(s), use, applicable construction requirements and nature of the alternative solution.

   This project involves the construction of a new 12-storey mixed use commercial office tower over a 3-level below grade parkade. The building will be of encapsulated mass timber construction for above grade storeys and noncombustible construction for the below grade parkade. The building will include commercial retail units (Group E) and a restaurant (Group A, Division 2) on the main floor, as well as an entry lobby and public corridors to access stores. The second storey will include an English language school (Group A, Division 2). The third to twelfth storey will include multiple business and personal services suites (Group D) served by a central public corridor. The building will be equipped with automatic sprinkler, standpipe and fire alarm and detection system. The building is considered a high building and will be subject to the measures and requirements of Subsection 3.2.6.

   Commentary: Some background on why the alternative solution is proposed or desired should be included. The description should cover where, why and how. Typically, alternative solutions arise from a design, site or construction challenge, or a design innovation or vision, or may be a result of an energy target, design specification, goal or an incentive that must be met for the project.

   The first storey entry lobby and public corridor system include a double height ceiling. To maintain the historic aesthetics of this commercial block it is proposed to include combustible interior ceiling finishes at the first storey entry lobby and public corridor using 25mm thick wood planks. The wood planks will be Pacific Coast yellow cedar, which has a flame spread rating of 50 based on testing done at the Hardwood Plywood Veneer Association in conformance with CAN/ULC-S102 *"Standard Method of Test for Surface Burning Characteristics of Building Materials and Assemblies"*. As the proposed ceiling finish has an assigned flame spread rating of 50, this exceeds the flame spread rating of 25 permitted for ceilings by Sentence 3.1.18.12.(2). It is proposed to apply a fire-retardant coating to the subject cedar wood ceiling finish to reduce the surface flame spread rating of the proposed ceiling finish and achieve a level of performance as well as intended by the building code.

2. **Applicable Building Code References**

   Commentary: This is really step one when considering an alternative solution, first the author must carefully read through the applicable Article, Subsection, Section and possibly the entire Part of the building code to account for all references, cross-references and exceptions that may need to be addressed as part of the alternative solution. For clarity only state the applicable Division B acceptable solution(s) the proposed design deviates from and state relevant exceptions or criteria specified by the acceptable solution. The less references stated, the more reader friendly the alternative solution will be. In this case only one acceptable solution reference is identified. It should be noted that Article 3.1.4.5. only applies to instances where the Building Code 'requires' the use of fire-retardant treated wood in Part 3. This Article is not referenced as it is proposed to use a fire-retardant coated wood product and not a fire-retardant treated wood product.

The applicable building code reference for this alternative solution is Division B Sentence 3.1.18.12.(3) which is reproduced below for reference:

> *Except as provided in Sentences (4) and 3.1.18.4.(3) and (6), combustible interior ceiling finishes, other than foamed plastics, that are not more than 25 mm thick are permitted in a building or part of a building permitted to be of encapsulated mass timber construction, provided they have a flame-spread rating not more than 25 on any exposed surface or on any surface that would be exposed by cutting through the material in any direction, except that not more than 10% of the ceiling area within each fire compartment is permitted to have a flame-spread rating not more than 150. (See Note A-3.1.11.3.(3).)*

Key points of the above acceptable solution are:

- A combustible ceiling finish not more than 25mm thick is permitted
- Foamed plastic combustible interior ceiling finishes are not permitted
- The flame spread rating of the combustible material cannot be more than 25
- Any exposed surface or any surface that would be exposed by cutting through the material in any direction cannot have a FSR more than 25
- Exception: 10% of the ceiling area in a fire compartment is permitted a FSR of not more than 150

3. Functional and Objective Statement(s) and Description of Intent

Commentary: The purpose of objective and functional statements is to identify the level of performance of an acceptable solution. Typically, the building code does not attribute objectives and functional statements to references (acceptable solutions) that are an exception. In these cases, it is necessary to identify the root acceptable solution and use the statements attributed to the root reference.

Table 3.10.1.1. does not include statements attributed to Article 3.1.18.12, as this Article provides exceptions to Sentence 3.1.18.2.(1). Therefore, the statements attributed to the root acceptable solution of Sentence 3.1.18.2.(1) have been applied.

The following pair(s) of objectives and functional statements attributed to Sentence 3.1.18.2.(1) are identified by Division B Table 3.10.

- F02-OS1.2
- F02-OP1.2

The above objectives and functional statements are defined as follows:

- F02: To limit the severity and the effects of fire or explosions.
- OS1.2: To limit the risk of injury to occupants due to fire impacting beyond its point of origin.
- OP1.2: To limit the risk of damage to building due to fire impacting beyond its point of origin.

The below table is provided to paraphrase the above objectives/functional statement pairs and capture the level of performance intended to be achieved.

Sentence	Statements	Function	Link	Objective
3.1.18.2.(1)	[F02-OS1.2]	To limit the severity and the effects of fire or explosions on areas beyond its point of origin,	in order to	reduce the risk of injury to occupants in or adjacent to a building.
	[F02-OP1.2]	To limit the severity and the effects of fire or explosions on areas beyond its point of origin,	in order to	reduce the risk of damage to a building

Intent statements for most acceptable solutions are published online by the National Codes Council for the National Building Code 2015, which the current building code in effect in British Columbia is modelled after. Intent statements provide explanatory commentary for the subject acceptable solutions. Intent statements for encapsulated mass timber construction did not exist under the NBCC 2015 edition. Since Sentence 3.1.18.2.(2) references that materials in buildings permitted to be of EMTC conform to Subsection 3.1.5., the intent statement for Sentence 3.1.5.1.(1) is included below as the same pairs of objective and function statements also apply:

Intent 1:
To clarify what constitutes noncombustible construction.

Intent 2:
To limit the probability that construction materials will contribute to the growth and spread of fire, which could lead to harm to persons or to damage to the building.

Intent 1 above is not relevant to this alternative as the building will be constructed of EMTC. Therefore, intent 2 clarifies that the objectives and functional statements are to limit the probability the subject combustible interior ceiling finishes will not contribute to the growth or spread of fire in the building.

4. Summary of Solutions/List Mitigating Features

Commentary: Prior to developing an alternative solution, the feasibility of a concept or approach is commonly assessed to see what works and what does not. This includes vetting and detailing options, or reverse engineering using a qualitative analysis to assess performance. To identify a concept, the author must consider available options and the feasibility of these options. This can be an initial brainstorm with a brief list of options based on discussion with coworkers, peers, design consultants, building owner, key stake holders, etc. For this alternative solution, several bullet points are provided below as examples of possible conceptual solutions and why they may or may not work.

- *Use a noncombustible wood like material as the interior ceiling finish?*
  This does not meet the architects' design vision, specification. Also using a noncombustible material does not provide the sustainability points required to meet design certification being sought.

- *Provide enhanced sprinkler protection by increasing the sprinkler density?*
  This is not practical as increasing the density is good at controlling the spread of a fire but is not likely to provide a reduction in flame spread of a fire along ceiling surfaces if ignited.

- *Use FRT wood?*
  This is a good option, but not feasible due to colour change from FRT process and an estimated higher material cost.

- *Use a factory or field applied fire retardant coated (FRC) wood to reduce the flame spread rating?*
  This appears to be feasible as there are coatings available that will not alter the wood colour or appearance over time and there are coatings that meet the same test requirements of FRT wood. The high ceiling height of the subject space reduces the probability of surface damage/integrity of the coated wood.

It is proposed to use a fire-retardant coated wood as the interior ceiling finish at the double height ceiling of the first storey entry lobby and public corridor to meet the flame spread limit of not more than 25 required and material integrity required by the acceptable solution as follows:

- To address the flame spread rating is no more than 25:
  - The subject wood ceiling finishes will be installed at the first storey entry lobby and public corridor only.
  - Use only Pacific yellow cedar plank as the wood ceiling finish which naturally has a low flame spread rating not more than 50.
  - Use a factory or field applied fire-retardant coating on all surfaces of the wood planks.
  - Use a fire-retardant coating that has been tested to CAN/ULC-S102 and does not exceed 25.
- To address that the integrity of the flame spread rating is maintained if the material is cut in any direction:
  - Touch up all cuts in the field with the same fire-retardant coating.
  - The entry lobby and public corridors have a double height ceiling, approximately 6 metres high. The high location of the combustible ceiling finish reduces the probability of the finished ceiling surface being damaged from use of the building below.
  - Incorporate inspection and maintenance procedures for the subject ceiling finish as part of the maintenance schedule in the building's fire safety plan.

5. Analysis and Evaluation to Validate Acceptance

Commentary: First, it's important to state what the expected performance criterion of the acceptable solution is. This statement accounts for the wording of the acceptable solution, and the applicable objective, functional and intent statements.

The intent of the acceptable solution in prescribing a flame spread limit is to reduce the probability of a combustible interior ceiling finish contributing to the growth or spread of fire in the building. Therefore, a flame spread limit of not more than 25 is considered by the building code as the acceptable limit. It should be noted that the building code requires the flame spread rating of a material to be determined based on a series of tests conducted in accordance with CAN/ULC-S102. Further, the acceptable solution requires that the ceiling finish material not exceed the flame spread limit if it is cut in any direction. This requirement is meant to address the integrity of the ceiling finish material, that if the surface of the material is cut or damaged, the flame spread limit will not be exceeded.

Based on the above a performance criterion of the acceptable solution can be set as follows:

1. Does the combustible ceiling finish material have a surface flame spread rating not more than 25, and
2. Will the combustible ceiling finish material contribute to growth and spread of fire in the building if it is cut in any direction due to the exposed flame spread rating?

Commentary: Next provide an analysis and evaluation to validate the proposed alternative solution approach with reference to evidence such as manufacturer's literature, product data sheets, fire test reports (if available), research papers or other technical literature. This should describe the performance of the alternative solution and how the performance of the acceptable solution is being met.

As noted earlier it is proposed to install 25mm thick Pacific yellow cedar plank as the ceiling finish at the entry lobby and public corridors on the first storey of the building, in this case architectural details for the project illustrate that the cedar wood planks will be fastened directly to the gypsum board that encapsulates a CLT floor slab above.

The Pacific yellow cedar planks have a surface flame spread rating of 50 based on a series of tests conducted in conformance with CAN/ULC-S102. Therefore, the flame spread limit of the subject wood ceiling finish is naturally low for a wood product; however, it is more than the 25 limit required by Sentence 3.1.18.(3) for combustible ceiling finishes in buildings of encapsulated mass timber construction. The following discusses the proposed alternative solution approach and performance.

Flame Spread Rating

1. To reduce the flame spread rating of the Pacific yellow cedar wood plank ceiling finish it is proposed to apply **Product X**, which is a fire-retardant coating that will be applied to all surfaces of the cedar planks. **Product X** was tested on red oak in conformance with CAN/ULC-S102 and **Product X** data sheets indicate a flame spread rating of 20 was obtained when applied in accordance with the manufacturer's literature. Red oak is a benchmark material used in S102 flame spread tests and has a natural flame spread rating of 100, which is double the natural flame spread rating of Pacific yellow cedar. Therefore, the cedar wood planks coated with **Product X** will meet the flame spread rating of 25 (or perform better) as required by the building code.

2. Manufacturer data sheets indicate that **Product X** has also been tested in accordance with ASTM E84 "Standard Test Method for Surface Burning Characteristics of Building Materials" and ASTM E2768 "Test Method for Extended Duration Surface Burning Characteristics of Building Materials", which are commonly referred to as the 30-minute E84 test. The CAN/ULC-S102 flame spread test is similar to the ASTM E84 test; both use the same test apparatus (Steiner tunnel), benchmark materials (cement board and red oak), and 10-minute test duration measuring flame front propagation starting at a zero point. A key difference between CAN/ULC-S102 and ASTM E84 is that S102 provides a flame spread rating based on the average flame spread value of a minimum of three consecutive successful tests while the E84 test provides a flame spread index based on calculated rate and total distance of flame propagation from one successful test.

   The ASTM 2768 is similar but also measures flame propagation for a total 30-minute duration from the centreline of the burner, with the passing criteria being that the flame does not progress more than 3.2m beyond the centreline of the burner. Successfully meeting the conditions of the ASTM 2768 test provides evidence that the surface material does not contribute to significant progressive combustion. In this case the manufacturer provided an excerpt from the ASTM 2768 test report which indicates that the flame front did not advance more than 900mm beyond the centreline of the burner.

   Since flame propagation beyond 10-minute time frame is not a passing criterion of the CAN/ULC-S102 standard or ASTM E84 standard alone, it can be reasonably considered that a fire-retardant coating which further inhibits propagation for an additional 20 minutes is better performing than a coating that is tested to CAN/ULC-S102 or ASTM E84 only. This provides further evidence that fire-retardant coated wood ceiling finish using **Product X** will perform as well as or better than the building code maximum permitted ceiling flame spread limit of 25.

3. To address the quality of **Product X** application the coating will be factory applied or field applied. A factory applied process provides consistency that replicates the quality of the coating applied for successful flame spread testing. If **Product X** is field applied on entire planks (not just cut ends) acceptance testing will be provided by a manufacturer's representative or qualified third party to comment that the quality of the application is consistent with manufacturer's installation literature.

Combustible Ceiling Finish Integrity

1. All sides of the cedar ceiling planks will be coated with **Product X**, either factory applied or field applied as noted above. Cuts along the ends of ceiling planks have a small surface area and are usually butted against other ends or walls, therefore these areas will not be exposed when installed. Except for recessed sprinklers and lighting units no other penetrations of the finished ceiling are expected.

   To address the cutting concern of the acceptable solution and the integrity of the ceiling finish material, in situations where cedar ceiling planks are cut to suit site conditions or penetrations, **Product X** will be applied to all cut ends in accordance with manufacturer's literature. This will maintain the integrity of the flame spread rating at the ceiling.

2. A minimum headroom clearance of 2.05m is required by the building code. The entry lobby and public corridors have a double height ceiling, approximately 6 metres high, which is almost 3 times the minimum ceiling height permitted by the building code. It should be noted that the main floor plan is designed so that merchandise or material deliveries occur via a loading bay and back of house corridor.

   Therefore, based on the floor plan design and the high location of the combustible ceiling finish the integrity of the ceiling finish is expected to be well maintained and the probability of the finished ceiling surface being damaged from circulation use of the entry lobby and public corridor below is significantly reduced compared to a minimum permitted ceiling height.

3. To further address the integrity of fire-retardant coating at main floor entry lobby and public corridor ceiling finish, inspection and maintenance procedures for the subject ceiling finish will be incorporated into the building's fire safety plan. As a minimum, the maintenance plan should include a frequent visual inspection of the ceiling finish by building operation or maintenance staff to the same degree that the fire code requires inspection and maintenance of fire doors. In cases where new penetrations or damage to the ceiling is observed, the fire safety plan should include a procedure for the touch up of such areas using **Product X**.

Alternative Solution Sample: Curtain Wall Firestop System

Commentary: It should be noted that the format of this sample alternative solution follows the City of Vancouver alternative solution template to present information in a consistent manner for this guide.

1. Brief Building Description and Scope of Project

Commentary: A brief description of the project or building provides context and basic information to the authority having jurisdiction and demonstrates that the alternative solution author has a basic knowledge of the project or building as a whole and that the author has not just focused on building design or construction relative to the subject code requirement. The description should be a paragraph or two and include the characteristics of the overall building, major occupancy classification(s), use, applicable construction requirements and nature of the alternative solution.

This project involves the construction of a new 12-storey mixed use commercial office tower over a 3-level below grade parkade. The building will be of encapsulated mass timber construction for above grade storeys and non-combustible construction for the below grade parkade. The building will include commercial retail units (Group E) and a restaurant (Group A, Division 2) on the main floor, as well as an entry lobby and public corridors to access stores. The second storey will include an English language school (Group A, Division 2). The third to twelfth storey will include multiple business and personal services suites (Group D) served by a central public corridor. The building will be equipped with automatic sprinkler, standpipe and fire alarm and detection system. The building is considered a high building and will be subject to the measures and requirements of Subsection 3.2.6.

Commentary: Some background on why the alternative solution is proposed or desired should be included. The description should cover where, why and how. Typically, alternative solutions arise from a design, site or construction challenge, or a design innovation or vision, or may be a result of an energy target, design specification, goal or an incentive that must be met for the project.

Commentary: Design innovation and construction techniques usually drive building code changes. Utilizing prefabricated curtain wall façade systems is becoming more frequent as a strategy to meeting energy and speed of construction targets. Enclosing a building quickly during construction provides other benefits such as:

- *meeting fire code height limits of unencapsulated construction by providing an enclosed space to progressively sequence the encapsulation of floor assemblies.*
- *In some cases, meeting fire code requirements for providing exposure protection to adjacent properties during construction.*

The building design utilizes a prefabricated curtain wall system which incorporates vertical and horizontal aluminum mullions, insulated steel back pan spandrel panels and near full height glazing. The curtain wall system will be attached to the slab edge of CLT floor slabs using aluminum fasteners and steel plates. The installation of the curtain wall will leave a gap up to 200mm wide between the edge of the floor slab and interior face of the curtain wall at the second storey through to the twelfth storey. Sentence 3.1.8.3.(4) of the building code requires the continuity of a floor fire separation to be maintained where it abuts an exterior wall. It is proposed to maintain the continuity of the floor fire separation on an alternative solution basis using a custom firestop detail.

2. **Applicable Building Code References**

Commentary: This is really step one when considering an alternative solution, first the author must carefully read through the applicable Article, Subsection, Section and possibly the entire Part of the building code to account for all references, cross-references and exceptions that may need to be addressed as part of the alternative solution. For clarity only state the applicable Division B acceptable solution(s) the proposed design deviates from and state relevant exceptions or criteria specified by the acceptable solution. The less references stated, the more reader friendly the alternative solution will be. In this case only one acceptable solution reference is identified.

The applicable building code reference for this alternative solution is Division B Sentence 3.1.8.3.(4) which is reproduced below for reference:

> *The continuity of a fire separation shall be maintained where it abuts another fire separation, a floor, a ceiling, a roof, or an exterior wall assembly. (See Note A-3.1.8.3.(4).)*
>
> *A-3.1.8.3.(4) Fire Separation Continuity. The continuity of a fire separation where it abuts against another fire separation, a floor, a ceiling or an exterior wall assembly is maintained by filling all openings at the juncture of the assemblies with a material that will ensure the integrity of the fire separation at that location.*

In this case a minimum 2-hour fire resistance rating is required to be maintained for continuity of floor assembly fire separations. The Note clarifies that filling openings (joints) at the junction of a wall and floor is a method of maintaining the integrity of the fire separation.

3. **Functional and Objective Statement(s) and Description of Intent**

Commentary: The purpose of objective and functional statements is to identify the level of performance of an acceptable solution.

The following pair(s) of objectives and functional statements attributed to Sentence 3.1.18.2.(1) are identified by Division B Table 3.10.

F03-OS1.2

F03-OP1.2

The above objectives and functional statements are defined as follows:

- F03: To retard the effects of fire on areas beyond its point of origin.
- OS1.2: An objective of this code is to limit the probability that, as a result of the design or construction of the building, a person in or adjacent to the building will be exposed to an unacceptable risk of injury due to fire or explosion impacting areas beyond its point of origin.
- OP1.2: An objective of this code is to limit the probability that, as a result of its design or construction, the building will be exposed to an unacceptable risk of damage due to fire or explosion impacting areas beyond its point of origin.

The below table is provided to paraphrase the above objectives/functional statement pairs and capture the level of performance intended to be achieved.

Table 1 – Objective/Functional Statement Plans

Sentence	Statements	Function	Link	Objective
3.1.18.2.(1)	[F03-OS1.2]	To retard the effects of fire or explosions on areas beyond its point of origin,	in order to	reduce the risk of injury to occupants in or adjacent to the building
	[F02-OP1.2]	To retard the effects of fire or explosions on areas beyond its point of origin,	in order to	reduce the risk of damage to the building

Commentary: Intent statements for most acceptable solutions are published online by the National Codes Council for the National Building Code 2015, which the current building code in effect in British Columbia is modelled after. Intent statements provide explanatory commentary for the subject acceptable solutions.

Intent statements for Sentence 3.1.8.3.(4) are provided for each functional and objectives statement pair. The intent statements have been combined and reproduced below for reference:

Intent 1:
To limit the probability that fire will spread from one fire compartment to another fire compartment through gaps where the fire separation abuts other assemblies, which could lead to harm to persons and/or damage to the building or facility.

Intent 1 clarifies that the objectives and functional statements are to limit the probability of smoke and fire spread and resulting consequences of fire spread, e.g. injury to occupants and/or damage to the building.

4. Summary of Solutions/List Mitigating Features

Commentary: The concept of this alternative solution is relatively straightforward, use a custom firestop system to fill the gap between the curtain wall and edge of the floor slab. However, the problem with firestopping curtain wall systems is multifaceted and the following should be considered in developing the alternative solution:

- *The CAN/ULC-S115 (2015 edition) firestop standard referenced by the building code does not include a means to evaluate firestopping of curtain wall systems. Thus, there are no listed curtain wall firestop systems meeting the acceptable solutions of the building code.*
- *A common approach to address the use of curtain wall firestop systems is to apply the criteria of a listed firestop system that was fire tested using Standards referenced by U.S. building codes, such as the ASTM E-2307 standard, which includes specific methods for evaluating the firestopping of curtain wall systems.*
- *The basic premise of this alternative solution is to demonstrate that the ASTM E-2307 fire testing method is a best practice in the absence of a method referenced by the building code. Therefore, the curtain wall system design being used must exactly match the listing details; how it is attached, design/configuration, building materials, firestop materials etc.*

- *A variety of listed firestop systems for fire tested curtain wall systems using mass timber floor assemblies are currently not available. At this time there appears to be only one listed firestop system for curtain walls attached to a mass timber floor.*
- *In most cases proposed curtain wall systems do not exactly match design listings. Common deviations include attachment method, different curtain wall configurations and/or different material components. A criterion of the ASTM 2307 test is that the firestop system remain in place for the test duration. Therefore, the curtain wall assembly is expected to adequately remain in place during the test duration so that the firestop system does not fail. As such the alternative solution needs to assess and demonstrate that the integrity of the firestop system will be maintained with deviations in the curtain wall design.*
- *Depending on the degree of deviation in curtain wall system design from the listing some compensating measures may need to be incorporated at the floor to curtain wall interface such as additional support, use of fire resistance rated bulkheads/pony walls or additional firestop materials such as sealant thickness, over spray or additional packing material depth.*
- *All aspects of the alternative solution should be coordinated with design consultants such as the architect, envelope, structural, and energy consultants, general contractor and other project team members as required.*

It is proposed to maintain the continuity of the floor fire separation by filling the gap between the curtain wall and floor edge slab at the second storey through to the twelfth storey using a custom firestop detail. In the absence of a building code referenced Standard that addresses firestopping of curtain walls, the performance of the custom firestop detail has been assessed based on comparison to Intertek design no. STI/BPF 120-11, which is a curtain wall firestop system that has successfully met the fire test conditions of ASTM E2307 as providing a 2-hour fire resistance rating at the edge of a mass timber floor assembly.

In this case details of the proposed firestop system will include the following:

- Minimum 150mm depth of 4pcf density mineral wool insulation.
- Mineral wool insulation compressed a minimum of 25% between the curtain wall and edge of the floor slab.
- Minimum 3mm thick wet film thickness of STI SpecSeal AS200 series elastomeric Firestop Spray or SpecSeal Fast Tack Firestop Spray.
- Attachment of the curtain wall to the floor slab will be different than Intertek listing and is addressed by mass timber encapsulation required by the building code.

5. **Analysis and Evaluation to Validate Acceptance**
Commentary: First, it's important to state what the expected performance criterion of the acceptable solution is. This statement accounts for the wording of the acceptable solution, and the applicable objective, functional and intent statements.

Mass timber floor assemblies using a 5-ply cross-laminated timber (CLT) will be provided from the first storey through to the twelfth storey and require a minimum 2-hour fire resistance rating which must be maintained where the floor abuts exterior walls. The intent of the acceptable solution in prescribing continuity of a floor fire separation where it intersects an exterior wall is to limit the potential for smoke or fire spread by filling in any gaps or openings using appropriate materials such as a fire tested firestop system.

Based on the above a performance criterion for the acceptable solution can be set as follows:

- ***Will the installation of the proposed curtain wall firestop system retard the effects of fire on areas beyond its point of origin as well as or better than a condition where the slab itself extends to the exterior (so there is no gap)?***

As noted earlier there is no building code Standard that evaluates curtain wall firestop systems. Therefore, in the absence of a building code Standard it is proposed to compare the firestop system to one that has been successfully tested to ASTM E2307 *"Standard Test Method for Determining Fire Resistance of Perimeter Fire Barriers Using Intermediate-Scale, Multi-story Test Apparatus"*. The ASTM E2307 Standard is similar to the CAN/ULC-S115 Standard and is referenced by building codes throughout the U.S. as the applicable firestop Standard. A distinct difference between the S115 and E2307 Standards is that the E2307 Standard incorporates a perimeter joint firestop test specifically for curtain wall systems.

However, currently only one curtain wall firestop system tested to ASTM E2307 with a mass timber floor assembly is available, Intertek design no. STI/BPF 120-11. This curtain wall firestop system was assessed by Intertek for a 2-hour fire resistance rating at the edge of a mass timber floor assembly. The proposed curtain wall firestop system uses the same firestop materials included in the Intertek listing and overall the prefabricated curtain wall is designed as described by the listing, except that connection of the curtain wall to the floor slab will include anchors and steel located at the midpoint of the slab edge face instead of anchors and steel angles at the top side of the floor slab edge. The following discusses the proposed alternative solution approach and performance.

Commentary: Next provide an analysis and evaluation to validate the proposed alternative solution approach with reference to evidence such as design details, fire test reports (if available), research papers or other technical literature. This should describe the performance of the alternative solution and how the performance of the acceptable solution is being met.

Firestop System Details

Table 2 provides a summary of the floor assembly and firestop system components required by the Intertek listing and the components proposed.

Table 2 – Summary of Firestop System

Component	Intertek design no. STI/BPF 120-11	Proposed Firestop System	Comments
Floor Assembly	Minimum 2-hour fire resistance rated 5-ply CLT minimum 175mm thick	2-hour fire resistance rated 5-ply CLT minimum 175mm thick	Same component proposed
Encapsulation	Optional, not required	Required by BCBC, proposed 2-layers 15.7mm thick gypsum board at underside of floor and minimum 38mm thick concrete topping	Superior performance expected. See additional technical discussion section below.
Width of Opening	Maximum 200mm	Maximum 200mm	Same component proposed
Packing Material Type	Rockwool mineral wool, Roxul SAFE 4pcf (64kg/m^3)	Rockwool mineral wool, Roxul SAFE 4pcf (64kg/m^3)	Same component proposed
Packing Material Depth	Minimum 150mm	Minimum 150mm	Same component proposed
Packing Material Compression	Minimum 25%	Minimum 25%	Same component proposed
Firestop Sealant Type	STI SpecSeal AS200 series elastomeric Firestop Spray or SpecSeal Fast Tack Firestop Spray	STI SpecSeal AS200 series elastomeric Firestop Spray or SpecSeal Fast Tack Firestop Spray	Same component proposed
Firestop Sealant Thickness	Minimum 3mm	Minimum 3mm	Same component proposed
Firestop Sealant Overspray	Minimum 12.7mm onto curtain wall and floor	Minimum 12.7mm onto curtain wall and floor	Same component proposed
Firestop Sealant Movement Capability	Not specified	Ranges from 50% to 200% based on sealant type proposed	Same component proposed; same sealants in both examples

As noted by Table 2 above the proposed firestop system matches the firestop system described by the Intertek listing. Therefore, the same level of performance, namely continuity of the mass timber floor assembly 2-hour fire resistance rating, will be provided.

Integrity of the Curtain Wall System

As noted earlier, the proposed curtain wall system matches the curtain wall system described by the Intertek listing. The only difference is curtain wall attachment anchors are relocated for energy optimization purposes to connect to steel plates embedded at the face of the slab edge instead of steel angles mounted flush at the top side of the slab (the anchor head has been relocated vertically down along vertical mullions so that the anchor end attaches to steel plates at the mid-point of the slab). The following points assess the potential impact of this modification:

1. **Thermal Protection of Attachments:** The top and bottom of the attachment anchors and mounting points will be thermally protected from the effects of fire by being completely covered by at least a 75mm depth of the firestop packing mineral insulation. Mineral wool is noncombustible and an excellent thermal insulator that provides significant protection from the effects of fire in several fire protection applications.

2. **Compression and Movement:** In this case the mineral wool will be compressed into the perimeter floor joint by at least 25%. The compression factor is incorporated to address potential for building movement so that the mineral does not fall out and also to address potential for curtain wall movement due to fire. It should be noted that the firestop sealants included in the Intertek listing also have a 50 to 200% movement capability, meaning that the sealant is expected to stretch and also remain in place to maintain a smoke seal in the event of a fire.

3. **Curtain Wall Integrity:** The success of the firestop system component remaining in place for the duration of a 2-hour E2307 fire test relies on the capability of the curtain wall structure (framing, spandrel panel and attachments) to sufficiently resist the effects of fire. In this case the use of rigid non-combustible materials such as aluminum frames and insulated steel back pan spandrel panels has demonstrated through testing that the firestop system will remain in place for the required duration. The relocation of the anchors and connection points is not expected to reduce the integrity of the curtain wall system as the anchors and connection points will remain protected from the fire compartment.

4. **Gypsum at Underside of Floor Slab:** As an additional measure and since the curtain wall firestop system was not tested with the attachment anchors and mounting points at the midpoint of the floor slab edge, the underside of CLT floor assemblies will be encapsulated using two layers of at least 13mm thick Type X gypsum board. This degree of encapsulation is deemed by the building code to provide up to a 50-minute encapsulation rating. We note the building code permits a small area of the mass timber slab to be exposed at the ceiling. As the encapsulation rating is being applied as an alternative solution feature, at least a 1.2m wide area measured horizontally for the slab edge should be encapsulated as noted above regardless of the exceptions of acceptable solutions that permit an exposed mass timber ceiling.

The above analysis has demonstrated the proposed curtain wall firestop system will maintain the continuity of the mass timber floor fire separations at the perimeter joint. The curtain wall firestop system will retard the effects of fire on areas beyond its point of origin at least as well as required by the Division B acceptable solution.

Definitions (from EGBC – AIBC)

Applicants are advised to refer to the definitions in the building code (and other relevant regulations). These definitions are meant to support the reading of this document, not to aid in the interpretation of building codes or other jurisdictional documentation.

Authority Having Jurisdiction – the governmental body responsible for the enforcement of any part of the BC Building Code or the official or agency designated by that body to exercise such a function.

BCBC – the British Columbia Building Code (BC Building Code).

NBCC – National Building Code of Canada.

Alternative solution – a design or solution which does not conform to the prescriptive requirements of the BC Building Code but provides the level of performance required by the BC Building Code (see Division C, Part 2, Section 2.3 Alternative Solutions, Article 2.3.1.1).

Combustible – a material that fails to meet the acceptance criteria of CAN/ULC-S114, "Test for Determination of Non-Combustibility in Building Materials."

Noncombustible – a material that meets the acceptance criteria of CAN/ULC-S114, "Test for Determination of Non-Combustibility in Building Materials."

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.

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